



## Résumé

Ma thèse porte sur l'écologie, la taphonomie et la conservation des grands carnivores au Kenya dans le but de rechercher des stratégies pratiques pour atténuer les conflits homme-carnivore. Le comté de Samburu, site d'étude principal, est unique en ce sens qu'il héberge les populations des six grandes espèces de carnivores présentes en Afrique de l'Est, à savoir: lion, léopard, hyène tachetée, hyène rayée, chien sauvage africain et guépard. C'est donc un terrain idéal pour la mise en œuvre de stratégies communautaires de sensibilisation à la faune sauvage et de conservation visant à atténuer les conflits homme-faune sauvage, par la création et la promotion de zones de gestion de la faune sauvage associées à de meilleures pratiques d'élevage pour lutter contre la déprédation du bétail. Le deuxième site d'étude est la Soysambu Wildlife Conservancy, dans le comté de Nakuru. Enfin, des données complémentaires concernent les sites-repaires d'hyènes issues de deux précédentes études de doctorat, mises à ma disposition de cette étude pour une analyse comparative des schémas de consommation des carcasses de proies de grands carnivores africains. Toutes les analyses statistiques ont été effectuées à l'aide du logiciel de statistiques R-software (version 3.6.0).

Les points saillants de notre étude sont les suivants: il a été possible de distinguer statistiquement les marques dentaires de perforation ('punctures') sur les os de proie entre l'hyène brune et les autres carnivores (hyène rayée, hyène tachetée, lion et léopard). Cependant, il n'a pas été possible de distinguer statistiquement entre les marques dentaires de lion, du léopard et de l'hyène tachetée, alors qu'il est possible de distinguer les marques entre hyène rayée de celles de hyène tachetée, lion et léopard. La taille de la proie affecte les marques dentaires des grands félins et des hyènes sur les éléments osseux de la proie, une force de morsure accrue étant requise sur les os des proies plus grandes. En ce qui concerne la morphométrie des fèces de carnivores, il était possible de différencier statistiquement entre léopard et hyène tachetée selon leur poids sec global et la largeur minimale des fragments/segments dans l'ensemble de nos échantillons collectés à Samburu et sur des données complémentaires sur les hyènes tachetées. Cependant, il n'a pas été possible de différencier statistiquement selon la hauteur (ou longueur) des segments fécaux et également sur la largeur maximale (grande variabilité).

La volonté des communautés pastorales de fournir un espace à la faune persiste. Les responsables politiques doivent prendre en compte les sentiments marqués des communautés vis-à-vis de la coexistence avec les espèces sauvages dans l'intérêt réciproque des communautés et de la faune. Les facteurs écologiques et socioculturels ont des effets différents sur les tendances à la prédation du bétail suivant chaque espèce de grand carnivore africain. À cette fin, il est important de bien identifier et exploiter de manière positive ces effets différentiels des facteurs écologiques et socioculturels qui influent sur la déprédation du bétail par les grands carnivores ; ainsi l'utilisation de technologies de pointe telles que les SIG et la télédétection, et l'intégration des connaissances et des techniques traditionnelles en matière de conservation, constituent un pas de géant vers la mise en œuvre de stratégies efficaces axées sur l'atténuation des conflits entre humains et carnivores. Enfin, l'apport de cette étude au débat chasse-charognage dans les études de paléoanthropologie est que si ces deux stratégies favorisent une communauté pastorale Africaine moderne, c'est que ce le trait doit reposer sur des fondements évolutifs issus des sociétés humaines anciennes.

**Mots clés:** *Grands carnivores africains, prédation du bétail, atténuation des conflits hommes-carnivores, marques dentaires de carnivores, types de proies, débat chasse-charognage, anthropologie, coexistence.*

## Abstract

My PhD study assessed the ecology, taphonomy and conservation of large carnivores in Kenya with a goal of seeking practical strategies to mitigate human-carnivore conflict. Samburu County, the main study site is unique in the sense that it hosts populations of the six large carnivore species found in Eastern Africa, namely; lion, leopard, spotted hyaena, striped hyaena, African wild dog and cheetah. It is therefore an ideal surrogate, for implementation of community wildlife awareness and conservation strategies towards mitigation of human-wildlife conflict, through creation and promotion of wildlife management areas and better husbandry practices to deal with livestock depredation. The second study site was Soysambu Wildlife Conservancy in Nakuru County. Complementary hyaena den site data from two previous PhD studies were made available to this study for a comparative analysis of African large carnivore prey carcass consumption patterns. All statistical analyses were conducted using the R-software statistical package (version 3.6.0).

