A COMPARTIVE STUDY OF VEGETATION STRUCTURE AND VISIBILITY AT WILD DOG (*Lycaon pictus*) KILL SITES IN AND OUTSIDE HWANGE NATIONAL PARK

by

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Abstract

The objective of this study was to compare vegetation structure and visibility at sites at which wild dogs (*Lycaon pictus*) had killed kudu (*Tragelaphus strepsiceros*) and impala (*Aepyceros melampus*). The kill sites, within Hwange National Park (HNP) and the adjacent forest areas, were recorded by Gregory Rasmussen between 1997 and 2002. Vegetation structure at each kill site was characterized in five 10 m x 10 m plots, one at the kill and the other four randomly placed within 1000 m from the kill site at each of the four major compass directions (North, South, East, West). Shrubs were characterized in a 5 m x 5 m quadrant within the 10 m x 10 m plot. Grass height was estimated in three randomly thrown 0.5 m x 0.5 m quadrats within the 10 m x 10 m. Twenty random non-kill sites were generated and measured in the same way and the following vegetation attributes were measured at each kill site and non-kill site: tree canopy cover, basal area, tree canopy volume, tree height, tree density, shrub height, shrub volume, and shrub density and grass height. The results of this study revealed that vegetation cover was denser outside the park ($F = 6.658$; $P < 0.001$). Visibility was also lower outside the park ($F = 32.882$; $P < 0.001$). Dogs selectively hunted impala in bushed grassland within the park and in bushed woodland outside park. Kudu were killed in the same vegetation types within and outside the park but in much taller and denser vegetation than impala ($F = 6.847$; $P < 0.05$). Grass height was insignificantly different between the two sides and also between the two species. Random non-kill sites vegetation characteristics differed significantly from the kill sites ($F = 9.389$; $P < 0.05$). Visibility was influenced by shrub height than any other vegetation characteristic and from this study it was concluded that the movement of wild dogs outside Hwange National Park can be explained by differences in vegetation structure within and outside the park.

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Anything we do in science is built on the work of those who have gone before us. Both from their successes and from their failures we learn and thus advance. I am deeply indebted to the many who have struggled to find better ways for us to live in harmony with each other and our environment and on whose work I have built particularly that of Gregory Rasmussen.

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Table of Contents

Abstract ii

Acknowledgements iii

Table of Contents iv

List of Tables vi

List of Figures vii

List of Appendices viii

List of abbreviations ix

1.0 CHAPTER ONE: Introduction 1

2.0 CHAPTER TWO: Literature Review 4

2.1 Wild dog history 4

2.2. Habitat preferences 6
2.2.1 Wild dogs 6
2.2.2 Prey species 7

2.3 Hunting success 8

2.4 Kleptoparasitism 8

2.5 Anti-predation mechanisms 9

3.0 CHAPTER THREE: Materials and Methods 11

3.1 Study area 11

3.2 Selection of kill sites 13

3.3 Generation of random non-kill sites 14

3.4 Habitat characteristics 14

3.5 Visibility 16

3.6 Data analysis 16

4.0 CHAPTER FOUR: Results 17

4.1 Vegetation types at kill sites where kudu and impala were killed by wild dogs 18

4.2 Comparison of vegetation attributes inside HNP and in adjoining areas 19
4.2.1 Kill sites and randomly selected sites 19
4.2.2 Kill sites within and outside the park 20
4.2.3 Visibility at kill sites within and outside HNP 20

4.3 Factors affecting visibility 24
5.0 CHAPTER FIVE: Discussion and Conclusion.. 26
6.0 References.. 32
7.0 APPENDICES 38

List of Tables

Table 4.1: Frequency of kill sites of kudu and impala made by wild dogs in the different vegetation types, which were identified……………………………………………18

Table 4.2: Descriptive statistics of visibility and tree and shrub characteristics between animal species ……………………………………………………………………………21

Table 4.3: Descriptive statistics of visibility and shrub and tree characteristics between kill sites and non-kill random sites…...………………………………………………………22

Table 4.4: Descriptive statistics of visibility and tree and shrub characteristics between kill sites within and outside park...……………………………………………………………23

List of Figures

Figure 2.1: Historical range of African wild dogs showing countries that currently holds populations greater than 100 ……………………………………………………….4

Figure 3.1: Map showing the location of kill sites and the main study area…………………..12

Figure 4.1: Euclidian distance cluster analysis based on significantly different vegetation attributes between in and outside park ……………………………………………..17

Figure 4.2: Frequency of plots used to characterize vegetation around kills of impala and kudu in and of park …………………………………………………………………….19

Figure 4.3: Projection of vegetation attributes on Axis 1 and 2 of the Principal Component Analysis (PCA) ordination ………………………………………………………24

Figure 4.4: PCA scatter of kill sites ………………………………………………………...25

Figure 5.1: A conceptual model of likely factors influencing wild dog hunting success……...26

List of Appendices

Appendix 1: Kill site field recording sheet……………………………………………………….38

Appendix 2: Two-way analysis of variance of vegetation structure between in and out of the park and between animal species…………………………………………………….39

Appendix 3: One-way analysis of variance of visibility and tree and shrub characteristics between kill sites and non-kill random sites……………………………………………..43

Appendix 4: List of GPS coordinates (UTM projections) for all plots that were measured (i.e. kill site and the four neighbouring sites) on species killed…………..…………….46

List of abbreviations

ANOVA	: Analysis of Variance
GPS	: Geographic Positioning System
HNP	: Hwange National Park
IUCN	: International Union for the Conservation of Nature
PCA	: Principal Component Analysis
UTM	: Universal Transverse Mercator grid co-ordinates
ICA	: Intensive Conservation Area

1.0 CHAPTER ONE: Introduction

Wild dogs (*Lycaon pictus*), once distributed through much of the Sub-Saharan Africa (apart from rainforest and deserts) have been extirpated from most of their range (Creel & Creel, 2002) and are inevitably under very high risk of extinction (IUCN, 2003). Zimbabwe is one of the six countries that still has a viable, though widely distributed population of wild dogs. Populations presently occur in Hwange National Park (HNP), Matusadona National Park, Save Valley Conservancy, Gonarezhou National Park and a remnant population around Bubi Valley Conservancy. Understanding the conditions for wild dog maintenance in ecosystems where they remain is therefore crucial for their conservation. Hunting success is a key component of their survival, as wild dogs live on a tight energy budget (Gorman *et al*., 1998). Several factors have been observed to influence success or failure of a hunt. Some of these are environmental, including time of day, brightness of moon, and wind direction. Other factors relate directly to the dogs, among them are the age and sex of the hunters, the method of hunting used and number of dogs involved. Other factors include, prey size, prey abundance and competition, and still others involve the anti-predator behaviour of prey animal species. However, little research has examined how hunting success in wild dogs is affected by vegetation structure (Van Orsdal, 1984; Creel & Creel, 1995).

Horizontal and vertical distribution of woody and herbaceous components have been assessed in a number of studies through analysis of individual structural measures such as canopy height, canopy cover, stem density and basal area (Lefsky *et al*., 1999; Harding *et al*., 2001). However, until recently, such information had not been compiled into meaningful data layers for use in landscape level models for applications such as wildlife habitat suitability analysis. The African wild dog illustrates the need for consideration of its foraging success in conservation biology and specifically show how hunting success is affected by vegetation structure and sighting visibility of a habitat. Since such a study has not been carried out in Zimbabwe specifically for wild dogs, it is essential that information be made available. Hwange National Park is acting as the source for wild dogs and the surrounding forest areas as sinks and it has been observed that their hunting success is greater in the forest area (Rasmussen pers comm.) but mortality due to snaring, road accidents, direct poaching, shooting and poisoning is also greater (Rasmussen, 1999; Creel & Creel, 2002). This may turn out to be crucial if differences in vegetation structure may explain why dogs are moving out of HNP into surrounding forest areas.

Creel and Creel (1998) observed that dense populations of prey support dense populations of hyenas and lions and high densities of these predators may cause dogs to move out of the park. In the Serengeti National Park and the Ngorongoro Crater wild dogs declined to local extinction whilst prey densities were high, but attained their highest density in Selous where prey densities are moderate to low (Creel & Creel, 1998). In summary, these findings suggest high levels of kleptoparasitism. Now the question is, other than prey abundance, what else can facilitate kleptoparasitism, of which in this study it was hypothesized that vegetation structure and visibility have an influence on the hunting success of wild dogs in and outside HNP? Vegetation characteristics may also affect the risk of kleptoparasitism in addition to hunting success (Creel, 2001).

A thorough knowledge of the relationships between animals and their food resources is fundamental to our understanding of population dynamics and foraging patch selection (Lack, 1954; Watson, 1970; Hassel & May, 1985). Prey abundance, detectability and accessibility can all influence functional and aggregative responses and depletion rates (Zwarts & Wanink, 1993).

However, although food abundance is relatively straightforward to measure, few studies have directly examined the effect of habitat variation on prey detectability and accessibility. For species that rely on visual cues to detect prey, increasing the structural complexity of a patch can influence foraging behaviour through consequent reductions in prey detectability and accessibility (Eriksson, 1985; Zwarts & Wanink, 1993; Whittingham & Markland, 2002), and reduced forager mobility (Broadman *et al*, 1997).The influence of these factors is most clearly demonstrated by foraging site selection. However, although there is evidence that habitat structure influences foraging site selection (Pole, 2000), the underlying effects of habitat structure on foraging behaviour, which are likely to drive these observed site selections are much less clear.

