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**INFLUENCE OF INDUSTRIAL ACTIVITIES ON THE SPATIAL
DISTRIBUTION OF WILDLIFE IN
MURCHISON FALLS NATIONAL PARK, UGANDA
BY
SAMUEL AYEBARE**

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
IN
ENVIRONMENTAL SCIENCE**

UNIVERSITY OF RHODE ISLAND

2011

MASTER OF SCIENCE THESIS
OF
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UNIVERSITY OF RHODE ISLAND
2011

ABSTRACT

Activities carried out by resource extraction industries in and adjacent to protected areas have increased the risk to biodiversity conservation in different parts of the world. Oil and natural gas developments in the Albertine rift, one of Africa's biodiversity hotspots, have raised concerns about the potential impacts to wildlife populations and the associated land-cover change. The influence of oil and gas industrial activities on the spatial distribution of wildlife in Murchison Falls National Park was examined by conducting wildlife surveys along 2-km long transects that radiated away from well pads and access roads. The position of large mammal sightings were recorded along transects at 50 m intervals using a Global Positioning System. The study tested the hypothesis that the occurrence of species would be constant as a function of distance from the well pads and access roads.

The study compared the average frequency of sightings per survey at 50 m intervals for distances of 0-500 m and 1,500-2,000 m from the well pads and access roads. Species response curves were fitted using General Additive Models to explore any trends along spatial and temporal gradients. The results suggested that there was indirect habitat loss at different temporal and spatial scales due to avoidance behavior. The study found that elephants, Uganda kob, hartebeest, buffalo and giraffes showed increased habitat avoidance around well pads while trends for oribi and warthog suggested a level of tolerance behavior towards well pad activity. Spatial response curves illustrated species-specific differences in thresholds to disturbance stimuli from the well pads. The shape and direction of spatial and temporal species response curves suggested a shift in habitat use which varied with level of activity.

The use of spatial temporal gradients was proposed in modeling different scenarios of hydrocarbon developments in the park, however the use of other covariates that affect species distribution could be considered. Spatial temporal models enable stakeholders in the oil and gas industry effective scheduling of hydrocarbon activities so as to minimize species' disturbance. Sustainable development requires access to affordable energy as well as conservation of biodiversity which is a significant challenge to the different stakeholders in the oil industry in the Uganda. Oil and gas development has the potential to provide funding for conservation, and therefore, integrating biodiversity considerations into oil and gas development management plans will be useful in promoting conservation in the region.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the valuable support and assistance extended to me from several people and organizations during this research. Funding for my graduate study and research was provided by Wildlife Conservation Society, Tellus Education Foundation, Graduate School of the University of Rhode Island (URI) and the College of Environment and Life Sciences URI.

I would like to express my sincere thanks to my major professor Dr. Yeqiao Wang. Dr. Wang encouraged me to join the department of Natural Resource Science and made thoughtful comments throughout my studies and work on my thesis, as well enabling me to develop a clear understanding of the subject of terrestrial remote sensing.

My thesis committee members provided valuable feedback about my thesis and insightful discussions regarding different approaches of data analysis. Many thanks to Dr. Peter August, Professor in the Department of Natural Resource Science, Dr. Peter Paton, Professor and chair of the Department of Natural Resource Science, Dr. Howard Ginsberg, Professor in the Department of Plant Sciences and Entomology.

Dr. Charles Roman of the U.S National Park Service served as my defense chair. I thank him for his valuable service.

I would like to thank Dr. Andrew Plumptre, Director Albertine Rift Program, Wildlife Conservation Society (WCS), for his supervision and support throughout my work at WCS. Over the years, I have benefited considerably from discussions with him about biodiversity research and conservation.

I would like to express my gratitude to my colleagues at Wildlife Conservation Society, Uganda program, for their support and work on monitoring the impacts of oil and gas exploration in the Albertine rift. Many thanks to Sarah Prinsloo, Oil Mitigation Manager, Dr. Grace Nagendo, GIS and Remote sensing specialist, Carol Bogezi, Senior Field Coordinator, Paul Mulondo, Senior Field Coordinator, Ken Fehling, Data Entry Clerk and all the research assistants that were involved in the monitoring program.

I wish to thank Uganda Wildlife Authority (UWA) staff in Murchison Falls National Park, for their support during monitoring activities and entire team of Rangers that were working on oil and gas monitoring activities.

I thank all the members of the laboratory for Terrestrial Remote Sensing, Environmental Data Center and the Department of Natural Resources Science for their support during my graduate study at the University of Rhode Island.

Finally, I wish to acknowledge my family members, relatives, classmates and friends for their moral support.

TABLE OF CONTENTS

ABSTRACT	ii
ACKNOWLEDGMENTS.....	iv
TABLE OF CONTENTS.....	vi
LIST OF TABLES	viii
LIST OF FIGURES	ix
CHAPTER 1 LITERATURE REVIEW	1
1.1 <i>An Overview</i>	1
1.2 <i>Albertine Rift</i>	2
1.3 <i>Land-Use and Land-Cover Change</i>	3
1.4 <i>Study Population</i>	4
1.5 <i>Social Structure and Behavioural Ecology of the Study Population</i>	5
1.5.1 <i>African Elephant</i>	5
1.5.2 <i>African Buffalo</i>	6
1.5.3 <i>Giraffe</i>	6
1.5.4 <i>Hartebeest</i>	7
1.5.5 <i>Uganda Kob</i>	8
1.5.6 <i>Warthog</i>	8
1.5.7 <i>Oribi</i>	9
CHAPTER 2 THESIS RESEARCH	10
2.1 <i>Introduction</i>	10
2.2 <i>Methodology</i>	13
2.2.1 <i>Study Area: Murchison Falls National Park</i>	13
2.2.2 <i>Data Collection</i>	14
2.2.3 <i>Wildlife Surveys</i>	15

2.2.4 Data Analysis	15
2.3 Results	18
2.3.1 Comparing Encounter Rates per Pad.....	18
2.3.2 Comparing Encounter Rates for All the Pads at 0-500 m	19
2.3.3 Comparing Encounter Rates for All the Pads at 1,500-2,000 m.....	19
2.3.4 Relationship between the Number of Species (pooled) Observed at Distances 0-500 m and 1,500-2,000 m with Survey Period.....	19
2.3.5 Comparing Encounter Rates per Species.....	20
2.3.5.1 L1 (Activity=Low)	20
2.3.5.2 L2 (Activity=Low)	20
2.3.5.3 M1 (Activity=Moderate).....	21
2.3.5.4 H1 (Activity=High)	21
2.3.6 Comparing Encounter Rates at Distances 0-500 m and 1,500-2,000 m from Access roads.....	22
2.3.7 Habitat Use	22
2.4 Conclusion and Discussion	23
Appendix 1: Some of the Species in the Study Area	57
Elephants (<i>Loxondonta Africana</i>).....	57
Buffalos (<i>Syncerus caffer</i>).....	57
Hartebeests (<i>Alcelaphus buselaphus</i>)	58
Giraffes (<i>Giraffa cameopardalis</i>).....	58
Appendix 2: Some of the Habitats in the Study area	59
Dense Borassus.....	59
Grassland.....	59
Appendix 3: Oil and Gas Activities	60
Access Road	60
Oil Well Pad (No activity)	60
BIBLIOGRAPHY	61