The key highlights from the PhD study include: it was possible to statistically differentiate brown hyaena tooth puncture marks from striped hyaena, spotted hyaena, lion and leopard tooth puncture marks on prey bones. However, it was not possible to statistically differentiate between lion, leopard and spotted hyaena tooth puncture marks on prey bones. It was also possible to statistically differentiate striped hyaena tooth puncture marks from spotted hyaena, lion and leopard tooth puncture marks on prey bones. Prey size affects large felid and hyaenid tooth puncture marks on prey bone elements, with greater bite forces required on bones of larger prey. In terms of carnivore scat morphometry, it was possible to statistically differentiate lion scat from leopard and spotted hyaena scat based on global dry scat weight; and minimum scat fragment width based on carnivore scat samples from the Samburu National Reserve, and a complimentary data set of spotted hyaena scat measurements. However, it was not possible to statistically differentiate lion, leopard and spotted hyaena scat based scat fragment height and maximum scat fragment width.

Community goodwill to provide space for wildlife persists. Salient community sentiments towards coexistence with wildlife needs to be addressed appropriately by policy makers for the benefit of the communities and wildlife. Ecological and socio-cultural factors have differential effects on the livestock depredatory tendencies of each species of African large carnivore. To this end, identifying and positively harnessing these differential effects of ecological and sociocultural factors influencing livestock depredation by large carnivores; and using cutting-edge technology such as GIS and remote sensing, as well as incorporating traditional conservation knowledge and techniques, is a giant step towards implementing effective strategies geared towards successful mitigation of human-carnivore conflict. Finally, the contribution of this study to the hunting-scavenging debate in the domain of anthropology is that; if both hunting and scavenging favours a modern African pastoralist community, then the trait must have evolutionary underpinnings from past human societies.

**Key words:** *African large carnivores, livestock depredation, human-carnivore conflict mitigation, carnivore tooth marks, prey bones, hunting-scavenging debate, anthropology, coexistence.*

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## TABLE OF CONTENTS

Résumé Français .....	ii
Abstract in English.....	iii
Acknowledgements .....	iv
Table of Contents .....	vii
List of Tables.....	xii
List of Figures .....	xv
List of Acronyms.....	xix
 <b>CHAPTER 1: Introduction .....</b>	 <b>1</b>
1.1. Résumé du Chapitre 1: contexte.....	1
1.2. Summary of Chapter 1: context.....	3
1.3. Palaeoecological perspective of the human-carnivore conflict .....	5
1.4. Ecological perspective of the human-carnivore conflict .....	6
1.5. Problem statement and justification .....	7
1.6. Null Hypotheses .....	9
1.7. General study aim.....	10
1.8. Study objectives.....	10
 <b>CHAPTER 2: Literature review .....</b>	 <b>11</b>
2.1. Résumé du Bilan de la Littérature .....	11
2.2. Summary of Literature review.....	13
2.3. Carnivore evolution, ecology and conservation .....	15
2.4. Carnivores and humans .....	18
2.5. Carnivores and their prey base .....	20
2.6. Carnivores and their key habitat requirements .....	23
2.7. Ecological reconstructions and taphonomy .....	26
2.8. Human-carnivore conflict.....	31
2.9. Evolutionary history, taxonomy, ethology, ecology and species account for each of Africa's seven largest mammalian carnivore species under focus of PhD study.....	36
2.9.1. Lion <i>Panthera leo</i> .....	36
2.9.1.1. Taxonomic and evolutionary history.....	36
2.9.1.2. Morphology and identification .....	36
2.9.1.3. Distribution range .....	38