This study aimed to compare vegetation structure and visibility at wild dog kill sites in and out of HNP and was based on accumulated data from sites at which kudu (*Tragelaphus strepsiceros*) and impala (*Aepyceros melampus*) had been killed by wild dogs. More specifically, the following hypotheses were tested:

1 Vegetation structure differed between HNP and neighbouring woodland areas.
2 Visibility differed between HNP and neighbouring woodland area.
3 Vegetation structure and visibility differed between kill sites and randomly selected non-kill sites.

The study was part of a larger one examining the question of source/sink dynamics in the HNP wild dog population.

2.0 CHAPTER TWO: Literature Review

2.1 Wild dog history

African wild dogs are medium sized (18-28 kg) canids that live in highly cohesive packs holding from 2 to 28 adults with mean adult pack size of 4.8-8.9 across five ecosystems (Creel & Creel, 2002). For wild dogs, cooperative breeding is nearly obligatory. Only the alpha female, the oldest female and beta males, and the fittest males reproduce and litters of 10-11 pups on average are produced (Woodroffe *et al*., 1997). Wild dogs have a low population density (approximately one adult per 60-100 km^2) and large home ranges of over 1,000 km^2 and also large dispersal distances of approximately 29.6 km in a day (Creel & Creel, 2002; Green, 2004). Wild dogs prey mainly on ungulates, focusing on wildebeest (*Connochaetes taurinus*), impala (*A. melampus*) and Kudu (*T. strepiceros*) in East Africa (Fanshawe & FitzGibbon, 1993; Creel & Creel, 1995). Around HNP they have been observed preying mainly on impala and kudu and sometimes opportunistically on duiker (*Sylivcapra grimmia*) (Davies, 1992).

Figure 2.1: African countries that currently hold wild dog populations greater than 100 (the historical range is shown by the stippled area) (Creel & Creel, 2002).

Remnant populations and historical ranges are shown in figure 1. Fragmentation of the wild dog range has resulted in their home ranges extending beyond game reserve borders, leading to increased mortality risk due to edge effects, persecution by humans, and poaching activity, such as snaring which can cause high mortality (Rasmussen, 1996; Creel & Creel, 2002). Wild dogs were actively destroyed by wildlife managers in most areas until late in the 20^{th} century, due to the perception that their method of killing prey was cruel, and that their cursorial hunting was disruptive for ungulate populations (Mills & Hes, 1997). This early perception is supported by the writings of wildlife managers where the status of the wild dog has evolved from 'Scourge' to 'Successful and efficient carnivore', for example, Bere, (1956) "*Wild dogs hunt in packs, killing wantonly far more than they need for food, and by methods of the utmost cruelty*": However, in a later comment, Bere noted *'this is now known to be nonsense'*. Hunter (1960) wrote, "*The rapacious appetite of these foul creatures is staggering*". This was culminated by the wildlife bulletin statement "*Wild dogs are very successful and efficient hunters and, in spite of their reputation, are no more cruel than any other beast of prey*" (Bere, 1975).

In Zimbabwe, *L. pictus* was first classified as vermin in 1916, and under subsequent Wildlife Conservation Acts, rewards were paid for its destruction (Childes, 1984). The existing Parks and Wild Life Act was promulgated in 1975, and *L. pictus* was included in the Eighth Schedule of this Act under its new title of 'Problem Animal'. In January 1977, it was removed from the Eighth Schedule as a result of an unpublished survey and report by Cumming (1976), which indicated that the wild dog populations were becoming endangered. Two decades later, its current legal status remains as that of 'Vulnerable Game' and the species has only recently been protected outside National Parks areas through a Restriction on Hunting Notice. Between 1956 and 1975 in

Zimbabwe alone, 3404 wild dogs were killed through, poisoning, shooting, and snaring (Childes, 1988). Due to the perception of wild dogs as being competitors in hunting areas and a threat to livestock, persecution both within and outside protected areas elsewhere in Africa still occurs (Woodroffe *et al*., 1997). However livestock loss to wild dogs is low overall (Fuller & Kat, 1990; Rasmussen, 1999). Over half of adult wild dog mortalities in HNP, were found to be due to road deaths caused by a high-speed road linking the park and the highway to Victoria Falls (Woodroffe *et al*., 1997; Creel & Creel, 2002). In addition, snaring and other human-caused deaths remain a substantial cause of mortality in the population around HNP (Rasmussen, 1996; Woodroffe & Ginsberg, 1998).

2.2. Habitat preferences

2.2.1 Wild dogs

An inverse relationship between habitat preferences of wild dogs and impala across different habitat types was found in the Kruger National Park, South Africa (Mills & Gorman, 1997). A similar result was obtained by Davies (1992) in Zimbabwe, where there was no significant correlation between habitat use by wild dogs and relative densities of impala. The habitat selection and distribution of wild dogs is, therefore, likely to be the result of a trade-off between the distribution of food and other factors (Pole, 2000). Sight has been reported to be the primary sense used by wild dogs when hunting (Estes & Goddard, 1967; Fanshawe & FitzGibbon, 1993). It can therefore be expected that the dogs will show a general preference for hunting in habitats offering good visibility. A similar finding was obtained on Namibian cheetahs (*Acinonyx jubatus*) where sighting visibility was the best predictor of high-use habitats (Muntifering *et al*., 2006). Given that kudu, their primary prey, were more abundant in low-use areas of cheetah, this suggests that habitat structure may be more important than absolute prey density (Muntifering *et al*., 2006). In the Serengeti, cheetahs were observed to frequently utilize ecotones to provide cover for stalking (Caro, 1994).

Creel and Creel (1995) observed that the amount of vegetation in the area can play a significant role in the number of group members involved in chase and capture as well as needed to protect a kill. In wooded areas, prey do not flee in a straight line, and it may be necessary for one dog to chase the prey while other dogs intercept it (Creel & Creel, 1995). However, Fanshawe and Fitzgibbon (1993), researching in East Africa, found that the amount of vegetation cover did not play a role in the success of hunts. Yet one must consider vegetation as offering oneway through which, wild dogs can approach their prey without being detected. However, in the study by Fanshawe and Fitzgibbon (1993), wild dogs were always detected by gazelles before the chase began. But Schaller (1972) observed that the vigilance of these prey species vary citing gazelle as one of the most vigilant animals. This could be the reason why dogs were always detected before a chase began and also this research was carried out in open plains of East Africa. Fuller and Kat (1993) reported only 6% of dense woody areas in their study site and this left them with inconclusive result on whether wild dogs use this little vegetation to improve their hunting success.

2.2.2 Prey species

Impala is a medium sized ungulate, approximately 0.9 m at shoulder height, with females weighing approximately 40 kg and males 60 kg (Mills & Hess, 1997). They favour woodlands with an under-storey of shrubs and grass on flat or gently undulating terrain (Mills & Hes, 1997). They are mixed feeders, selecting leaves of woody plants and grasses. In summer, they feed on grass but as this dries they turn to shrubs and bushes. Edible fruits and Acacia pods are eaten when available. Impala are water-dependant species, drinking almost daily.

Kudu occupy a range of savanna vegetation types, from open woodland to dense woodland. In some instances they favour rocky hills. They are also found in mopane and miombo woodland and have an average shoulder height of 1.25 m for females and 1.4 m for males and weighing approximately 210 and 300 kg, respectively (Mills & Hess, 1997). Kudu are browsers, favouring forbs, creepers, fruits and pods when these are available and they eat a wide spectrum of tree leaves.

2.3 Hunting success

Although hunting success of wild dogs in itself is not affected by vegetation type (Fanshawe & Fitzgibbon, 1993), chase distance and flight distance of prey are. Reich (1981) found that the average flight distance was lower in areas with low visibility than in areas with high visibility, meaning the dogs are able to approach prey to within a shorter distance. He also found the average chase distance in low visibility areas to be lower than in high visibility areas. Reduced flight distances seemed to encourage longer chases. In higher visibility habitats, chase distances increase as flight distance decreased probably because of an improved ability to maintain contact with prey (Reich, 1981).

2.4 Kleptoparasitism

Most reported examples of interspecific competition among carnivores are from open habitats such as savanna, open woodland, or semi-desert (Creel *et al*., 2001), where kills can be located by other predators. In open habitats for example, spotted hyenas (*Crocuta crocuta*) and vultures were observed to follow the hunts of wild dogs before a kill has been made and "*then congregate in large numbers soon after a kill is made*" (Creel, 2001). Fanshawe & Fitzgibbon (1993) followed a pack of wild dogs in the Serengeti National Park and witnessed spotted hyenas outnumbering wild dogs at 30% of their kills. However, Creel & Creel (1998) observed that in closed habitats, hyenas do not often locate wild dog kills and do not congregate as rapidly, which allows wild dogs to consume their prey before being parasitised (Creel & Creel, 1998). Kleptoparisitism was observed to have high energy costs to the kleptoparasite in closed habitats than in open habitats where kills can be easily located without searching (Fanshawe & Fitzgibbon, 1993).

The concentration of "*avian scavengers may affect the intensity of interference competition among carnivores*, *since rapidly descending vultures simplify the task of locating fresh kills"* (Creel, 2001). In support of Creel (2001), two incidents were witnessed in Sikumi forest where hyenas were led to a kill by dropping vultures (personal observation) and on one incident it was a buffalo stuck in the mud. In open habitats, dropping vultures can be seen kilometers away whereas closed habitats limit the distances at which sight can be used to locate kills (Creel, 2001).