LIST OF TABLES

TABLE	PAGE
Table 1.1: Home range sizes of the different species in the study area.	27
Table 2.1: Comparing the frequency of sightings per species at distances 0-500 m and 1,500-2,000 m as function of survey period using the G test, Pads L1, L2, M1 and H1.	28
Table 2.2: Comparing the average frequency of sightings between oil pads and access roads at distances of 0-500 m.	29
Table 2.3: Comparing the average frequency of sightings between oil pads and access roads at distance of 1,500-2,000 m.	30
Table 2.4: Vegetation description along transects.	31

LIST OF FIGURES

FIGURE	PAGE
Figure 1: Extent of oil and gas exploration in the Albertine Rift, Uganda.	32
Figure 2: Map showing the Location of Uganda.	33
Figure 3: Murchison Falls National Park, Uganda.	34
Figure 4: Location of study area.	35
Figure 5: Flow chart of the monitoring design.	36
Figure 6: Basic monitoring design with four main transects per pad and two transects on the access road.	37
Figure 7: Comparing encounter rates (17 to 18 days of survey effort) at 50 m intervals per Pad (L1, L2, M1, H1) for all species at distances of 0-500 m and 1,500-2,000 m along transects.	38
Figure 8: Comparing encounter rates (17-18 days of survey effort) at 50 m intervals per species (L1; Low) at distances of 0-500 m and 1,500-2,000 m along transects.	39
Figure 9: Comparing encounter rates (17-18 days of survey effort) at 50 m intervals per species (L2; Low) at distances of 0-500 m and 1,500-2,000 m along transects.	40
Figure 10: Comparing encounter rates (17-18 days of survey effort) at 50 m intervals per species (M1; Moderate) at distances of 0-500 m and 1,500-2,000 m along transects.	41

Figure 11: Comparing encounter rates (17-18 days of survey effort) at 50 m intervals per species (H1; High) at distances of 0-500 m and 1,500-2,000 m along transects.	
.....	42
Figure 12: Comparing encounter rates (17-18 days of survey effort) for all the Pads at distances 0-500 m.	43
Figure 13: Comparing encounter rates (17-18 days of survey effort) for all the Pads at distances 1,500-2,000 m.	43
Figure 14: Comparing encounter rates (17-18 days of survey effort) at distances 0-500 m and 1,500-2,000 m from access roads for Pads (L1, L2, M1, H1).	44
Figure 15: Habitat use Pads L1 and L2.	45
Figure 16: Habitat use Pads M1 and H1.	46
Figure 17: Number of species along an increasing distance gradient from Pads L1, L2, M1 and H1.	47
Figure 18: Number of Uganda kob along a distance gradient from Pads L1, L2, M1 and H1.	48
Figure 19: Number of oribi along a distance gradient from Pads L1, L2, M1 and H1.	49
.....	49
Figure 20: Number of hartebeest along a distance gradient from Pads L1, L2, M1 and H1.	50
Figure 21: Number of buffalo along a distance gradient from Pads L1, L2, M1 and H1.	51
.....	51
Figure 22: Number of giraffe along a distance gradient from Pads L1 and M1.	52

Figure 23: Number of warthog along a distance gradient from Pads L1, L2, M1 and H1	53
Figure 24: Number of elephant dung along a distance gradient from Pads L1, L2, M1 and H1.	54
Figure 25: Species temporal response curves at distances 0-500 m, Pads L1, L2, M1, and H1.	55
Figure 26: Species temporal response curves at distances 1,500-2,000 m, Pads L1, L2, M1 and H1.....	56

CHAPTER 1 LITERATURE REVIEW

1.1 *An Overview*

Studies quantifying responses of wildlife behavior to industrial disturbances have shown that activities carried out at the different phases of oil and gas exploration, and production have resulted into direct loss of wildlife, their habitats, as well as reduction in habitat use following avoidance behavior (Theobald et al. 1997, Wilkie et al. 2000, Dyer et al. 2001, Sawyer et al. 2009, Rabanal et al. 2010). The impact of oil and gas activities on wildlife may be direct such as habitat loss due to infrastructure development, however the physical foot print may be negligible compared to habitat avoidance (Dyer et al. 2001, Johnson et al. 2005, Sawyer et al. 2009). Avoidance behavior may also lead to cumulative social and physiological consequences that may have implications on population productivity (Jalkotzy et al. 1997, Johnson et al. 2005). However avoidance is not absolute and the responses to industrial activities vary between the different species with some species showing no response (Haskell et al. 2006, Kolowski and Alonso 2010, Rabanal et al. 2010).

Most of the studies quantifying the impacts of oil and gas drilling activities on wildlife have been conducted in the Arctic on Caribou (*Rangifer tarandus*) (Cronin et al. 1997, Cronin et al. 1998, Dyer et al. 2001, Haskell et al. 2006). Although oil field development may impact individual caribou through disturbance, some studies point to an increasing caribou herd size despite oil and gas activities (Cronin et al. 1997). While creation of protected areas is a key instrument in countering habitat destruction and biodiversity loss, their existence and functioning is hampered by competing

economic interests and resource use pressure (Mena et al. 2006). The recent success in oil and gas exploration followed by subsequent production in the Albertine Rift region (Figure 1) requires an understanding of how species respond to disturbance stimuli across different spatial and temporal scales to allow for effective planning.

1.2 Albertine Rift

Africa's western rift valley or the Albertine rift straddles along the borders of Democratic Republic of Congo, Rwanda, Burundi, Uganda, Tanzania up to Zambia and Malawi. The geological process that shaped the Albertine rift over millions of years of tectonic movements and inter-climatic cycles produced great scenery ranging from low land savannah grasslands to high tropical rain forests. With an altitude ranging from 5,100 m at the highest peak, the rift is a mosaic of mountains, hills, forests, swamps, savannah grasslands, glaciers, lakes, rivers, gorges, volcanic craters, waterfalls and hot springs all sandwiched between two valley walls. The diversity of habitats makes the Albertine rift one of Africa's biodiversity hotspots supporting a very high degree of rare plants and animals (Brooks et al. 2001, Olson et al. 2001, Kuper et al. 2004, Burgess et al. 2006, Plumptre et al. 2007). It is the most species rich region for vertebrate conservation in Africa (Brooks et al. 2001, Plumptre et al. 2003) and is globally recognized under several classification schemes (Plumptre et al. 2007). Thus, the Rift Valley region is a mega diversity area incorporated within the Eastern Afromontane Hotspot, which also includes the Ethiopian Highlands and the Eastern Arc Forests of Tanzania and Kenya (Brookes et al. 2001, Plumptre et al. 2003). Global biodiversity assessments have recognized the Albertine Rift to be among the top conservation priorities across Africa (Brooks et al. 2001) and as an

ecoregion with the highest number of endemic mammals (Olson et al. 2001). It contains four World Heritage Sites, two Biosphere Reserves and four Ramsar sites (wetlands of international importance). As such, it is a critically important region for global conservation.

1.3 Land-Use and Land-Cover Change

The effects that spatial patterning and changes in landscape structure have on the distribution, movement and persistence of species are the focus for landscape ecological studies (Turner, 1989). By understanding how disturbances vary in space and time, through quantifying landscape patterns and changes we can predict the effects of disturbances on the population productivity. The interactive effects of disturbances operating at various scales produce the observed landscape mosaic and they are difficult to predict (Turner, 1989). Human driven land-use and land-cover change at local, regional and global scales are among the greatest threats to biodiversity conservation (Kerr and Ostrovsky, 2003, Lindermana et al. 2005, Wenguang et al. 2008, Giam et al. 2010).