2.9.1.4. Social and reproductive behaviour .....	39
2.9.1.5. Feeding ecology, foraging behaviour and competition .....	42
2.9.1.6. Relationship with man and the ensuing conservation challenges.....	45
2.9.2. Leopard <i>Panthera pardus</i> .....	46
2.9.2.1. Taxonomic and evolutionary history .....	46
2.9.2.2. Morphology and identification .....	47
2.9.2.3. Distribution range .....	48
2.9.2.4. Social and reproductive behaviour .....	49
2.9.2.5. Feeding ecology, foraging behaviour and competition .....	51
2.9.2.6. Relationship with man and the ensuing conservation challenges.....	53
2.9.3. Cheetah <i>Acinonyx jubatus</i> .....	54
2.9.3.1. Taxonomic and evolutionary history .....	54
2.9.3.2. Morphology and identification .....	55
2.9.3.3. Distribution range .....	56
2.9.3.4. Social and reproductive behaviour .....	57
2.9.3.5. Feeding ecology, foraging behaviour and competition .....	59
2.9.3.6. Relationship with man and the ensuing conservation challenges.....	61
2.9.4. African wild dog <i>Lycaon pictus</i> .....	62
2.9.4.1. Taxonomic and evolutionary history .....	62
2.9.4.2. Morphology and identification .....	62
2.9.4.3. Distribution range .....	63
2.9.4.4. Social and reproductive behaviour .....	65
2.9.4.5. Feeding ecology, foraging behaviour and competition .....	67
2.9.4.6. Relationship with man and the ensuing conservation challenges.....	70
2.9.5. Spotted hyaena <i>Crocuta crocuta</i> .....	71
2.9.5.1. Taxonomic and evolutionary history .....	71
2.9.5.2. Morphology and identification .....	72
2.9.5.3. Distribution range .....	74
2.9.5.4. Social and reproductive behaviour .....	75
2.9.5.5. Feeding ecology, foraging behaviour and competition .....	77
2.9.5.6. Relationship with man and the ensuing conservation challenges.....	80
2.9.6. Striped hyaena <i>Hyaena hyaena</i> .....	81
2.9.6.1. Taxonomic and evolutionary history .....	81
2.9.6.2. Morphology and identification .....	82

2.9.6.3. Distribution range .....	83
2.9.6.4. Social and reproductive behaviour .....	84
2.9.6.5. Feeding ecology, foraging behaviour and competition .....	85
2.9.6.6. Relationship with man and the ensuing conservation challenges.....	87
2.9.7. Brown hyaena <i>Parahyaena brunnea</i> .....	88
2.9.7.1. Taxonomic and evolutionary history .....	88
2.9.7.2. Morphology and identification .....	89
2.9.7.3. Distribution range .....	90
2.9.7.4. Social and reproductive behaviour .....	91
2.9.7.5. Feeding ecology, foraging behaviour and competition .....	93
2.9.7.6. Relationship with man and the ensuing conservation challenges.....	94
<b>CHAPTER 3: Materials and methods.....</b>	<b>95</b>
3.1.1. Résumé du matériaux et méthodes .....	95
3.1.2. Summary of materials and methods .....	97
3.2.1. Samburu County, northern Kenya .....	99
3.2.2. Soysambu Conservancy, Nakuru, central Kenya .....	102
3.3. Methods .....	103
3.3.1. Documenting carcass consumption patterns by lion, leopard and spotted hyaena at kill sites in Kenya (Samburu and Nakuru).....	103
3.3.2. Collecting carnivore scats for morphometric assessment.....	105
3.3.3. Mapping and determining cattle depredation conflict rates .....	105
3.3.4. Ethnographic study on community practices and perceptions in relation to human-carnivore conflict .....	107
<b>CHAPTER 4: Carnivore carcass consumption and the hunting-scavenging debate .....</b>	<b>108</b>
4.1.1. Résumé du Chapitre 4.....	108
4.1.2. Summary of Chapter 4 .....	110
4.2. Carnivore carcass consumption.....	112
4.2.1. Effect of carnivore species on tooth puncture widths between kill site and dens and between species .....	115
4.2.2. Carnivore tooth puncture marks relative to prey size class at kill sites and den sites .....	120
4.2.3. Carnivore tooth puncture marks relative to prey skeletal region at kill sites and den sites .....	123