2.5 Anti-predation mechanisms

Numerous anti-predator strategies exist, though all come with energy costs and sometimes also dilute social benefits. Taller or denser habitat structure generally increases visual obstruction for foraging animals (Butler & Gillings, 2004), and also may increase predation risk (Metcalfe, 1984); alternatively it may reduce predation rates by improving crypsis. Foraging animals can compensate for an increase in predation risk by being more vigilant (Lima & Dill, 1990 and Devereux *et al*., 2004). Vigilance is generally defined as time spent with the head raised during periods of foraging for species that rely on detecting predators by sight (Lima, 1990; Lima & Dill, 1990). Increased visual obstruction has been shown to increase vigilance in a variety of different species from many taxa including large mammalian herbivores (Whittingham & Evans, 2004;

Scheel, 1993). One important point about habitat structure and foraging is the way in which prey perceive cover. Proximity to cover can have two effects on a prey animal; it can provide a hiding place and protection from attack, but can obstruct view of approaching predators (Fitzgibbon, 1990).

Most herbivores have some morphological modifications of the body that make fleetness possible, eyes that bulge laterally from the head providing wide-angle vision, long mobile pinna with which to concentrate sounds and large nostrils and complex nasal passages used to smell danger, are all characteristics which have been under strong selection pressures from predators (Schaller, 1972). Estes (1966) noted that wildebeest cows tend to give birth in the morning rather than at night when hyenas and lions, their major predators, are most active, and that the placenta which could attract predators, is expelled only after the calf can run. All species have one or more birth peaks, which limit the time that small young are available to predators (Schaller, 1972), and this trait is common in impala and kudu. Most species form herds and it has been hypothesized that danger is better detected by many animals than by one and that groups may communally defend themselves against predators (Kruuk, 1972). However, animals in large herds are also vulnerable because an attacking predator often gains valuable seconds before all become aware of danger. The two species in this study are always found in herds, which might make them more vulnerable to predation, and found to be the primary prey species for wild dogs south of the Sahara (Creel & Creel, 1995).

3.0 CHAPTER THREE: Materials and Methods

3.1 Study area

Hwange National Park covers just over 14 600 km^2 and lies between latitudes 18°30′ and 19°50′S, and longitudes 25°45′ and 27°30′E. Hwange is bounded by Botswana to the west, Tsholotsho communal land to the south east, Forestry Commission land to the east and Matetsi safari area to the north. Four geological types are found in HNP: Kalahari sands, Batoka basalts, Karoo sediments and pre-cambrian rock. The average annual rainfall based on records over more than six decades varies across the park from 590 mm to 650 mm (Rogers, 1993). Daily maximum temperature ranges from 24 to 33 ^{0}C. Frost is common in HNP during winter, and minimum temperatures of -5°C or lower during this period are recorded. Black frosts, with temperatures lower than -7°C, occur approximately once in every 5 years. The vegetation of HNP is primarily woodland (64%) and scrubland (32%) with only 4% grasslands and savannahs (Rodgers, 1993). Hwange’s main camp area is generally flat with an altitude which ranges from 900 to 1100 m above sea level. From casual observations, elephant damage is concentrated around water points inside the park. Also during assessment of vegetation structure, elephant sightings were minimal in the Gwaai area. However, signs of fire were significant within the Sikumi Forest.

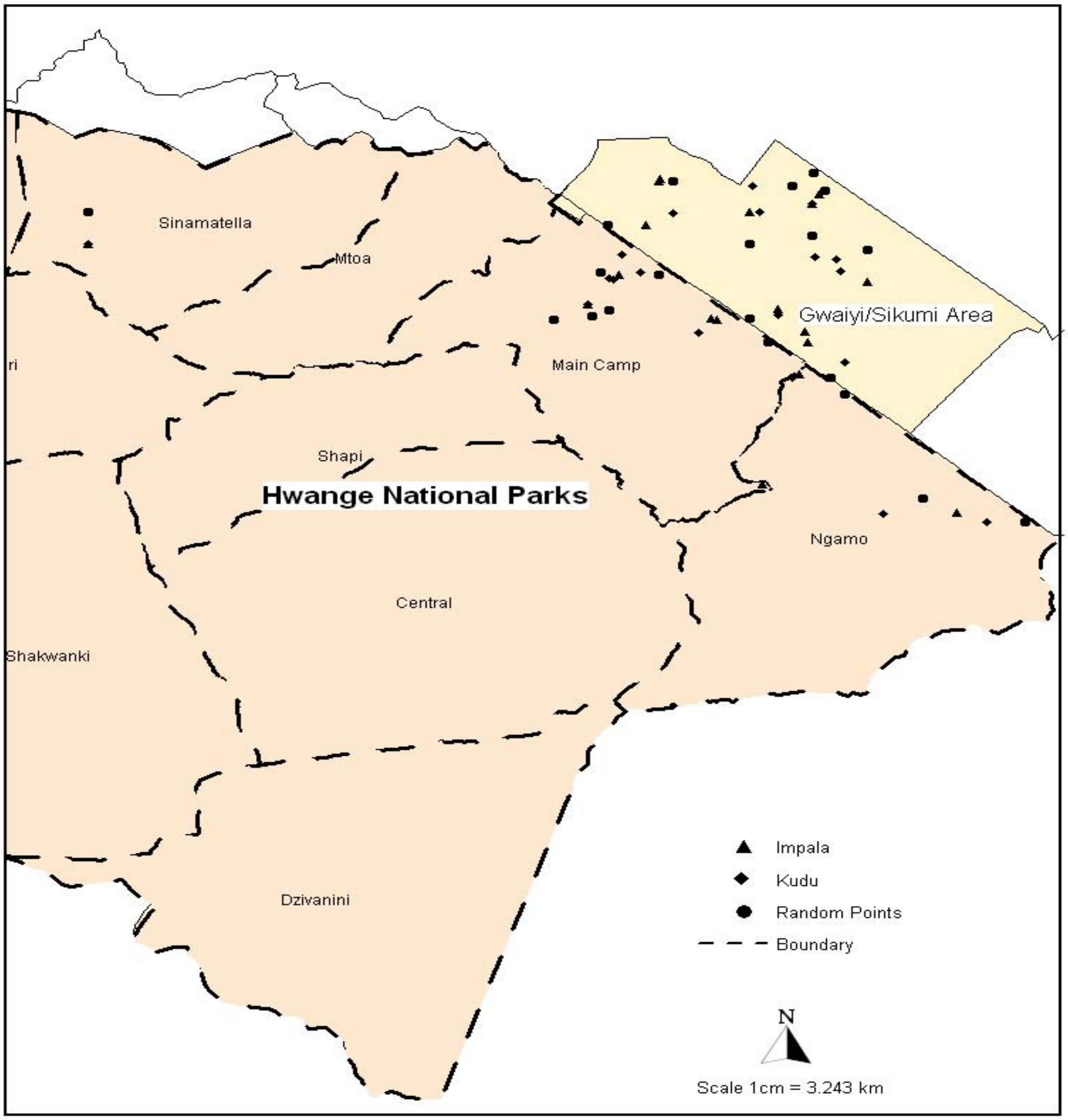

Figure 3.1: Map of Hwange National Park and the adjacent Gwaai/Sikumi forest area showing kill sites where wild dogs killed impala and kudu and the random points. (Map by G Mapuvire 2007).

3.2 Selection of kill sites

Rasmussen recorded data on wild dog kills both inside HNP and neighbouring area between 1991 and 2002 whilst working as a researcher at the Painted Dog Conservation Project. The Painted Dog Conservation Project located radio-tracked wild dogs utilizing both aerial and ground tracking to minimize error (White & Garrott, 1986), and collected data in the early and late hours of the day to capture highest activity period (Schaller, 1972). Data for this thesis were collected between 1997 and 2002 and were recorded from 10 different packs. Kill sites located outside the park were in the Sikumi Forestry Land and the Gwaai Intensive Conservation Area (ICA), a large-scale commercial farming area. Before the 2001 land reform programme, Gwaai was a photographic safari area. Change of land ownership since 2001 has seen Gwaai being turned into an open access hunting area with rampant poaching due to poor management. Inside the park, kills were concentrated around main camp area.

Kill sites of impala and kudu-the two major prey species of wild dogs-were considered. From the available data on kill sites a sampling intensity of at least 30% was considered for both impala and kudu between 1997 and 2002 when dogs were last tracked. From the available database of 94 kill site records, 20 kill sites were randomly selected for each prey animal with 10 from outside the park and 10 from inside. The procedure for the selection of kill sites where wild dogs had killed impala and kudu was as follows: random numbers were generated against the 94 kill sites and then sorted in ascending order of their random numbers. The first 10 impala kill sites from inside the park and the first 10 from outside the park were selected. The same procedure was repeated for the selection of kudu kill sites. Kill sites were recorded on a Universal Transverse Mercator (UTM) projection using a hand held GPS garmin 45 with an error of 3.24 ± 0.24 m. Accuracy and error of the GPS were determined by marking a fixed point in the bush near Jwapi Lodge which was visited twenty five times over a period of two weeks taking the deviate distance to the location of the point. It was from this data set that accuracy was calculated.

Five 10 m x 10 m plots were constructed at each kill site to characterize vegetation structure with one plot at the kill site and four placed randomly in the four major compass directions within a radius of 1,000 m, which was found to be the average chasing distance of the dogs for both impala and kudu. Vegetation type at each plot was characterized by scanning the area around the plot.