Industrial activities within or adjacent to protected areas have had tremendous effects on biodiversity conservation in different parts of the world (Lindermana et al. 2005, Mena et al. 2006, Finer et al. 2008). These range from less intensive local scale activities (e.g., fuel wood collection) to large scale industrial activities (e.g., logging and mining). The impacts of less intense local-scale activities may seem negligible in the landscape but their accumulation over time and within the landscape are likely to cause change and influence the way the landscape functions (Theobald et al. 1997, Lindermana et al. 2005). The rapid development in remote sensing technology in both

spatial and spectral resolutions has led to improvements in understanding of the drivers of land-use land-cover change within and adjacent to protected areas (Turner et al. 2003). Studies quantifying landscape pattern and process in East and Central Africa have shown that the main drivers of land-use and land-cover change are due to the expanding agriculture and industrial activities such as mining and timber harvesting (Laporte et al. 2004, Duveiller et al. 2008, Hartter et al. 2010).

1.4 Study Population

The study population involved large mammals in Murchison Falls National Park (MFNP). Some of the large mammals found in the park include buffalos (*Syncerus caffer*), giraffes (*Giraffa camelopardalis*), bush duiker (*Sylvicapra grimmia*), African civet (*Civettictis civetta*), patas monkey (*Erythrocebus patas*), Savanna baboon (*Papio cynocephalus*) Uganda kob (*Kobus kob*), elephants (*Loxodonta africana*), waterbuck (*Kobus ellisiprymns*), warthog (*Phacochoerus aethiopicus*), bush buck (*Tragelephus scriptus*), hartebeest (*Alcelaphus buselaphus*), reed buck (*Redunca redunca*), lions (*Panthera leo*), leopards (*Panthera pardus*), oribi (*Ourebia ourebi*), spotted hyena (*Crocuta crocuta*) and jackals (*Canus adustus*). From 1975 to 1990, MFNP lost over 90 % of its large mammal populations due to the prevailing political instability during that period (Uganda Wildlife Authority, 2001). However recent aerial surveys in 1995, 1999 and 2005 indicate that the wildlife populations are recovering (Lamprey 2000, Rwetsiba and Wanyama, 2005). The large mammals that are the subject of this study include buffalos, giraffes, Uganda kob, elephants, warthogs , hartebeest and oribi.

1.5 Social Structure and Behavioural Ecology of the Study Population

The social life of large mammals varies among species, but there are broad categories into which many of them can be classified (Eltringham 1979). Leuthold (1977) defined social organization as “the result of all social interactions and spatial relations among members of a single species population.” Although social organization of mammals tends to be specie’s specific, several aspects are subject to considerable variation related to changing environmental conditions (Leuthold 1977, Eltringham 1979). The social structure of large mammals can be categorized into families, herds, packs, prides and as solitary animals. Changing environmental conditions influence the nature and extent of the social organizations of the various species of large mammals, which also affects the spatial distribution and home range size (Table 1.1) of the individuals, families, herds, packs, and prides (Leuthold 1977, Dyer et al. 2001). However, the degree to which the different wildlife species adjust their feeding habits and home ranges due the presence of industrial disturbances is poorly understood as well as the cumulative effects on population productivity.

1.5.1 African Elephant

The range and distribution of elephants has been reduced significantly in recent decades due to habitat encroachment and poaching for ivory (Estes 1992). Their social structure is centered around the matriarch, who plays a leadership role for the whole family (Eltringham 1979, Estes 1992). The matriarch is concerned with leading the family to suitable feeding grounds and deciding on the day to day activities. Elephants in southern Africa prefer areas with increased proximity to water, low vegetative cover and avoided human settlements when present (Harris et al. 2008). Various studies

indicate that the home range size of elephants varies from 14 to 5,060 km² (Galanti et al. 2005, Leuthold 1977). Elephants spend about 75% of their time feeding, have a more catholic diet and wander more widely than most herbivores (Eltringham 1979, Estes 1992). They can subsist in most habitats that provide adequate food and water (Estes 1992).

1.5.2 African Buffalo

The African Buffalo (tribe Bovini) inhabits a wide range of habitats ranging from open forests, woodlands to savannah grasslands (Eltringham 1979, Estes 1992). Buffalos are highly gregarious, non territorial and form large mixed herds with male dominance hierarchy (Eltringham 1979, Ryan et al. 2006). Herds range in size from a few individuals to hundreds of animals, however old bulls tend to live a solitary life.

Buffalos are known to exhibit seasonal social ecology, in which large mixed herds are formed during the breeding season and then for the rest of the year the herds split into mixed herds and bachelor groups (Eltringham 1979, Ryan et al. 2006). Buffaloes are a water dependent species that are bulk grazers that are able to feed on tall grasses, but also are capable of browsing. Based on studies in Ruwenzori National Park, Tsavo East National Park, Serengeti National Park and Klaserie Private Nature Reserve, the home range of buffalos varied from 10 to 450 km² (Leuthold 1977, Ryan et al. 2006).

1.5.3 Giraffe

Giraffes inhabit lightly wooded savannah areas of Africa although they have been eliminated from most of their former ranges (Estes 1992). They are gregarious, non territorial and live in open herds. Various species of *Acacia* and *Combretum* form the

bulk of their diet (Estes 1992). There is a clear ecological separation in feeding between sexes; female-biased groups tend to use open vegetation, regenerating trees, and shrubs, while male-biased groups prefer tall, thick vegetation (Young et al. 1991, Estes 1992). Giraffes form no lasting bonds and associations are mostly casual with other individuals whose ranges overlap. Even when resting, giraffes stay at least 20 m apart (Estes 1992). The home range of the giraffes in Tsavo and Nairobi National Parks varies from 12 to 650 km² (Leuthold 1977).

1.5.4 Hartebeest

Hartebeest, wildebeest (*Connochates taurinus*), topi (*Damaliscus lunatus*) and blesbok (*Damaliscus dorcus*) (tribe Alcelaphini) are large antelopes inhabiting savannah grasslands and open woodland areas across Africa (Estes 1992). Adult males stand at 115 cm in height and weigh an average of 142 kg, while females stand about 112 cm high and weigh on average 126 kg (Estes 1992). They graze selectively on leafy, growing perennial grasses and have a particular preference for medium grasslands dominated by red oat grass (*Themeda triandra*) (Eltringham 1979, Estes 1992). They typically live in herds of 6 to 15 female individuals, while territorial bulls are usually solitary except when actively herding or courting (Estes, 1992). Young male hartebeest form bachelor herds although they are usually smaller than the female herds. The home range of hartebeest in Nairobi National Park and Maralal, Kenya varied between 2.6 to 10.3 km² (Leuthold 1977).

1.5.5 Uganda Kob

Uganda kob is a medium-sized antelope that inhabit the savannah grasslands of East Africa along with reedbucks, waterbucks (*tribe Reduncini*). They are gregarious, forming female and bachelor herds, with adult males primarily territorial (Eltringham 1979, Estes 1992). The Uganda kob is a grazer and prefers short perennial grasses (*Sporobolus pyramidalis*) which are high in protein and low in fiber (Balmford 1992, Estes 1992). Kobs live in conventional, and lek territories and territorial males are spaced at least 100-200 m apart occupying the best habitat. Females live in herds of 5-15 individuals, but herds of up to 40 can be observed (Estes 1992). In their most preferred habitats, the density of kob averaged 182 animals per km² in Queen Elizabeth National Park, Uganda, which was among the highest for non-migratory species (Balmford 1992). The home range size of Uganda kob was found to vary from 3 to 15.6 km² with a mean core area of 3.1 km² in Queen Elizabeth National Park (Balmford 1992).