4.2.4. Carnivore tooth puncture marks relative to placement (diaphyseal vs epiphyseal) on prey long bones at kill sites in Kenya .....	127
4.2.5. Carnivore prey size class representation at kill sites and den sites .....	128
4.2.6. Assessment of prey skeletal part representation at kill sites and den sites .....	130
4.2.7. A complementary contribution to the hunting and scavenging debate .....	139
<b>CHAPTER 5: Large carnivore scat morphometry .....</b>	<b>143</b>
5.1.1. Résumé du Chapitre 5 .....	143
5.1.2. Summary of Chapter 5 .....	143
5.2. Large carnivore scat assessment .....	144
5.2.1. Effect of carnivore species on global dry scat weight .....	145
5.2.2. Effect of carnivore species on maximum scat fragment width .....	146
5.2.3. Effect of carnivore species on minimum scat fragment width .....	148
5.2.4. Effect of carnivore species on scat fragment height .....	149
<b>Chapter 6: Assessing key ecological and socio-cultural factors influencing human-carnivore conflict in Samburu County .....</b>	<b>153</b>
6.1.1 Résumé du Chapitre 6 .....	153
6.1.2. Summary of Chapter 6 .....	155
6.2. Key ecological variables (climate and habitat) influencing human-carnivore conflict in Samburu .....	157
6.2.1. Standardised Precipitation Index (SPI) and Normalized Difference Vegetation Index (NDVI) .....	159
6.2.1.1. Standardised Precipitation Index (SPI) .....	160
6.2.1.2. Normalized Difference Vegetation Index (NDVI) .....	162
6.2.3. Rainfall .....	163
6.2.4. Maximum and minimum temperatures .....	165
6.2.5. Correlations between climatic variables .....	166
6.2.6. Livestock abundance relative to wild herbivores in Samburu .....	168
6.2.7. Livestock losses in Samburu due to lion depredation .....	169
6.2.8. Livestock losses in Samburu due to leopard depredation .....	170
6.2.9. Livestock losses in Samburu due to spotted hyaena depredation .....	172
6.2.10. Livestock losses in Samburu due to cheetah depredation .....	173
6.2.11. Livestock losses in Samburu due to African wild dog depredation .....	174

6.2.12. Effect of seasonality, habitat and livestock type on livestock depredation by large carnivores.....	183
6.2.13. Livestock depredation by large carnivores relative to NDVI.....	189
6.2.14. Livestock depredation by large carnivores relative to SPI.....	191
6.2.15. Livestock depredation by large carnivores relative to minimum and maximum temperatures.....	192
6.2.16. Economic impact of livestock depredation by large carnivores in Samburu County from 2010 to 2018.....	195
6.3. Key socio-cultural factors influencing human-carnivore conflict in Samburu .....	203
6.3.1. Carnivore conservation workshop in Samburu .....	218
<b>Chapter 7: Conclusions and perspectives .....</b>	<b>220</b>
7.1.1. Résumé du Chapitre 7.....	220
7.1.2. Summary of Chapter 7.....	222
7.2. Conclusions and perspectives.....	224
7.2.1. Prey size class representation at African large carnivore kill sites and den sites .....	225
7.2.2 African large carnivore prey bone consumption at kill sites and den sites .....	226
7.2.3. Lion, leopard and spotted hyaena scat morphometry .....	228
7.2.4. Carnivore conservation in a modern East African pastoralist landscape .....	229
7.2.5. Hunting vs scavenging, which way to go? .....	233
7.3. General conclusions.....	234
7.4. General perspectives.....	235
<b>Bibliography .....</b>	<b>236</b>
<b>Appendices .....</b>	<b>291</b>
<u>Appendix I.</u> Carnivore tooth puncture marks on prey bones at kill sites .....	291
<u>Appendix II.</u> Carnivore tooth puncture marks on prey long bones at kill sites.....	296
<u>Appendix III.</u> Carnivore tooth puncture marks on prey bones at den sites.....	297
<u>Appendix IV.</u> Large carnivore kill sites inventory indicating nature of damage(s) and/or modification(s) on prey bones collected at each kill site. ....	303
<u>Appendix V.</u> A comparative sample showing nature of damage(s) and/or modification(s) on prey bones at leopard and lion kill sites .....	310
<u>Appendix VI.</u> Carnivore scat morphometry data set.....	313
<u>Appendix VII.</u> Animal population census data set for Samburu County.....	316
<u>Appendix VIII.</u> Climatic variables data set for Samburu County .....	317
<u>Appendix IX.</u> Questionnaire sample for ethnographic data collection in Samburu.....	321
<u>Appendix X.</u> Livestock depredation by large carnivores data set for Samburu County.....	324
<u>Appendix XI.</u> Comparative carnivore scat samples from the Samburu National Reserve showing the typical morphology types for each species .....	382
<u>Appendix XII.</u> Carnivore species scat fragment height vs maximum scat fragment width .....	384