3.3 Generation of random non-kill sites

Random numbers were generated against the randomly selected groups of 10 kill sites for each animal species, that is, 10 kudu kill sites inside park and another 10 outside, 10 impala kill sites inside park and another 10 outside. Kill sites were sorted in ascending order of the random numbers and the first five kill sites from each group were considered. A total of 20 kill sites was produced with 10 from outside and the other 10 from inside the park. The selected kill sites were put in a column and random numbers were generated against each kill site. Kill sites were then sorted in ascending order of the random numbers. The first quarter was labeled north, followed by east, then south and then lastly west. To the north and east-labeled kill sites, 5,000 m were added to the y and x co-ordinates of the kill sites respectively. To the south and west-labeled kill sites, 5,000 m were subtracted from the y and x co-ordinates of the kill sites respectively. Random non-kill sites were placed 5,000 m from kill sites to capture habitat heterogeneity.

3.4 Habitat characteristics

Information concerning habitat was collected during the month of May 2007 following the methods outlined in Walker (1976). Habitat characteristics measured in each plot were: (i) tree height, (ii) stem height, (iii) the long and short diameters of the crown, (iv) circumference of the tree trunks, (v) shrub height, (vi) the long and short diameter of trees and shrubs and (vii) the grass height. The basal area was calculated as follows:

Basal area = $\pi d^2/4$ in (cm^2)…………………………………………………………….(1)

The basal area for multi-stemmed trees was considered for individual stems and area assigned as an average of all the stems (Campbell *et al*., 1995). Tree density was estimated by dividing the number of trees recorded by the area of the plot. Tree canopy cover was estimated by direct multiplication of the long diameter and the short diameter, canopy depth was estimated by subtracting stem height from tree height and tree volume was estimated using the formula;

Tree Volume = $\pi/4$ x long diameter x short diameter x canopy depth (in m^3)…………(2)

Shrub density was estimated as number per area. Shrub volume was estimated using the formula:

Shrub Volume = $\pi/4$ x long diameter x short diameter x height of shrub (in m^3)……….(3)

Basal area was measured through the circumference estimates made at the base of the tree above the basal swelling (Anderson, 1973). In this study, any woody plant with basal diameter greater than 6 cm was considered a tree and any woody plant with diameter less than 6 cm was considered a shrub. Alternatively, in terms of height, any woody plant less than 3 m was recorded as a shrub and any woody plant greater than 3 m was recorded as a tree. Shrub attributes were measured in a 5 m x 5 m plot, which was selected randomly within the 10 m x 10 m plot for trees.

Grass height was measured in three randomly selected 0.5 m x 0.5 m quadrats, the dimensions being determined using a tape measure. Only grasses at the four corners and centre of the quadrat were considered.

3.5 Visibility

Sighting visibility was estimated by positioning a seated observer at the centre of each plot at an eye level of 75 cm above ground, simulating a wild dog's eye height as in Marker & Dickman (2003) and Muntifering *et al*., (2006). A second person then walked away from the observer in each of the major compass directions (North, South, East and West) until the observer could no longer view him, and then whistled. After whistling the second person started pacing back towards the observer. As soon as the person was seen the observer whistled, the person walking then stopped and recorded the distance between himself and the observer using the Garmin GPS.

3.6 Data analysis

Data on the vegetation attributes measured were tested for normality using the Kolmogorov-Smirnov tests. These were not normally distributed and were log-transformed and retested for normality to meet the assumptions of parametric tests as in Zar (1999). Log-transformed data were subjected to the Euclidian distance hierarchical cluster analysis, an ordination technique to explore similarities among kill sites from in and outside the park. Habitat metrics for in and outside the park and between animals was subjected to a two-way ANOVA. One-way analysis of variance was used to test for differences between kill sites and random generated points. Correlations between vegetation attributes metrics were investigated using Principal Component Analysis (PCA). Data were considered significant at $P < 0.05$. Analysis of variance and all the ordination techniques were carried out using STATISTCA Version 7.

4.0 CHAPTER FOUR: Results

The hierarchical classification of the kill sites based on vegetation attributes produced two distinct clusters (Figure 4.1). One of the clusters consisted of kill sites from inside the park and the other of kill sites from outside the park. However, sites 30 and 24, which were from inside, fell into the outside group because there were close to the boundary.

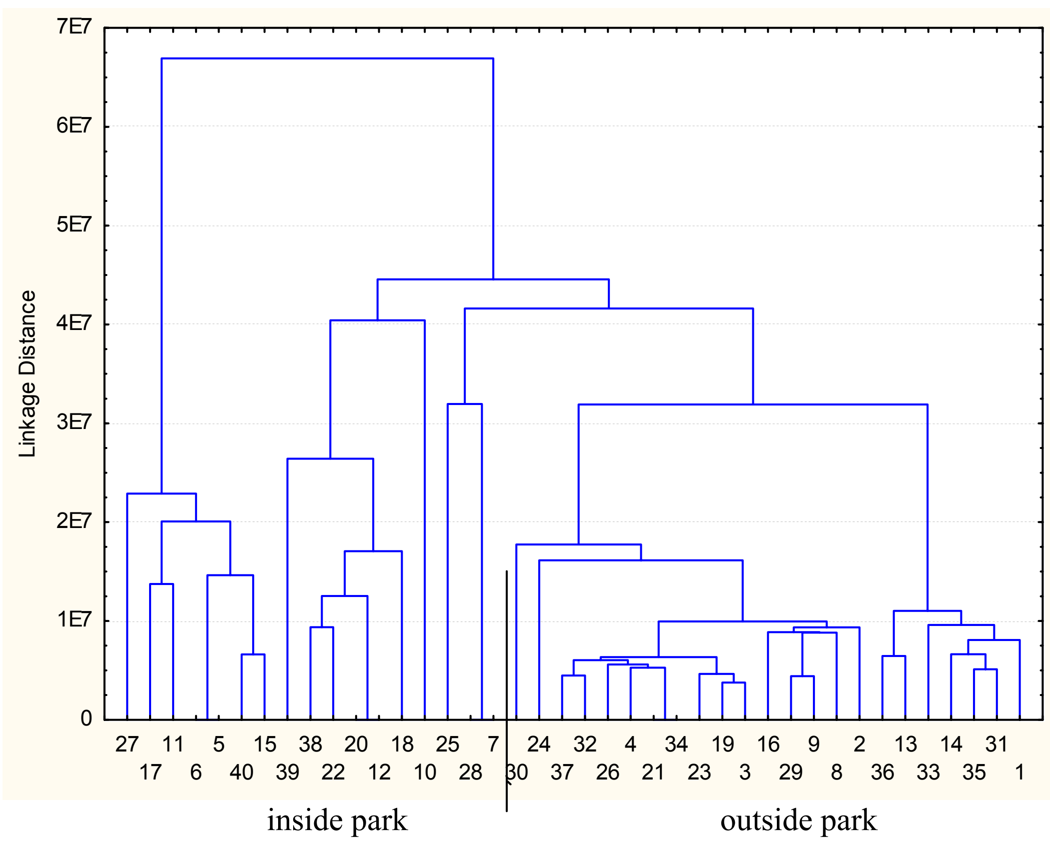

Figure 4.1: Euclidian distance cluster analysis based on significantly different vegetation attributes between in and outside park. Plots 24 and 30 are from inside the park.

4.1 Vegetation types at kill sites where kudu and impala were killed by wild dogs

Seven vegetation types were identified around kill sites. These were wooded shrubland, open grassland, bush land, bushed grassland, wooded grassland, and closed woodland and bushed woodland. The highest number of kudu kill sites was located in closed woodland and bushed woodland whilst for impala it was in bushed grassland and bushed woodland (Table 4.1).

Table 4.1: Frequency of kill sites of kudu and impala made by wild dogs in the different vegetation types.

	Frequency of kill sites	
Vegetation type	Kudu	Impala
Wooded shrubland	12	8
Open grassland	16	13
Bush land	6	9
Bushed grassland	11	18
Wooded grassland	10	10
Closed woodland	25	12
Bushed woodland	20	30

More impala kills sites were located in bushed grassland within the park and bushed woodland outside the park (Figure 4.2). However, kudu were killed more in closed woodland and bushed woodland both in and outside the park (Figure 4.2).