1.5.6 Warthog

The warthog belongs to the family *Suidae* together with bushpig (*Potamochoerus porcus*), giant forest hog (*Hylochoerus meinertzhageni*) and wild boar (*Sus scrofa*). They inhabit the northern and southern savannah areas of Africa and are gregarious, non-territorial and form harem groups with one male. Matriarch groups usually associated with adult males (Estes 1992). Warthogs prefer underground rhizomes of short perennial grasses, sedges as well as bulbs and tubers (Eltringham 1979, Estes 1992). The basic social unit consists of females and young, with conventional home ranges shared by bachelor and solitary males (Estes 1992). In Nairobi National Park,

the home range size of warthogs was found to vary from 0.7 to 3.6 km² (Leuthold 1977).

1.5.7 Oribi

Oribis are known as dwarf antelopes and belong to the tribe Neotragini together with steenbok (*Raphicerus campestris*), dik dik (*Madoqua kirkii*) and klipspringer (*Oreotragus oreotragus*). Adult male stands between 51 - 63.5cm in height and weigh an average of 14 kg, while females stand between 51 - 63.5 cm and weigh an average of 14.2 kg (Estes 1992). Oribis are the only neotragine that are primarily grazers and they avoid habitats dominated by woodland or bush. They prefer open grasslands and ecotones where bush blends into open plains (Estes 1992). They are a territorial species that are monogamous with a tendency to polygyny. Males maintain territories which they share with 1 or 2 females. The home range sizes of female oribi vary from 0.12 to 0.95 km² and male territorial behavior is related to the size of the female home ranges (Brashares et al. 2002).

CHAPTER 2 THESIS RESEARCH

2.1 Introduction

Uganda is a landlocked country located in east Africa, with a total surface area of 236,040 km². The country is bordered by Sudan to the north, Kenya to the east, Democratic Republic of Congo to the west, and Tanzania and Rwanda to the South (Figure 2). It is a home to varied flora and fauna reflecting the diversity of habitats ranging from high tropical forests to the lowland savannah. The high tropical forests in the western part of the country provide a habitat to several primates including the endangered mountain gorilla (*Gorilla gorilla beringei*), while the fauna in northern Uganda is representative of extremely dry areas of northern Kenya. A total of 345 terrestrial vertebrates have been recorded, 1,012 species of birds representing more than half of Africa's bird species (10% of the world's bird list), 1,242 species of butterflies, 142 species of reptiles, and 86 species of amphibians (Winterbottom and Eilu, 2006). However conservation efforts in the country and region are hampered by challenges such as poaching, high rate of human population growth, expanding agriculture, deforestation and resource extraction industries (Winterbottom and Eilu, 2006). According to the 2002 Uganda population and housing census (Uganda Bureau of Statistics, 2002), the total population was 24.4 million people which represented a 3.3% growth rate per year from the 1991 population census. Most Ugandans (88%) live in the remote rural areas, which also are sympatric with protected areas with high biodiversity. With the increase in human population, there has been tremendous pressure on natural resources outside of protected areas and now on the protected areas to supply the products and services demanded by the people. As a result, the country is

experiencing one of the highest deforestation rates on the continent as the demand for fuel wood energy, land for agriculture and settlement continue to rise (Winterbottom and Eilu, 2006). This situation has left the government with no choice but argue for easement of regulations that govern protected areas, for example on the Mabira Forest Reserve (Howden, 2007).

To exacerbate the situation, substantial amounts of oil and gas have been discovered in the same areas such as the Albertine Rift region. Africa's western rift valley, or the Albertine Rift, is one of the most biologically diversified regions in Africa, is also endowed with oil and gas deposits. Recent discoveries of oil and natural gas deposits have raised concerns about the impacts of industrial activities and the associated land-cover change on wildlife. The effects of industrial activities on wildlife include individual disruption, habitat avoidance, habitat disruption or enhancement, direct and indirect mortality and population impacts (Jalkotzy et al. 1997). However the effect of a particular impact varies from species to species (Jalkotzy et al. 1997). Global energy demand is anticipated to increase by 49 percent, or 1.4 percent per year from 495 quadrillion British thermal units (Btu) in 2007 to 739 quadrillion Btu in 2035, with fossil fuels likely to remain the largest source of energy (U.S Energy Information Administration, 2010). Increasing global demand for energy has increased the risk to biodiversity conservation from oil and gas exploration, development and production projects in different parts of the world (Finer et al. 2008, Copeland et al. 2009, Sawyer et al. 2009). Four oil well construction sites were monitored in Murchison Falls

National Park, Uganda using a system of transects that radiated away from the well pads and access roads.

The primary objectives to this research were to:

- 1) Examine the spatial distribution of wildlife along transects from well pads and access roads in relation to oil and gas industrial activities.
- 2) Examine ways of modeling a network of wells in the park that minimizes species disturbance through the use of species response curves.

Although the physical footprint of habitat loss and perturbations can be quantified through the use of remote sensing acquired imagery and GIS models, it is difficult to quantify the indirect habitat loss that results at different phases of the oil and gas exploration, and production activities due to habitat avoidance of the affected wildlife. With the potential of widespread oil and gas exploration activities in the Albertine rift region, there is a need to manage the oil and gas industry across the region.

2.2 Methodology

2.2.1 Study Area: Murchison Falls National Park

Murchison Falls National Park (MNFP) was established in 1952 and lies in the northern end of the Albertine rift which includes part of the valley floor and part of the eastern escarpment (2° 15' 0" N, 31° 48' 0" E) (Figure 3). It is the largest national park in Uganda that covers 3,893 km² in area with a high diversity of flora and fauna. The Bugungu (678 km²) Wildlife Reserve (WR) in the south and the Karuma (678 km²) WR in the southeast, along with the MFNP, comprise the Murchison Falls Conservation Area. In Bugungu WR, the western escarpment rises 100 m over the valley floor to provide a spectacular view of Lake Albert. The park ranges from 619 m on Lake Albert in the west to 1,291m at the highest point at Rabongo hill in the east (Uganda Wildlife Authority, 2001). The Victoria Nile runs from east to west and bisects the park into the north and south banks. The Nile plunges 45 m through the rift escarpment to form the spectacular view of the Murchison falls. Vegetation is comprised of savannah grasslands, tropical woodlands, tropical deciduous forest, tropical evergreen forest and permanent swamps (Olupot et al. 2010). Climate is hot and humid, with relative humidity averaging 60%, while the temperature ranges from a mean minimum of 22 °C to a mean maximum of 29 °C.

The Uganda Wildlife Authority's management plan from 2001 to 2011 documented 80 species of mammals (Uganda Wildlife Authority, 2001). Some of the species include elephants, hippopotamus, buffalo, giraffe, Uganda kob, water buck, hartebeest, bohor reed buck, bush buck, bush pig, warthog, oribi, lion, leopard, jackal and the spotted hyena. The park is also home to six species of primates including

black-and-white colobus (*Colobus guereza*) and chimpanzees (*Pan troglodytes*). The study area was located in the western part of the park with the predominate vegetation being the savannah grassland (Figure 3). It covered approximately 111.18 km² which represents 12.4% of the total area allocated for hydrocarbon activities north of the Victoria Nile (Figure 4)

2.2.2 Data Collection

Data collection was organized by the Oil and Gas Mitigation component of the Wildlife Conservation Society, Uganda program. A total of four oil well construction sites were monitored in the study area. The four sites were spaced about 4-5 km and they were at different stages of construction, which would enable comparison of species' responses to different levels of disturbance stimuli. Oil well pads were monitored on a four-day rotation from mid February 2010 to the end of March 2010. During the survey, transects were walked twice every four days, early morning on the first day and from 4:00 PM to dusk on the subsequent day (Figure 5). Each transect was surveyed a total of 17 to 18 times representing 36 days of survey effort. Data were also collected on the oil pad activities, as well recording the number of vehicles accessing the pad was recorded. The level of activity at the pad sites was classified as Low (no activity), Medium (Intermittent activity) and High (Pad construction ongoing) depending on the number of people, machinery and how far noise can be heard from the well pads. There were two sites at the Low activity category (L1 and L2), one site at Medium activity category (M1) and one site at the High activity category (H1).