## LIST OF TABLES

<u>Table 4.1.</u> The prey size class categories .....	112
<u>Table 4.2.</u> Prey skeletal consumption by the terrestrial mammalian large carnivores demarcated into six regions .....	113
<u>Table 4.3.</u> Summary statistics on maximum tooth puncture widths impacted on prey bone elements by large carnivores at kill sites in Kenya and den sites in Namibia and Djibouti ....	115
<u>Table 4.4.</u> Summary statistics on carnivore species kill sites and den sites data for minimum puncture widths on prey bone elements .....	115
<u>Table 4.5.</u> Test results on the inter carnivore species variation of maximum tooth puncture widths impacted on prey bones at kill sites (lion, leopard, lion-and-spotted hyaena) in relation to those impacted on prey bones at den sites (spotted, striped and brown hyaena).....	116
<u>Table 4.6.</u> Test results on the effect of carnivore species at kill sites (lion, leopard, lion-and-spotted hyaena) in relation to carnivore species at den sites (spotted, striped and brown hyaena) on minimum puncture widths on prey bone elements.....	116
<u>Table 4.7.</u> Test results on the effect of prey class size on large carnivore maximum tooth puncture widths at kill sites and den sites .....	120
<u>Table 4.8.</u> Test results on the effect of prey class size on large carnivore minimum tooth puncture widths at kill sites and den sites .....	120
<u>Table 4.9.</u> Test results on the effect of prey skeletal region on large carnivore maximum tooth puncture widths at kill sites and den sites .....	123
<u>Table 4.10.</u> Test results on the effect of prey skeletal region on large carnivore minimum tooth puncture widths at kill sites and den sites .....	124
<u>Table 4.11.</u> Carnivore maximum width tooth puncture marks relative to placement (diaphyseal vs epiphyseal) on prey long bones at kill sites .....	127
<u>Table 4.12.</u> Carnivore minimum width tooth puncture marks relative to placement (diaphyseal vs epiphyseal) on prey long bones at kill sites .....	127
<u>Table 4.13.</u> Prey size class representation at large carnivore kill sites and den sites in Kenya, Namibia and Djibouti .....	128
<u>Table 4.14.</u> Cumulative NISP and MNI computed from lion, leopard, cheetah and lion-and-spotted hyaena kill sites (Samburu and Nakuru Counties) .....	131
<u>Table 4.15.</u> Cumulative NISP and MNI computed from a spotted hyaena den site in Samburu (SaNguODen1) County .....	131
<u>Table 4.16.</u> Prey skeletal region proportions found at kill sites in Kenya .....	132
<u>Table 4.17.</u> Prey NISP and MNI found at large carnivore (lion, leopard, cheetah & spotted hyaena) kill sites and a spotted hyaena den site in Kenya .....	132
<u>Table 5.1.</u> Test on the effect of carnivore species on dry scat weight .....	145
<u>Table 5.2.</u> Test on the effect of carnivore species on maximum scat fragment widths .....	146
<u>Table 5.3.</u> Test on the effect of carnivore species on maximum scat fragment when the complementary hyaena scat measurements were reanalysed with PhD project data.....	146
<u>Table 5.4.</u> Test on the effect of carnivore species on minimum scat fragment width.....	148
<u>Table 5.5.</u> Test on the effect of carnivore species on minimum scat fragment height .....	149

<u>Table 5.6.</u> Test on the effect of carnivore species on scat fragment height when the complementary hyaena scat measurements were reanalysed with PhD project data.....	149
<u>Table 6.1.</u> SPI ranges and their indications of climate precipitation conditions.....	161
<u>Table 6.2.</u> Kendall's ( <i>tau</i> ) rank correlation coefficient output from R software testing for associations within our climatic data for Samburu County (January 2009 to December 2018) .....	167
<u>Table 6.3.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to lion attacks during the day .....	169
<u>Table 6.4.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to lion attacks during the night .....	169
<u>Table 6.5.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to lion attacks during day and night .....	170
<u>Table 6.6.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to leopard attacks during day .....	170
<u>Table 6.7.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to leopard attacks during night .....	171
<u>Table 6.8.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to leopard attacks during day and night .....	171
<u>Table 6.9.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to spotted hyaena attacks during day .....	172
<u>Table 6.10.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to spotted hyaena attacks during night.....	172
<u>Table 6.11.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to spotted hyaena attacks during day and night .....	173
<u>Table 6.12.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to cheetah attacks during day .....	173
<u>Table 6.13.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to African wild dog attacks during day.....	174
<u>Table 6.14.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to large carnivore attacks during day .....	175
<u>Table 6.15.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to large carnivore attacks during night.....	175
<u>Table 6.16.</u> A mixed model anova output from R software showing effects of climatic variables and habitat on livestock depredation losses due to large carnivore attacks during day and night .....	176
<u>Table 6.17.</u> Probabilities (relative frequencies) for livestock type fatalities in case of any reported depredation incident in Samburu in any given year from 2010 to 2018 .....	195
<u>Table 6.18.</u> Extrapolated cumulative totals of livestock killed by each carnivore species in Samburu County from 2010 to 2018.....	196
<u>Table 6.19.</u> Cumulative totals per livestock type killed by lion in Samburu County from 2010 to 2018.....	196