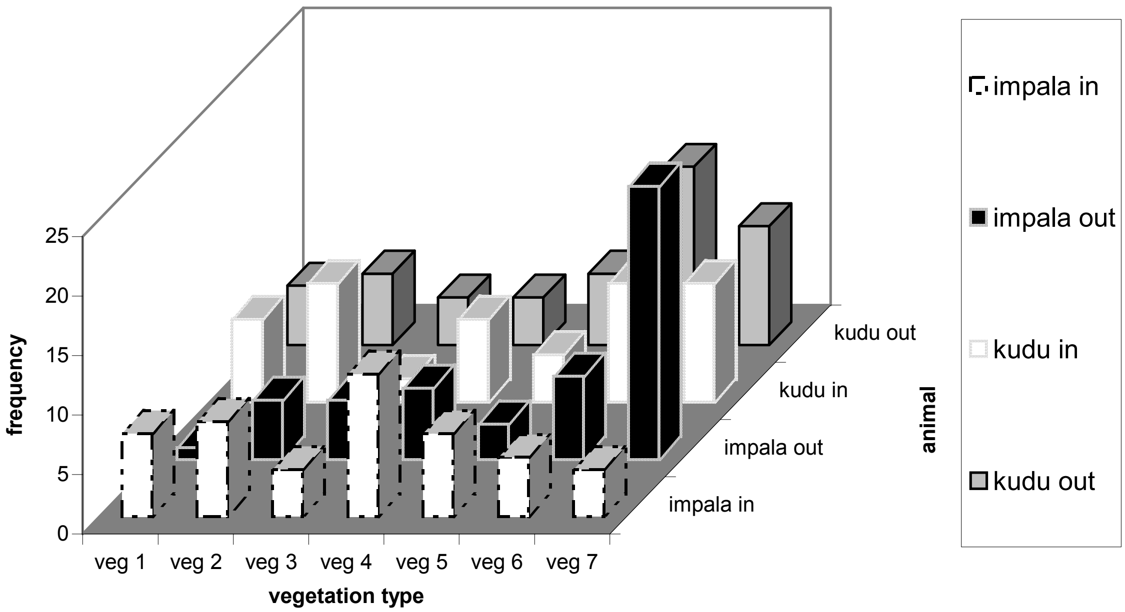

Figure 4.2: Frequency of plots used to characterize vegetation around kill sites for impala and kudu made by wild dogs in and outside the park. (veg 1=wooded shrubland, veg 2=open grassland, veg 3=bush land, veg 4=bushed grassland, veg 5=wooded grassland, veg 6=closed woodland and veg 7=bushed woodland)

.

4.2 Comparison of vegetation attributes inside HNP and in adjoining areas

There was a significant difference in the vegetation attributes between in and out of Hwange National Park ($F = 4.517$; $P < 0.05$). However there was no significant difference in vegetation attributes between animal species either inside or outside the park (Table 4.2).

4.2.1 Kill sites and randomly selected sites

Kill sites and random non-kill sites differed significantly ($F = 2.819$; $P = 0.002$). Vegetation characteristics differed significantly ($P < 0.05$) except for shrub height ($F = 2.551$, $P = 0.111$)

(Table 4.3). Visibility did not differ significantly ($F = 0.240$; $P = 0.622$) between kill sites and random non-kill sites.

4.2.2 Kill sites within and outside the park

Only five of the vegetation attributes differed significantly differences between inside and outside the park (Table 4.4). Basal area varied significantly ($F = 8.945$; $P < 0.05$) with a higher basal area recorded outside. Tree density was significantly higher outside the park ($F = 13.055$; $P < 0.001$). Shrub height and volume were significantly higher outside the park ($F = 17.488$, $P < 0.001$; $F = 17.210$, $P < 0.001$, respectively). Shrub density, tree volume, tree height and grass height were not significantly different between in and out of the park.

Of the measured vegetation attributes at sites where impala and kudu were killed three variables differed significantly, number of trees ($F = 6.153$; $P < 0.05$), tree density ($F = 6.002$; $P <0.05$) and tree height ($F = 6.847$; $P < 0.05$). The three variables were significantly higher at kudu kill sites (Table 4.2).

4.2.3 Visibility at kill sites within and outside HNP

Visibility was significantly different between inside and outside the park ($F = 32.882$; $P < 0.001$) with a higher visibility inside the park (Table 4.4). However visibility did not differ significantly between animal species (Table 4.2).

Table 4.2: Descriptive statistics of visibility and tree and shrub characteristics between animal species.

	Impala		Kudu	
Variable	n	Mean ±SE	n	Mean ±SE
basal area (cm^2)^{NS}	100	67.054 ±7.278	100	88.344 ±8.851
tree height*	100	489.672 ±22.783	100	550.341 ±32.362
tree volume (m^3)^{NS}	100	160.962 ±38.146	100	213.382 ±37.124
tree density*	100	0.035 ±0.004	100	0.052 ±0.006
tree canopy cover (%)^{NS}	100	35.795 ±5.922	100	46.823 ±5.965
visibility^{NS}	100	52.745 ±3.243	100	48.813 ±2.967
shrub height^{NS}	100	72.342 ±4.910	100	70.840 ±4.092
shrub volume^{NS}	100	6.813 ±0.729	100	7.595 ±0.930
shrub density^{NS}	100	0.560 ±0.051	100	0.598 ±0.048
grass height^{NS}	100	29.253 ±2.085	100	24.707 ±1.973

Significant variables. *$P < 0.05$. NS: not significant.

Table 4.3: Descriptive statistics of visibility and shrub and tree characteristics between kill sites and random non-kill sites.

	Kill sites		Random non-kill sites	
Variable	n	Mean±SE	n	Mean±SE
basal area (cm^2)*	200	77.752±5.791	100	93.647±8.21
tree height***	200	450.673±25.462	100	570.263±36.099
tree canopy volume (m^3)*	200	187.304±27.371	100	227.003±38.807
tree density**	200	0.044±0.004	100	0.065±0.006
tree canopy cover (%)*	200	36.337±4.114	100	49.701±5.833
visibility^{NS}	200	50.769±2.256	100	48.629±3.198
shrub height^{NS}	200	71.587±3.135	100	80.069±4.445
shrub volume (m^3)**	200	7.206±0.591	100	9.855±0.838
shrub density*	200	0.579±0.035	100	0.703±0.050
grass height*	200	26.969±1.377	100	20.497±1.952

Significant variables *P < 0.05; **P < 0.01; ***P < 0.001. NS not significant

Table 4.4: Descriptive statistics of visibility and tree and shrub characteristics between kill sites within and outside the park.

	Inside		Outside	
Variable	n	Mean ± SE	n	Mean ± SE
basal area (cm^2)**	100	60.966 ± 6.804	100	94.708 ± 9.065
tree height^{NS}	100	565.217 ± 48.366	100	515.043 ± 31.782
tree canopy volume (m^3)^{NS}	100	174.196 ± 40.811	100	200.544 ± 34.241
tree density***	100	0.027 ± 0.003	100	0.061 ± 0.006
tree canopy cover (%)^{NS}	100	37.969 ± 6.261	100	44.738 ± 5.636
Visibility***	100	62.408 ± 3.396	100	39.013 ± 2.238
shrub height***	100	58.829 ± 4.541	100	84.670 ± 4.061
shrub volume (m^3)***	100	4.856 ± 0.593	100	9.579 ± 0.972
shrub density^{NS}	100	0.513 ± 0.098	100	0.647 ± 0.050
grass height^{NS}	100	25.642 ± 1.764	100	28.309 ± 2.284

Significant variables **P < 0.01; ***P < 0.001. NS: not significant

4.3 Factors affecting visibility

Visibility is affected by a number of vegetation attributes and these were presented in an ordination diagram (Figure 4.3).

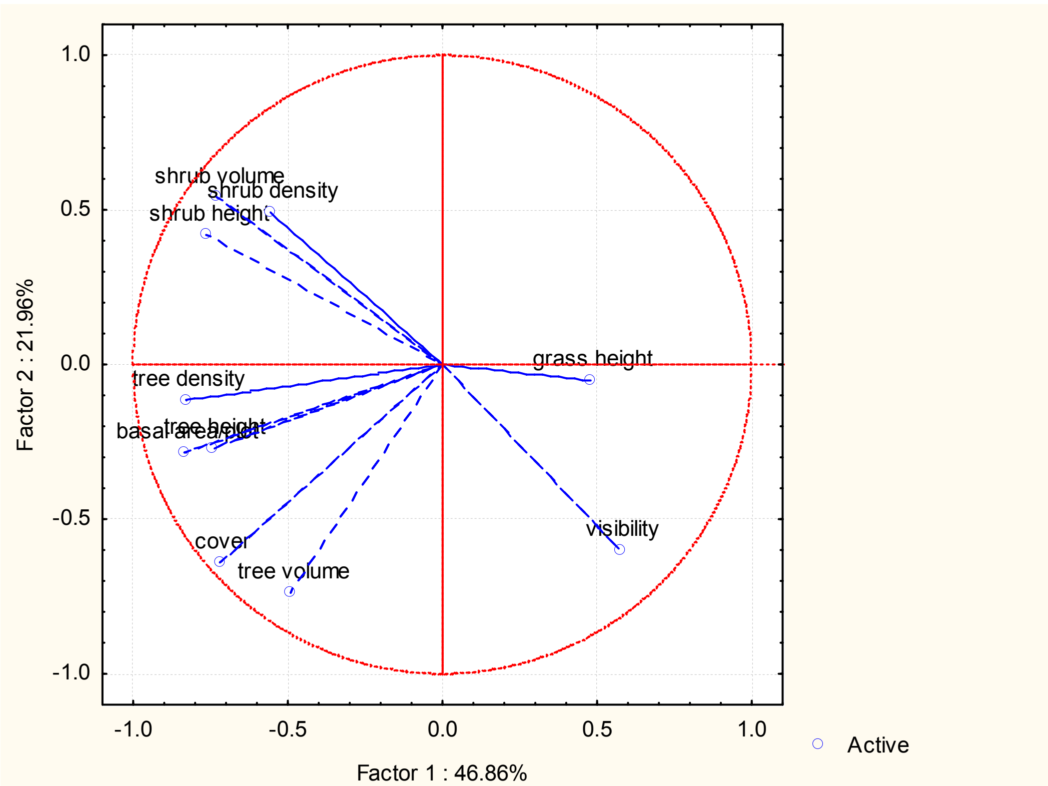

Figure 4.3: Projection of vegetation attributes on Axis 1 and 2 of the principal component analysis (PCA) ordination.