2.2.3 Wildlife Surveys

The systematic surveys involved a system of transects that radiated away from well pads and access roads. Four transects, each 2 km in length radiated out randomly from well pads and two transects from access roads (Figure 6). Transects were marked with stakes so that the same line was walked each time they were visited. They were subdivided into 50 m distance increments and animal observations assigned to a particular interval along transects. Sightings of all large mammals were recorded using a global positioning system receiver. Also elephant dung sightings along transects were recorded. The distance along transects where the animal or a group of animals were observed was noted as was the perpendicular distance (estimated using a range finder) from the transect. Transect width was variable and perpendicular distances were used to model detection curves. Efforts were made to record animals where they were first seen. Care was taken to ensure that the observer was not driving the animals away from the transect before they had been recorded. Data recorded included: date, transect number, and well pad number, GPS position of animal sightings along the transect, distance from pad/road, habitat type along the transect where the animal or group was observed. The distance along the transect was measured in 50 m intervals and animals assigned to the interval where they were observed.

2.2.4 Data Analysis

Data analysis involved comparing the average frequency of sightings per survey (50 m intervals) close to the well pad and access road (i.e., 0 to 500 m from the access road or well pad) compared to the average frequency of sightings per survey far from well pads or access roads (i.e., 1,500 to 2,000 m from the well pad or access road) for each

species and each pad. Spatial distribution of animal sightings along the transects was examined using non-parametric statistics. Exploratory data analysis plots of the distributions of sightings suggested that assumptions of normality were not met. The non-parametric statistics Wilcoxon-Mann-Whitney test and Kruskal Wallis test were used to examine the difference between the average frequencies of observed species. The Wilcoxon-Mann-Whitney test has higher power when the underlying populations have asymmetric distribution and is used whenever a t-test was appropriate. The Kruskal-Wallis test is a generalization of the two-sample Wilcoxon-Mann-Whitney test to three or more groups. It is used whenever a one-way Analysis of Variance (ANOVA) was appropriate. The G-test for independence was also used to compare the frequency of sightings per survey 0-500 m to the frequency of sightings 1,500-2,000 m from well pads in order to establish whether there was a temporal association. All species response curves were fitted using spline interpolation in a Generalized Additive Model (GAM) in SAS software. The species response curves illustrate (a) the number of species observed during sequential transect samples, and (b) the frequency of observation of wildlife species as a function of distance from a source of disturbance (pad or road). The GAM procedure focuses on data exploration and visualization thus uncovering nonlinear covariate effects (Hastie and Tibshirani, 1986). Smoothing parameters were automatically selected by Generalized Cross-Validation (GCV). The temporal gradient response curves were evaluated by fitting the frequency of sightings (50 m intervals) for all species per pad to establish any trends at distances 0 -500 m and 1,500- 2,000 m from well pads. Spatial gradient response curves were also fitted to examine how the different species varied along a

distance gradient from the well pads. Finally the average frequency of sightings along on well pad and access road transects were compared. All the statistical analyses were carried out using SAS statistical software. Seven species including Uganda kob, oribi, hartebeest, buffalo, giraffe, warthog and elephants (dung) were considered for analysis at each pad as they were common on all the pads and would allow for comparisons to be made.

2.3 Results

2.3.1 Comparing Encounter Rates per Pad

During the surveys, 18 mammal species were observed along the transects including buffalo, savanna baboon, bush buck, bush duiker, African civet, elephant, giraffe, hartebeest, jackal, leopard, lion, patas monkey, reed buck, spotted hyena, Uganda kob, warthog, water buck and oribi. A significant difference was detected between the average frequency of sightings for all species (pooled) per survey at 50 m intervals for distances of 0-500 m and 1,500-2,000 m for all the pads except M1 (Figure 7).

The well pads were surveyed at various stages of construction to allow for comparison of spatial distribution of animals during and after pad preparation stage. Level of activity on L1 and L2 was classified as low which means that the construction was already completed, M1 as moderate which means that the construction was close to completion, and H1 as the highest which means that the construction was ongoing. The mean encounter rates indicate that there were more sightings observed at distances of 1,500-2,000 m from L1 and H1 while L2 had more sightings observed at distances of 0-500 m from the pad. Species responses along temporal and spatial gradients varied for the different well pads (Figures 17 to 26), which could be explained by the level of activity at the different pads and the quality of the forage.

2.3.2 Comparing Encounter Rates for All the Pads at 0-500 m

There was a significant difference between the average frequency of sightings per survey at 50 m intervals for distances of 0-500 m from pads ($\chi^2 = 30.97$, $P < 0.0001$). M1 had the highest mean encounter rate and H1 had the lowest (Figure 12). The results suggest that more animals were present near pads with low activity compared to pads with moderate and high levels of activity.

2.3.3 Comparing Encounter Rates for All the Pads at 1,500-2,000 m

At distances of 1,500-2,000 m there was a significant difference in the average frequency of sightings among pads per survey at 50m intervals ($\chi^2 = 12.73$, $P = 0.0052$). L1 had the highest mean encounter rate and M1 the lowest (Figure 13). The results suggest that species responses varied across the pads due to different levels of perceived disturbances from well pad activities.

2.3.4 Relationship between the Number of Species (pooled) Observed at Distances 0-500 m and 1,500-2,000 m with Survey Period

Species temporal response curves at distances of 0-500 m and 1,500-2,000 m were fitted for all the pads. L1 and L2 illustrated an increasing trend with survey period for the number of species observed at distances 0-500 m close to the pads (Figure 25). The increase in the number of species at a distance 0-500 m close to the pads suggests that there was a gradual shift in habitat use around the pads when the disturbance stimuli from well pad activities were perceived to be minimal. M1 and H1 illustrated a decreasing trend for the number of species observed at distances 0-500 m close to the pads (Figure 25). The gradual decrease in the number of species at distances 0-500 m

close to the pads suggests indirect habitat loss around the pads due to well pad construction activities. At distances 1,500-2,000 m, the increase in the number of observed species for all pads followed by a subsequent decrease suggests that the perceived disturbance stimuli are lower regardless of the level of well pad activity (Figure 26).

2.3.5 Comparing Encounter Rates per Species

2.3.5.1 L1 (Activity=Low)

There was a significant difference between the average frequency of sightings per survey at 50 m intervals for distances of 0-500 m and 1,500-2,000 m for Uganda kob, hartebeest, elephants (dung) and warthogs (Figure 8), while there was no significant difference observed for oribi, buffalo and giraffe, suggesting differences in habitat use between species after the disturbance. Results comparing the frequency of sightings per species as a function of survey period indicate that there was an association between frequency of sightings at distances 0-500 m and 1,500-2000 m (Table 2.1).

2.3.5.2 L2 (Activity=Low)

There was a significant difference between the average frequency of sightings at distances of 0-500 m and 1,500-2,000 m for Uganda kob, and oribi (Figure 9). There was no significant difference observed for warthogs, buffalo, hartebeest and elephants (dung). Mean encounter rates suggested that higher numbers of Uganda kob and oribi were observed near the pad, which could be explained by habitat composition around the pad. There was an association between frequency of sightings as a function of survey periods at distances of 0-500 m and 1,500-2,000 m (Table 2.1).