<u>Table 6.20.</u> Cumulative totals per livestock type killed by leopard in Samburu County from 2010 to 2018.....	197
<u>Table 6.21.</u> Cumulative totals per livestock type killed by spotted hyaena in Samburu County from 2010 to 2018 .....	197
<u>Table 6.22.</u> Cumulative totals per livestock type killed by African wild dog in Samburu County from 2010 to 2018 .....	197
<u>Table 6.23.</u> Cumulative totals per livestock type killed by cheetah in Samburu County from 2010 to 2018.....	198
<u>Table 6.24.</u> Average market rates for each livestock type for Samburu County within the context of January 2010 to December 2018 using comparative data from annual reports the Ministry of Agriculture, Livestock and Fisheries .....	198
<u>Table 6.25.</u> Demographic constitution of 75 respondents interviewed during the semi-structured questionnaire surveys .....	203
<u>Table 6.26.</u> A GLM output followed by one-way ANOVA with a Chi-sq test statistic from R software showing the effect of demographic variables on the inherent ability of a Samburu local to coexist with large carnivores.....	208
<u>Table 6.27.</u> A GLM output followed by one-way ANOVA with a Chi-sq test statistic from R software showing the effect of demographic variables on the perceived benefits of large carnivore presence in the landscape .....	210
<u>Table 6.28.</u> A GLM output followed by one-way ANOVA with a Chi-sq test statistic from R software showing the effect of demographic variables on attitudes (positive vs negative) towards large carnivore presence in the landscape .....	211
<u>Table 6.29.</u> A GLM output followed by one-way ANOVA with a Chi-sq test statistic from R software showing the effect of demographic variables on tolerance of locals towards large carnivore presence in the landscape .....	212

## LIST OF FIGURES

<u>Figure 2.1.</u> Diagrammatic summary of the molecular phylogeny of major clades of living Carnivora.....	17
<u>Figure 2.2.</u> An evolutionary “super tree” of the carnivores showing the evolutionary relationships between the living species of the order Carnivora and is based on the combination of 177 separate, smaller phylogenetic trees. The distance of a branching point from the branch tips suggests the estimated age of each evolutionary divergence, as indicated by the scale below the tree.....	18
<u>Figure 2.3.</u> Photograph of a lion at the Samburu National Reserve.....	37
<u>Figure 2.4.</u> Current distribution range of the lion in Africa .....	39
<u>Figure 2.5.</u> Photograph of a leopard at the Samburu National Reserve resting after having killed a domestic cow calf along the banks of Ewaso Ng’iro River within the reserve.....	47
<u>Figure 2.6.</u> Current distribution range of the leopard in Africa .....	49
<u>Figure 2.7.</u> Photograph of a cheetah at the Samburu National Reserve. It was on the prowl along with two other cheetahs (possibly siblings) looking for possible prey near an airstrip within the reserve .....	55
<u>Figure 2.8.</u> Current distribution range of the cheetah in Africa .....	57
<u>Figure 2.9.</u> Photograph of a pair of African wild dogs resting in a thicket in Samburu .....	63
<u>Figure 2.10.</u> Current distribution range of the African wild dog in Africa .....	64
<u>Figure 2.11.</u> Photograph of a spotted hyaena scavenging on an eland carcass at the Soysambu Conservancy, Nakuru .....	73
<u>Figure 2.12.</u> Current distribution range of the spotted hyaena in Africa .....	74
<u>Figure 2.13.</u> Photograph of a pair of striped hyaenas scavenging at an elephant carcass (lion kill site) at night in the Samburu National Reserve. The lions were not in the vicinity.....	83
<u>Figure 2.14.</u> Current distribution range of the striped hyaena .....	84
<u>Figure 2.15.</u> Photograph of a brown hyaena .....	89
<u>Figure 2.16.</u> Current distribution range of the brown hyaena in Africa.....	90
<u>Figure 3.1.</u> Map showing location of Kenya in Africa; and Samburu County in Kenya, with approximate project study area highlighted by the red rectangle within the Samburu County map .....	101
<u>Figure 3.2.</u> Map of Soysambu Conservancy in Nakuru County .....	102
<u>Figure 4.1.</u> Carnivore tooth puncture marks (maximum and minimum widths) at kill sites and den sites .....	117
<u>Figure 4.2.</u> Photograph showing typical maximum and minimum tooth puncture mark measurements.....	119
<u>Figure 4.3.</u> Carnivore tooth puncture marks relative to prey size class at kill sites and den sites .....	121
<u>Figure 4.4.</u> Photograph of a common eland carcass at a lion kill site at the Soysambu Conservancy, Nakuru County .....	124
<u>Figure 4.5.</u> Carnivore tooth puncture marks relative to prey skeletal region at kill sites and den sites.....	125