The PCA on vegetation attributes showed that axis one accounted for 46.86% of the variance and axis two only 21.96%. The PCA ordination diagram indicated that visibility and grass height were positively correlated with axis 1 with grass height separated by a narrow angle to the axis. Grass height was negatively correlated with both shrub and tree attributes. The ordination diagram also revealed that there was no relationship between visibility, and canopy cover and tree canopy volume because they were separated by almost 90^0. There was a negative correlation between visibility and the entire shrub attributes (Figure 4.3). All variables placed close to each other influenced the PCA model in a similar way, for example, tree density, tree height and basal area.

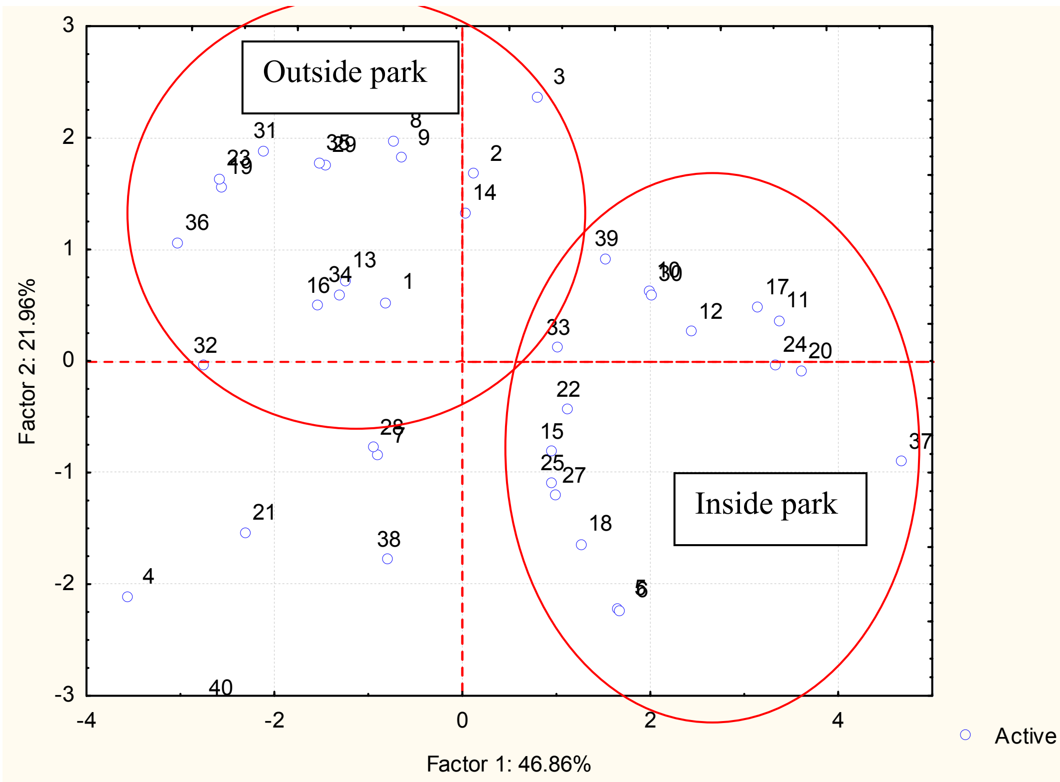

Figure 4.4: PCA scatter plot of kill sites.

The scatter plot showed two groups of kill sites with one above from outside and the one below from inside (Figure 4.4). Total variance accounted by the two axes was 68.82%. Plots 4 and 21 were outliers from the group outside the park and kill sites 40, 38, 7 and 28 were outliers from the group of kill sites within the park.

5.0 CHAPTER FIVE: Discussion and Conclusions

In the environment there are a number of factors that may influence hunting success of wild dogs (Figure 5.1). Comparison of vegetation structure at wild dog kill sites in and outside Hwange National Park for impala and kudu was the core objective of this study. Although differences in vegetation structure existed between inside and outside the park it remains difficult to conclude on whether vegetation structure is the one causing wild dogs to move out of the park and at the same time influencing their hunting success. From figure 5.1, it would appear that there are other confounding factors which can affect hunting success and it is unfortunate that little is known about them.

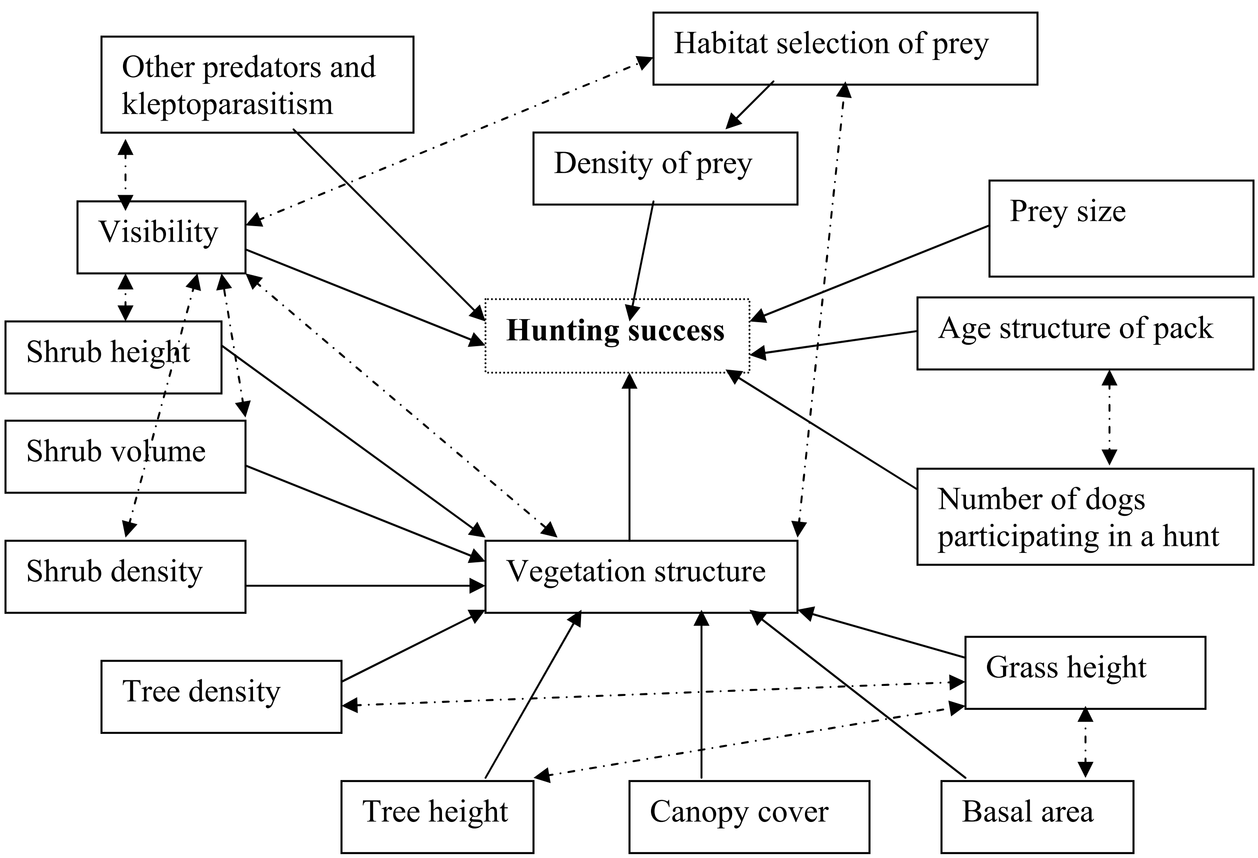

Figure 5.1: A conceptual model of likely factors influencing wild dog hunting success.

A cluster analysis indicated two groups of kill sites: those from inside the park and those from outside. This result indicated distinct differences in vegetation structure between the two areas. The possible explanation for two misclassified kill sites might be due to the fact that these sites were located along the boundary hence subject to edge effect.

Increased vegetation cover outside the park was expected to reduce prey detectability and accessibility (Erikson, 1985; Zwarts & Wanink, 1993; Whittingham & Markland, 2002) and reduce forager mobility (Broadman *et al*., 1997). However, dogs were convincingly doing well there (Rasmussen, pers comm). This suggests that dogs were utilizing this to their advantage, maybe through physical obstruction hence enhancing crypsis when approaching their prey or concealing their kills from hyenas which kleptoparasitise wild dogs when visibility is high (Creel & Creel, 1998). Since there was limited information on the densities of other predators it becomes haze to make a conclusive statement on the link between the moving of dogs outside the park and kleptoparasitism although visibility was higher inside the park. Another possibility is that maybe the dogs were using the intercept method (Creel & Creel, 1995), which is effective in closed environments. This could have perfectly concurred with Funston *et al*., (2001) who reported that the hunting success of male lions increased with increasing vegetation cover. Unfortunately, this research lacked data on failed hunts of wild dogs in and outside the park for comparative purposes.

Considering that vegetation cover was higher outside the park, there was a higher possibility that the chase distances for wild dogs out of the park were shorter than in the park, which concurs with Reich (1981) who reported shorter chase distances of wild dogs in closed environments. Also, there is supporting evidence from McNutt and Boggs (1997) who observed that chases in short-grass plains may last for several kilometers but chases through bush land or woodland habitat are usually significantly shorter. It is unfortunate that Rasmussen (pers comm) only located many kills in dense vegetation but did not witness the chases, which makes it difficulty to conclude on any important role vegetation structure might be playing in the foraging behaviour and success of wild dogs. However, this increased vegetation cover may affect the kudu and impala in the same manner as it does the wild dogs leading to a 'win-win' situation.