2.3.5.3 M1 (Activity=Moderate)

Significant differences between the average frequency of sightings per survey at 50 m intervals for distances of 0-500 m and 1,500-2,000 m were observed for Uganda kob, giraffe and elephants (dung) (Figure 10). There were no significant difference observed for oribi, hartebeest, buffalo and warthog. The mean encounter rates suggest an increasing trend for Uganda kob, giraffe and elephants (dung), a decreasing trend for hartebeest and no change with distance from the pad for other species (Figure 10). Results from comparing the frequency of sightings per species as a function of survey period indicate that there an association between observations at distances 0-500 m and 1,500-2,000 m for all the species (Table 2.1).

2.3.5.4 H1 (Activity=High)

There was a significant difference between the average frequency of sightings per survey at 50 m intervals for distances of 0-500 m and 1,500-2,000 m for Uganda kob, hartebeest, buffalo and giraffe (Figure 11). There was no significant difference observed for oribi, buffalo and elephant (dung). The mean encounter rates for Uganda kob, hartebeest, buffalo and giraffe suggest an increasing trend with distance from the pad. There was an association between frequency of sightings as a function of survey periods at distances of 0-500 m and 1,500-2,000 m (Table 2.1).

2.3.6 Comparing Encounter Rates at Distances 0-500 m and 1,500-2,000 m from Access roads

There was a significant difference between the average frequency of sightings per survey at 50 m intervals for distances of 0-500 m and 1,500-2,000 m from access roads for L1 and H1 (Figure 14). No significant difference observed for L2 and M1. The mean encounter rates suggest an increasing trend for the number of sightings with distance from the access road for L1 and H1.

Pad vs. Road: Significant differences between the average frequency of sightings at distances of 0-500 m from the well pads and access roads were observed for all pads, except for M1 (Table 2.2). However there was no significant difference between average frequency of sightings at distances of 1,500-2,000 m from the well pads and access roads (Table 2.3) for all pads. The difference in mean encounter rates suggests that levels of disturbances perceived by the animals are higher for well pads than access roads.

2.3.7 Habitat Use

During the survey the following vegetation types in which species were encountered along transects from pads were recorded; *grassland*, *open-woodland*, *dense-woodland*, *shrub/bush*, *dense-borassus*, and *open-borassus* (Table 2.4). About 42.9% of all the sightings were recorded in the grassland, 34.4% in the open-borassus, 10.3% in open-woodland, 9.8% in bush/scrub, 1.4% in dense-borassus and 1% in dense woodland (Figures 15 and 16). Habitat composition along the pads had an influence on species distributions along transects.

2.4 Conclusion and Discussion

Human-induced disturbances have been considered as potential threats to the social ecology and long term survival of wildlife populations (Barber et al. 2009). Results from this study illustrate a general trend of avoidance behavior in both space and time for all species along transects from oil well sites and access roads. The analysis suggests that elephants, giraffes, buffalo, hartebeest and Uganda kob are more likely to be influenced by oil and gas activities in terms of indirect habitat loss while trends for oribi and warthogs indicate a level of tolerance behavior towards well pad activity. Species-specific tradeoffs between the ability of individual animals or groups moving away from a disturbance or staying in relation to their home range confirms previous research showing that noise disturbance causes considerable indirect habitat loss for species with larger ranges (Rabanal et al. 2010). A home range is closely related to body mass by different scaling factors with larger mammals likely to feed over proportional greater areas (Swihart et al. 1988, Du Toit 1990). Burt (1943) defined a home range of a mammal as the area traversed by the individual in its normal activities of food gathering, mating and caring for young. Population level consequences of oil and gas disturbances may lead to increased risk of wildlife-human conflicts, as wildlife move away from the disturbance and are likely to get close to the surrounding communities.

Varying response curves for the different groups of species, suggested species-specific differences in thresholds to disturbance stimuli from the well pads. The shape and direction of species response curves along spatial and temporal gradients illustrated non-linear trends of species distribution from well pad activities. Species

optimum for buffalo (i.e., value of distance at which the number of buffalo were maximum) was observed at distances ranging from 750 m to 1,150 m along transects for all the pads (Figure 21). However species optimum for hartebeest, Uganda Kob, giraffes and elephants may be more than 2 km. Differences in trends and shapes of species response curves suggest interspecific interactions may have an influence on how different species react to hydro carbon activities in the park.

Species response varied with the level of the disturbance stimuli (low, moderate, high) from the four well pads with the most avoidance behavior observed during the peak levels of activity, however animals were observed to return gradually near the pads after well pad construction. Species response to disturbance stimuli is related in several forms to the ways in which prey responds to predation risk (Frid and Dill, 2002). Caribou have been found to habituate to active oil field infrastructure in northern Alaska, suggesting that different species are affected at different thresholds of the disturbance (Haskell et al. 2006). However, it is difficult to quantify specific species' response thresholds to the disturbance since different gradients are confounded by other environmental parameters.

There were habitat differences among all the pads with most species observed in grassland habitat, open woodland habitat, shrub habitat and dense borassus habitat. Although all the pads showed general effect of disturbance declining with distance, L2 had more sightings near the pad which could be due to the presence of open borassus habitat around the pad that could have provided quality forage and cover from the predators for Uganda kob and oribi as they reacted to the disturbance stimuli from

well pad activities. Habitat composition along the pads had implications on how the different species reacted to well pad activities.

The different levels of disturbance perceived by the species along well pads and access road transects suggest that intermittent noise exposure to wildlife species may have a less impact in terms of indirect habitat loss as compared to chronic noise exposure. Cumulative and compounding noise exposure is more likely to have a higher impact on population productivity. Barber et al (2009) defined masking as “the amount or process by which the threshold of detection for sound is increased by the presence of the aggregate of other sounds”. Acoustical masking affects the communication and reproductive behavior of wildlife populations with some species adjusting their vocalizations due to increased background noise levels (Barber et al 2009).

Management Implications: On average the density of oil wells in an oil field ranges from 1 to 6 wells per square kilometer (Tribal Energy and Environmental Information 2010). I propose the use of spatial temporal gradients in modeling different scenarios of hydrocarbon developments in the park, however the use of other covariates that affect species distribution could be considered. As oil and gas exploration activities expand across the region, the use of high resolution remote sensed acquired imagery will be important in complementing field based observations. The spatial temporal scenarios would have a direct application in the planning of oil and gas exploration, development and production activities in the region.

The results highlight the urgency for further studies regarding the influence of oil and gas activities on the distribution of predators and changes in their activity

patterns in relation to prey movement. A total of 10 sightings of lions, leopards and hyenas were observed over 36 days of survey effort which suggests avoidance behavior at a large scale. Aerial surveys of large mammals conducted in 1995, 1999 and 2005 in MFNP indicated an increasing trend for most of the mammals (Lamprey 2000, Rwetsiba and Wanyama, 2005). However, the seasonal movements of most species in the park are not well known. As well minimizing disturbance to wildlife, there is a need to study the nature and direction of potential wildlife-human conflicts within communities surrounding the park as species move away from well pad activities.

The distribution of species suggests the need to manage borassus habitat in the park. There were indications that borassus habitat provides cover for some species from oil and gas activities. However, further investigations are required to draw conclusions about the role of borassus habitat in providing optimum cover during hydro carbon activities. Oil and gas developments in Uganda have the potential to provide funding for conservation and to support scientific research therefore, integrating biodiversity considerations, into oil and gas development management plans, will be useful in promoting conservation of wildlife and landscapes in the Albertine Rift.

Table 1.1: Home range sizes of the different species in the study area.

Common Name	Scientific name	Home range (km ²)
Elephant	<i>Loxodonta africana</i>	14 – 5,060
Giraffe	<i>Giraffa cameopardalis</i>	12 - 650
African Buffalo	<i>Syncerus caffer</i>	10 - 450
Uganda Kob	<i>Kobus kob</i>	3 - 15.6
Hartebeest	<i>Alcelaphus buselaphus</i>	2.6 - 10.3
Warthog	<i>Phacochoerus aethiopicus</i>	0.7 -3.6
Oribi	<i>Ourebia ourebi</i>	0.12 - 0.95

Source: (Leuthold 1977, Balmford 1992, Brashares et al. 2002, Galanti et al. 2005, Ryan et al. 2006).

Table 2.1: Comparing the frequency of sightings per species at distances 0-500 m and 1,500-2,000 m as function of survey period using the G test, Pads L1, L2, M1 and H1.

Species	χ^2 (L1)	χ^2 (L2)	χ^2 (M1)	χ^2 (H1)	<i>P</i>
Uganda Kob	517.8	527.0801	269.2188	476.1063	< 0.0001
Oribi	62.4912	101.6596	88.4716	82.0593	< 0.0001
Hartebeest	59.6	124.89	181.2259	65.357	< 0.0001
Buffalo	148.32	351.0587	822.249	85.8145	< 0.0001
Giraffe	136.81		67.6335		< 0.0001
Warthog	56.68	129.72	159.3843	71.7484	< 0.0001
Elephant (dung)	26.222				0.0035
Elephant (dung)		120.2927	71.3983	91.2082	< 0.0001

Level of activity; L1 (Low), L2 (Low), M1 (Moderate), H1 (High)

Table 2.2: Comparing the average frequency of sightings between oil pads and access roads at distances of 0-500 m.

Mean encounter rates represent the number of animals observed per survey (17 to 18 days of survey effort) at 50 m intervals for distances of 0-500 m along the transects, in MNFP.

Pad Vs Road	Distance (0 - 500 m)	Mean encounter rate	<i>Z</i>	<i>P</i>
L1	Access road(Transects)	2.39	-2.99	0.0028
	Pad (Transects)	3.29		
L2	Access road(Transects)	5.83	-2.0418	0.0412
	Pad (Transects)	7.83		
M1	Access road (Transects)	5.52	-0.5669	0.5708
	Pad (Transects)	2.41		
H1	Access road(Transects)	3.12	3.4395	0.0006
	Pad(Transects)	1.38		

Table 2.3: Comparing the average frequency of sightings between oil pads and access roads at distance of 1,500-2,000 m.

Mean encounter rates represent the number of animals observed per survey (17 to 18 days of survey effort) at 50 m intervals for distances of 1,500-2,000 m along the transects.

Pad Vs Road	Distance (1500 - 2000 m)	Mean encounter rate	Z	P
L1	Access road (Transects)	7.63	0.8536	0.3933
	Pad (Transects)	7.19		
L2	Access road (Transects)	5.42	0.4597	0.6458
	Pad (Transects)	4.69		
M1	Access road (Transects)	4.20	0.2957	0.7675
	Pad (Transects)	3.38		
H1	Access road (Transects)	6.61	1.9043	0.0569
	Pad (Transects)	3.99		

Table 2.4: Vegetation description along transects.

Land Cover Type	Description
Grassland	At least 20 m radius of grassland with no trees/shrubs
Wooded Grassland	Between 10-50% woody cover, grassland under and between trees
Dense Woodland	More than 50% woody cover - grassland between trees
Bush / Shrub	Low stature bushes with little grass between - at least 50% cover
Open borassus	Between 10-50% borassus cover - grassland under and between trees
Dense borassus	More than 50% borassus cover

Figure 1: Extent of oil and gas exploration in the Albertine Rift, Uganda.

The map illustrates the overlap between protected areas and zoned blocks for hydro carbon activities.

Figure 2: Map showing the location of Uganda.

Figure 3: Murchison Falls National Park, Uganda.

Map produce by Wildlife Conservation Society, Uganda program (2006).

Figure 4: Location of study area.

The square black box represents the extent of transects along the well pads that were surveyed in the western portion of MFNP.

Figure 5: Flow chart of the monitoring design.

Transects were walked twice every four days. Each transect was surveyed a total of 17 to 18 times representing 36 days of survey effort.

Figure 6: Basic monitoring design with four main transects per pad and two transects on the access road.

Well Pad	Activity	Z	P
L 1	Low	-2.5	0.0124
L 2	Low	2.78	0.0054
M2	Moderate	0	1.0
H1	High	-2.99	0.0014

*The above plots represent: length of the box (interquartile range), cross (mean encounter rates), line in box interior (group median), vertical lines (group minimum and maximum values).

Figure 7: Comparing encounter rates (17 to 18 days of survey effort) at 50 m intervals per Pad (L1, L2, M1, H1) for all species at distances of 0-500 m and 1,500-2,000 m along transects.

Species	Z	p	Species	Z	p
Uganda Kob	-2.53	0.0112	Giraffe	0.51	0.6117
Oribi	-0.0705	0.94	Warthog	-2.19	0.0283
Hartebeest	-2.85	0.0043	Elephant(dung)	-2.05	0.0396
Buffalo	-1.23	0.217			

*The above plots represent: length of the box (interquartile range), cross (mean encounter rates), line in box interior (group median), vertical lines (group minimum and maximum values).

Figure 8: Comparing encounter rates (17-18 days of survey effort) at 50 m intervals per species (L1; Low) at distances of 0-500 m and 1,500-2,000 m along transects.

Species	Z	P	Species	Z	P
Uganda Kob	3.35	0.0008	Buffalo	-1.938	0.0526
Oribi	3.099	0.0019	Warthog	-1.0933	0.2743
Hartebeest	-1.37	0.1679	Elephant (dung)	-1.9081	0.0564

*The above plots represent: length of the box (interquartile range), cross (mean encounter rates), line in box interior (group median), vertical lines (group minimum and maximum values).

Figure 9: Comparing encounter rates (17-18 days of survey effort) at 50 m intervals per species (L2; Low) at distances of 0-500 m and 1,500-2,000 m along transects.

Species	Z	P	Species	Z	P
Uganda kob	-2.6837	0.0073	Giraffe	2.4688	0.0136
Oribi	1.1282	0.2593	Warthog	0.72	0.4715
Hartebeest	1.8679	0.0618	Elephant (dung)	-2.0575	0.0396
Buffalo	-0.1763	0.86			

*The above plots represent: length of the box (interquartile range), cross (mean encounter rates), line in box interior (group median), vertical lines (group minimum and maximum values).

Figure 10: Comparing encounter rates (17-18 days of survey effort) at 50 m intervals per species (M1; Moderate) at distances of 0-500 m and 1,500-2,000 m along transects

Species	Z	p	Species	Z	p
Uganda Kob	-2.2247	0.0261	Giraffe	-2.0027	0.00452
Oribi	-1.2335	0.2174	Warthog	1.0929	0.2874
Hartebeest	-3.1	0.0019	Elephant (dung)	-1.341	0.1799
Buffalo	-3.0692	0.00021			

*The above plots represent: length of the box (interquartile range), cross (mean encounter rates), line in box interior (group median), vertical lines (group minimum and maximum values).

Figure 11: Comparing encounter rates (17-18 days of survey effort) at 50 m intervals per species (H1; High) at distances of 0-500 m and 1,500-2,000 m along transects.

Figure 12: Comparing encounter rates (17-18 days of survey effort) for all the Pads at distances 0-500 m.