The fact that more kills were witnessed in the densely vegetated environment outside the park may mean that impala and kudu use this as a place to hide from attack whilst at the same time it was obstructing view of approaching predators (Fitzgibbon, 1990). Alternatively, it may be that there were higher densities of these two prey species outside the park. The fact that some kill sites were located in closed vegetation cover makes the results of this study contradictory to Fanshawe and Fitzgibbon (1993), who never noticed dogs in dense vegetation and also to Fuller and Kat (1993), where 6% dense woody area in their study site provided little information on whether wild dogs were using this vegetation to improve their hunting success in any way. However, it is important to note that these studies were carried out in the plains of East Africa and also vegetation structure metrics were not measured but rather visual characterization of habitats was used.

The findings of this research further highlighted that vegetation cover was low inside the park and it was observed that dogs were making less kills inside the park. Given that a reduction in cover tends to lower hunting success due to an increased vigilance (Van Orsdal, 1984; Fitzgibbon, 1988), this may explain why dogs were observed to be making less kills inside the park. Also, this can be explained by the fact that reduced cover was probably increasing the risk of kleptoparasitism (Creel, 2001; Mills & Gorman, 1997) since it was observed that the population of hyenas (Nolwenn, pers com) and lions was increasing inside the park (Davidson, pers coms). In higher visibility habitats, chase distances increase as flight distances decrease, probably because of an improved ability to maintain contact with prey Reich (1981), and also time spend foraging is a measure of cost, so frugality and optimization of this resource is critical to survival (Bolnick & Ferry-Graham, 2002).

Given that the simulated looking height was 0.75 m and that the average height of shrubs outside the park was 0.85 m it sounds logical to conclude that shrub attributes influenced visibility more than tree attributes. Tree volume, cover and height did not differ significantly between in and outside the park. It is also important to highlight that these variables had little or no relationship with visibility and hence may not have anything to do with the movement of dogs from in to outside the park. Although wild dogs were observed to use visual cue when hunting (Fanshawe & Fitzgibbon, 1993), in this study it appears that they favoured poorly visible outside park environment which is opposite to what was observed in Namibian cheetahs which also use visual cues when hunting (Muntifering *et al*., 2006).

Kudus were killed in denser taller vegetation than the impala, which supports the concept of resource partioning in feeding ecology of browsers. Given the shoulder heights of kudu and impala (1.3 and 0.9 m, respectively), this might explain why more kudu than impala were killed in taller and denser vegetation as they were more conspicuous.

Although expected to differ since almost the entire vegetation attributes differed significantly, visibility remained insignificantly different. There are two possible explanations for this. Firstly, the method of estimating visibility was subject to observer bias since the observer was aware of the direction taken by the other person who would be pacing away and also it was taken in straight lines. Secondly, shrub height may be the most important attribute influencing visibility since it also differed insignificantly. This is further supported by the correlations Principal Component Analysis in which of the entire shrub attributes, height was the one separated by a narrow angle to axis 1, meaning that it was the one accounting for the greatest variation in visibility. The fact that the random non-kill sites differed significantly with sites where wild dogs killed impala and kudu may be an indication that wild dogs selectively hunted their prey by vegetation structure.

The relationships between vegetation attributes were investigated in ordination and only grass height and visibility were correlated with the positive axis. Visibility showed a strong negative correlation with the entire shrub attributes more than it did with tree attributes. This outcome reveals that considering the looking height of a dog, it is likely that shrubs impact more on the visibility when dogs are hunting. Also grass height had a negative correlation with the entire tree and shrub attributes, which concurs with (Muntifering *et al*., 2006).

The results of this study warrant caution in interpreting or extrapolating on a national or regional scale at this point. Also, environmental attributes like visibility, which fluctuate with season, were not tested to see how they vary. The gape between the initial kill locations (1997-2002) and the habitat measurements (2007) is also cause for concern. Despite these potential setbacks, merit was found in utilizing this data set principally because it prompted the need to investigate hunting success, prey densities and habitat selection and other predator populations if any meaningful conclusions are to be drawn on the influence of vegetation structure on the source/sink dynamics in the HNP wild dog population. Since the wild dog is a highly endangered species it has been found necessary to draw some preliminary conclusions from the limited data that have been generated.

In conclusion, this study revealed that outside park environment has denser vegetation than inside park. Impala were killed in different vegetation types between in and outside the park. Kudus were killed in similar vegetation types between the two sides. Visibility is higher inside the park than outside. Considering the eye-level of wild dogs, visibility is highly influenced by shrub height and volume. As far as wild dogs are concerned, tree cover and tree volume have little or no influence on their visibility. When outside or inside the park, the two species were killed in similar vegetation types. Kudus were killed in taller denser vegetation as compared to impala. This study also highlighted that vegetation structure must be playing a role in the hunting success of wild dogs although data on the hunting success was not available. Tree and shrub attributes are negatively correlated with grass height. The risk of kleptoparasitism must be high inside park due to higher visibility. There is higher possibility that it may be vegetation structure which is having a greater influence on the observed trend of dogs moving outside the park.

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7.0 APPENDICES

7.1 Appendix I: Kill site field record sheet.

Entry Form Vegetation Attributes

Vegetation Type ……………………………………………………………………….

Animal ……………………………………………………………………………….

X ………………………………………………………..

Y ………………………………………………………..

IN	OUT

Trees

C1	C2	C3	C4	C5	C6	C7	HT	SH	LD	SD

Shrubs

HT	LD	SD

Grasses

H1	H2	H3	H4	H5

Estimated Visibility

N	E	S	W

7.2 Appendix 2: Two-way analysis of variance on vegetation attributes that were measured in and outside the park and between the animal species.

Analysis of variance all effects

	Test	Value	F	Effect	Error	p
Intercept	Wilks`	0.029967	423.1262	14	183	0.000000
In-Out	Wilks	0.662532	6.6581	14	183	0.000000
Animal	Wilks	0.918794	1.1553	14	183	0.313379

Basal area

	Df	SS	MS	F	P
Intercept	1	1203954	1203954	191.3389	0.000000
In-Out	1	56283	56283	8.9448	0.003140
Animal	1	22190	22190	3.5265	0.061880
Error	196	1233283	6292		
Total	198	1312114			

Tree height

	Df	SS	MS	F	P
Intercept	1	17262966	17262966	157.7633	0.000000
In-Out	1	237378	237378	2.1694	0.142389
Animal	1	749242	749242	6.8472	0.009570
Error	196	21446949	109423		
Total	198	22437854			

Tree volume

	Df	SS	MS	F	P
Intercept	1	6.976212E+18	6.976212E+18	49.31262	0.000000
In-Out	1	3.384830E+16	3.384830E+16	0.23926	0.625286
Animal	1	1.360161E+17	1.360161E+17	0.96145	0.328029
Error	196	2.772794E+19	1.414691E+17		
Total	198	2.789850E+19			

Number of Trees

	Df	SS	MS	F	P
Intercept	1	2624.197	2624.197	181.5557	0.000000
In-Out	1	352.773	352.773	24.4067	0.000002
Animal	1	88.934	88.934	6.1530	0.013962
Error	196	2832.975	14.454		
Total	198	3276.482			

Tree density

	Df	SS	MS	F	P
Intercept	1	0.380007	0.380007	177.0707	0.000000
In-Out	1	0.057362	0.057362	26.7287	0.000001
Animal	1	0.012881	0.012881	6.0022	0.015165
Error	196	0.420631	0.002146		
Total	198	0.491150			

Tree Cover

	Df	SS	MS	F	P
Intercept	1	3.398365E+13	3.398365E+13	96.49495	0.000000
In-Out	1	2.241639E+11	2.241639E+11	0.63650	0.425946
Animal	1	6.013012E+11	6.013012E+11	1.70737	0.192859
Error	196	6.902739E+13	3.521806E+11		
Total	198	6.985659E+13			

Visibility

	Df	SS	MS	F	P
Intercept	1	511899.0	511899.0	619.2178	0.000000
In-Out	1	27183.0	27183.0	32.8818	0.000000
Animal	1	723.8	723.8	0.8755	0.350575
Error	196	162030.6	826.7		
Total	198	189982.9			

Shrub height

	Df	SS	MS	F	P
Intercept	1	1021727	1021727	545.7663	0.000000
In-Out	1	32738	32738	17.4876	0.000044
Animal	1	132	132	0.0708	0.790493
Error	196	366931	1872		
Total	198	399782			

Shrub volume

	Df	SS	MS	F	P
Intercept	1	1.036023E+16	1.036023E+16	160.9402	0.000000
In-Out	1	1.107883E+15	1.107883E+15	17.2103	0.000050
Animal	1	2.858066E+13	2.858066E+13	0.4440	0.505989
Error	196	1.261714E+16	6.437314E+13		
Total	198	1.375543E+16			

Number of shrubs

	Df	SS	MS	F	P
Intercept	1	34573.40	34573.40	274.5671	0.000000
In-Out	1	401.93	401.93	3.1920	0.075546
Animal	1	25.61	25.61	0.2034	0.652471
Error	196	24680.26	125.92		
Total	198	25108.84			

Shrub density

	Df	SS	MS	F	P
Intercept	1	66.84826	66.84826	276.1758	0.000000
In-Out	1	0.88702	0.88702	3.6646	0.057036
Animal	1	0.07018	0.07018	0.2900	0.590861
Error	196	47.44173	0.24205		
Total	198	48.40148			

Grass height

	Df	SS	MS	F	P
Intercept	1	144924.7	144924.7	353.3996	0.000000
In-Out	1	360.0	360.0	0.8779	0.349933
Animal	1	1034.8	1034.8	2.5233	0.113785
Error	196	80377.1	410.1		
Total	198	81765.8			

7.3 Appendix 3: One-way analysis of variance of visibility and tree and shrub characteristics between kill sites and non-kill random sites.