Figure 13: Comparing encounter rates (17-18 days of survey effort) for all the Pads at distances 1,500-2,000 m.

*The above plots represent: length of the box (interquartile range), cross (mean encounter rates), line in box interior (group median), vertical lines (group minimum and maximum values).

Access roads	Activity	Z	P
L1	Low	-3.0662	0.0022
L2	Low	-0.176	0.8603
M1	Moderate	-0.7748	0.4384
H1	High	-2.14	0.0317

*The above plots represent: length of the box (interquartile range), cross (mean encounter rates), line in box interior (group median), vertical lines (group minimum and maximum values).

Figure 14: Comparing encounter rates (17-18 days of survey effort) at distances 0-500 m and 1,500-2,000 m from access roads for Pads (L1, L2, M1, H1).

*The above plots represent: length of the box (interquartile range), cross (mean number of species observed in each habitat type), line in box interior (group median), vertical lines (group minimum and maximum values).

L1; habitat types (O-bor = open borassus, O-woo = Open woodland).

L2; habitat types (D-Borassus = Dense borassus, O-Borassus = Open borassus).

Figure 15: Habitat use Pads L1 and L2.

*The above plots represent the following: length of the box (interquartile range), cross (mean number of species observed in each habitat type), line in box interior (group median), vertical lines (group minimum and maximum values).

M1; habitat types (D-woo = Dense woodland, O-bor = open borassus, O-woo = Open woodland).

H1; habitat types (D-woo = Dense woodland, O-Borassus = Open borassus, O-woo = Open woodland).

Figure 16: Habitat use Pads M1 and H1.

Pads	DF	Activity	Chi square	<i>P</i>
L1	3	Low	74.07	< 0.0001
L2	3	Low	52.16	< 0.0001
M1	3	Moderate	585.83	< 0.0001
H1	3	High	167.8	< 0.0001

*The graphs were fitted by spline interpolation and illustrate how sightings of all species (pooled) vary along a distance gradient. Smoothing Model Analysis; Analysis of deviance table of encounter frequency of all species along a distance gradient is shown above.

Figure 17: Number of species along an increasing distance gradient from Pads L1, L2, M1 and H1.

Pads	Activity	DF	Chi square	<i>P</i>
L1	Low	3	28.6	< 0.0001
L2	Low	3	117.7	< 0.0001
M1	Moderate	3	167.3	< 0.0001
H1	High	3	75.9	< 0.0001

*The graphs were fitted by spline interpolation and illustrate how sightings of Uganda kob vary along a distance gradient. Smoothing Model Analysis; Analysis of deviance table of encounter frequency of Uganda kob along a distance gradient is shown above.

Figure 18: Number of Uganda kob along a distance gradient from Pads L1, L2, M1 and H1.

Pads	Activity	DF	Chi square	<i>P</i>
L1	Low	3	39.3	< 0.0001
L2	Low	3	13.8	0.0031
M1	Moderate	3	51.3	< 0.0001
H1	High	3	6.38	0.0942

*The graphs were fitted by spline interpolation and illustrate how sightings of oribi vary along a distance gradient. Smoothing Model Analysis; Analysis of deviance table of encounter frequency of oribi along a distance gradient is shown above.

Figure 19: Number of oribi along a distance gradient from Pads L1, L2, M1 and H1.

Pads	Activity	DF	Chi square	<i>P</i>
L1	Low	3	35.4	< 0.0001
L2	Low	3	32.7	< 0.0001
M1	Moderate	3	112.3	< 0.0001
H1	High	3	13.7	0.0033

*The graphs were fitted by spline interpolation and illustrate how sightings of hartebeest vary along a distance gradient. Smoothing Model Analysis; Analysis of deviance table of encounter frequency of hartebeest along a distance gradient is shown above.

Figure 20: Number of hartebeest along a distance gradient from Pads L1, L2, M1 and H1.

Pads	Activity	DF	Chi square	<i>P</i>
L1	Low	3	113.2	< 0.0001
L2	Low	3	542.1	< 0.0001
M1	Moderate	3	449.6	< 0.0001
H1	High	3	199.5	< 0.0001

*The graphs were fitted by spline interpolation and illustrate how sightings of buffalo vary along a distance gradient. Smoothing Model Analysis; Analysis of deviance table of encounter frequency of buffalo along a distance gradient is shown above.

Figure 21: Number of buffalo along a distance gradient from Pads L1, L2, M1 and H1.

Pads	Activity	DF	Chi square	<i>P</i>
L1	Low	3	16.8	< 0.0008
M1	Moderate	3	9.27	< 0.0259

*The graphs were fitted by spline interpolation and illustrate how sightings of giraffe vary along a distance gradient. Smoothing Model Analysis; Analysis of deviance table of encounter frequency of giraffe along a distance gradient is shown above.

Figure 22: Number of giraffe along a distance gradient from Pads L1 and M1.

Pads	Activity	DF	Chi square	<i>P</i>
L1	Low	3	29.7	< 0.0001
L2	Low	3	14.5	0.0023
M1	Moderate	3	11.01	0.0117
H1	High	3	4	0.25

*The graphs were fitted by spline interpolation and illustrate how sightings of warthogs vary along a distance gradient. Smoothing Model Analysis; Analysis of deviance table of encounter frequency of warthogs along a distance gradient is shown above.

Figure 23: Number of warthog along a distance gradient from Pads L1, L2, M1 and H1.

Pads	Activity	DF	Chi square	<i>P</i>
L1	Low	3	15.4	0.0015
L2	Low	3	19.3	0.0002
M1	Moderate	3	16.3	0.001
H1	High	3	45.7	< 0.0001

*The graphs were fitted by spline interpolation and illustrate how sightings of elephant dung vary along a distance gradient. Smoothing Model Analysis; Analysis of deviance table of encounter frequency of elephant dung along a distance gradient is shown above.

Figure 24: Number of elephant dung along a distance gradient from Pads L1, L2, M1 and H1.

Pads	Activity	DF	Chi square	<i>P</i>
L1	Low	3	33.04	< 0.0001
L2	Low	3	866.8	< 0.0001
M1	Moderate	3	58.9	< 0.0001
H1	High	3	35.72	< 0.0001

*The graphs were fitted by spline interpolation and illustrate how sightings of all species (pooled) vary along an increasing temporal gradient (Survey period). Smoothing Model Analysis; Analysis of deviance table of encounter frequency of all species along a temporal gradient is shown above.

Figure 25: Species temporal response curves at distances 0-500 m, Pads L1, L2, M1, and H1.

Pads	Activity	DF	Chi square	<i>P</i>
L1	Low	3	698.6	< 0.0001
L2	Low	3	213.5	< 0.0001
M1	Moderate	3	305.3	< 0.0001
H1	High	3	439.6	< 0.0001

*The graphs were fitted by spline interpolation and illustrate how sightings of all species (pooled) vary along an increasing temporal gradient (Survey period). Smoothing Model Analysis; Analysis of deviance table of encounter frequency of all species along a temporal gradient is shown above.

Figure 26: Species temporal response curves at distances 1,500-2,000 m, Pads L1, L2, M1 and H1.

Appendix 1: Some of the Species in the Study Area

Elephants (*Loxondonta Africana*)

Buffalos (*Syncerus caffer*)

Hartebeests (*Alcelaphus buselaphus*)

Giraffes (*Giraffa camelopardalis*)

Appendix 2: Some of the Habitats in the Study area

Dense Borassus

Grassland

Appendix 3: Oil and Gas Activities

Access Road

Oil Well Pad (No activity)

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