Basal area

	Df	SS	MS	F	P
Intercept	1	575.8115	575.8115	701.1537	0.000000
Animal	1	4.7681	4.7681	5.8060	0.016578
Error	298	244.7278	0.8212		
Total	299	249.4959			

Tree height

	Df	SS	MS	F	P
Intercept	1	962.9021	962.9021	629.2422	0.000000
Animal	1	19.9027	19.9027	13.0061	0.000364
Error	298	456.0165	1.5303		
Total	299	475.9192			

Tree volume

	Df	SS	MS	F	P
Intercept	1	627.5127	627.5127	571.6598	0.000000
Animal	1	6.7931	6.7931	6.1885	0.013405
Error	298	327.1155	1.0977		
Total	299	333.9086			

Tree density

	Df	SS	MS	F	P
Intercept	1	0.130213	0.130213	263.9461	0.000000
Animal	1	0.004487	0.004487	9.0954	0.002783
Error	298	0.147013	0.000493		
Total	299	0.151500			

Visibility

	Df	SS	MS	F	P
Intercept	1	709.9637	709.9637	11116.75	0.000000
Animal	1	0.0155	0.0155	0.24	0.622212
Error	298	19.0316	0.0639		
Total	299	19.0471			

Shrub height

	Df	SS	MS	F	P
Intercept	1	768.4355	768.4355	1978.492	0.000000
Animal	1	0.9909	0.9909	2.551	0.111260
Error	298	115.7416	0.3884		
Total	299	116.7325			

Shrub volume

	Df	SS	MS	F	P
Intercept	1	163.4059	163.4059	799.3649	0.000000
Animal	1	2.1048	2.1048	10.2965	0.001478
Error	298	60.9171	0.2044		
Total	299	63.0219			

Shrub density

	Df	SS	MS	F	P
Intercept	1	10.28747	10.28747	646.5666	0.000000
Animal	1	0.08289	0.08289	5.2099	0.023163
Error	298	4.74146	0.01591		
Total	299	4.82435			

Grass height

	Df	SS	MS	F	P
Intercept	1	367.8611	367.8611	1327.419	0.000000
Animal	1	1.7184	1.7184	6.201	0.013315
Error	298	82.5833	0.2771		
Total	299	84.3016			

Tree canopy cover

	Df	SS	MS	F	P
Intercept	1	375.3007	375.3007	583.6869	0.000000
Animal	1	4.1699	4.1699	6.4852	0.011381
Error	298	191.6089	0.6430		
Total	299	195.7787			

7.4 Appendix 4: GPS coordinates (UTM projection) of all plots that were measured (i.e, is kill site) and the four neighbouring sites. On species killed, 1 represents impala, 2 represents kudu and 3 represents random non-kill site. For In-Out, 1 represents inside and 2 represents outside.

				Subsidiary plots & their GPS co-ordinates			
Number	species killed	In-out	kill site GPS	North	South	East	West
1	3	1	497400	497410	497388	497445	497266
			7929100	7929483	7928879	7929103	7929094
2	1	1	423500	423465	423574	424069	423342
			7933800	7933031	7934598	7933856	7933797
3	2	1	423500	423465	423574	424069	423342
			7933800	7933031	7934598	7933856	7933797
4	3	1	423500	423554	423843	423407	423407
			7938800	7939436	7938035	7938801	7938801
5	3	1	483800	483807	483881	484128	483213
			7922026	7922255	7921960	7922035	7922016
6	2	1	488300	488763	488747	488920	488428
			7924400	7927849	7926925	7927468	7927557
7	1	1	488300	488763	488747	488920	488428
			7924400	7927849	7926925	7927468	7927557
8	1	1	488300	488385	488301	488939	487395
			7924400	7925074	7924256	7924323	7924533
9	3	1	490000	490027	489965	490381	489921
			7929400	7929499	7929101	7929384	7929395
10	3	2	490900	490921	490388	491287	490766
			7936800	7936899	7936325	7936804	7936822
11	3	1	491000	491001	491002	491186	490055
			7923500	7923899	7923223	7923514	7923505
12	2	1	491000	491027	490972	490784	491181
			7928500	7928983	7927968	7928684	7928457
13	2	1	491600	491603	491635	491669	491512
			7928200	7928252	7927957	7928207	7928188
14	1	1	492400	492297	492410	493000	492182
			7929100	7929591	7929077	7929376	7929135
15	2	1	492700	492712	492733	492863	492513
			7932200	7932499	7932004	7932135	7932188
16	2	1	495000	495024	494997	495483	494834
			7929400	7929012	7929423	7929379	7929418
17	1	2	495900	495896	495899	496182	495387
			7936800	7937276	7936765	7936800	7936829
18	1	2	497400	497643	497643	497354	496811
			7943600	7943037	7943605	7944256	7943606
19	2	2	499400	499394	499447	499632	499345
			7938500	7938563	7938126	7938475	7938498
20	3	2	499400	499400	499407	499617	499190
			7943500	7943687	7943429	7943502	7943516
21	2	1	502700	502699	502663	502865	502077

			7920000	7920798	7919588	7919989	7919890
22	1	1	504300	504313	504241	504412	504045
			7922200	7922316	7921617	7922182	7922145
23	1	1	505000	504938	505004	505474	504766
			7922000	7922559	7921978	7922115	7921983
24	3	2	509300	509282	509277	509362	508576
			7922200	7922473	7921868	7922203	7922077
25	3	2	509300	509319	509305	509511	509134
			7933800	7934740	7933479	7933818	7933788
26	1	2	509300	509301	509254	509806	508610
			7938800	7939037	7938133	7938751	7938746
27	2	2	509700	509685	509705	509929	509599
			7942800	7943371	7942536	7942799	7942820
28	2	2	510500	510506	510493	510873	510441
			7938800	7939638	7938440	7938792	7938800
29	1	1	510900	510903	510824	510969	510776
			7896500	7896875	7896003	7896498	7896504
30	3	1	511700	511648	511667	512029	511580
			7918500	7918762	7918216	2918435	7918515
31	3	2	514700	514863	514864	514911	514830
			7942800	7942815	7942202	7942713	7942715
32	2	1	514800	514743	514819	515695	514185
			7913100	7913707	7912752	7913146	7913012
33	1	1	515700	515698	515660	515725	515173
			7913500	7913587	7912916	7913502	7913549
34	3	1	488800	488799	488813	489287	488458
			7922500	7922571	7922446	7922512	7922496
35	1	2	516400	516428	516322	516472	515988
			7920200	7920671	7919758	7920197	7920242
36	1	2	512900	512898	512928	513278	512717
			7923600	7923810	7922874	7923613	7923599
37	1	2	516700	516716	516703	516005	516707
			7918500	7918500	7918363	7918496	7918621
38	3	2	517300	517303	517300	517396	517083
			7935000	7935083	7934976	7934992	7934985
39	1	2	517300	517288	517296	517440	516975
			7940000	7940236	7939707	7940006	7939986
40	2	2	517300	517288	517296	517440	516975
			7940000	7940236	7939707	7940006	7939986
41	3	2	517487	517481	517560	517739	517453
			7944806	7944886	7944389	7944810	7944798
42	2	2	517700	517697	517695	518552	516956
			7931800	7931880	7931705	7931895	7931716
43	1	2	497600	497608	497596	497710	497023
			7944000	7944296	7943693	7944015	7944005
44	1	2	518200	518195	518202	518743	518132
			7941500	7941566	7941422	7941468	7941507
45	2	2	513000	513002	513001	513242	512943
			7922800	7923332	7922768	7922805	7922795
46	3	2	519000	518897	519017	519933	518339
			7942000	7942570	7941830	7942120	7941911
47	3	2	519800	519809	519793	520431	519702

			7913100	7913314	7912453	7913015	7913098
48	2	2	520500	520502	520516	520972	520264
			7931500	7931555	7931251	7931553	7931487
49	2	2	521100	521114	521126	521417	520808
			7929500	7929705	7929261	7929568	7929585
50	3	1	521500	521598	521493	521527	521278
			7910400	7911137	7910259	7910402	7910412
51	2	2	521500	521550	521515	521919	521285
			7915400	7915891	7914657	7915354	7915431
52	2	2	521600	521631	521560	522267	521257
			7915500	7916044	7914868	7915504	7915520
53	1	2	524600	524589	524585	524932	524194
			7927900	7928214	7927569	7927885	7927908
4	3	2	524600	524567	524575	524785	524482
			7932900	7933245	7932746	7932908	7932912
55	2	1	526500	526602	526553	526929	526175
			7891900	7892390	7891426	7891905	7891882
56	1	1	536100	536105	536103	536215	536036
			7892100	7892537	7891721	7892098	7892110
57	2	1	540000	539991	539990	540031	539305
			7890500	7890890	7890278	7890501	7890464
58	3	1	545000	544985	545016	545251	544179
			7890500	7890775	7889539	7890505	7890434
59	3	1	531611	531626	531607	532008	531418
			7894173	7894409	7894059	7894211	7894175
60	1	1	515700	515698	515660	515725	515173
			7913500	7913587	7912916	7913502	7913549