<u>Figure 4.6.</u> Carnivore tooth puncture marks impacted on the diaphyseal and epiphyseal regions of long bones of carnivore prey at kill sites .....	127
<u>Figure 4.7.</u> Prey size class representation at large carnivore kill sites and den sites in Kenya, Namibia and Djibouti .....	128
<u>Figure 4.8.</u> Prey skeletal proportions found at cheetah, leopard and lion kill sites in Kenya ...	133
<u>Figure 4.9.</u> Prey skeletal proportions found at shared lion and spotted hyaena kill sites in Kenya .....	134
<u>Figure 4.10.</u> Prey skeletal proportions relative to skeletal region at carnivore kill sites in Kenya .....	134
<u>Figure 4.11.</u> NISP at large carnivore kill sites and den site in Kenya within the context of ungulate prey size classes I-II & III-IV .....	135
<u>Figure 4.12.</u> MNI at large carnivore kill sites and den site in Kenya within the context of ungulate prey size classes I-II & III-IV .....	135
<u>Figure 4.13.</u> Photograph of spotted hyaena sharing a buffalo carcass with black-backed jackal .....	138
<u>Figure 5.1.</u> Photograph of a lion scat with porcupine quills highlighted in red .....	147
<u>Figure 5.2.</u> Photograph of a leopard scat.....	147
<u>Figure 5.3.</u> Photograph of a spotted hyaena scat with prey bone fragments.....	150
<u>Figure 5.4.</u> Photograph of a typical Samburu landscape. Carnivore scat was collected either at carnivore kills or during random searches .....	150
<u>Figure 5.5.</u> Carnivore scat measurements represented by mean box plots .....	151
<u>Figure 6.1.</u> A Photographic record of a livestock depredation incident inside Samburu National Reserve where locals at times graze livestock during dry seasons .....	158
<u>Figure 6.2.</u> SPI trends in Samburu County in a decade.....	161
<u>Figure 6.3.</u> NDVI trends in Samburu County in a decade .....	163
<u>Figure 6.4.</u> Rainfall trends in Samburu County in a decade .....	165
<u>Figure 6.5.</u> Maximum and minimum temperature trends in Samburu County in a decade .....	166
<u>Figure 6.6.</u> Samburu animal (domestic vs wild herbivores) census for Samburu County .....	168
<u>Figure 6.7.</u> Samburu animal (domestic vs wild herbivores) averaged census for 2010, 2013 and 2015 .....	168
<u>Figure 6.8.</u> Livestock depredation by lion, leopard and spotted hyaena (day vs night) per livestock type in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.....	177
<u>Figure 6.9.</u> Livestock depredation by cheetah and African wild dog per livestock type in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County....	178
<u>Figure 6.10.</u> Livestock depredation by leopard, spotted hyaena and lion during day and night per livestock type in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County .....	178
<u>Figure 6.11.</u> Livestock depredation by large carnivores (day vs night) per livestock type in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County .....	179

<u>Figure 6.12.</u> Livestock depredation by large carnivores per livestock type during day and night in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County .....	179
<u>Figure 6.13.</u> Livestock depredation patterns by lion, leopard and spotted hyaena (day vs night) in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County .....	180
<u>Figure 6.14.</u> Livestock depredation patterns by cheetah and African wild dog in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County....	181
<u>Figure 6.15.</u> Livestock depredation patterns by leopard, spotted hyaena and lion during day and night in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.....	181
<u>Figure 6.16.</u> Livestock depredation patterns by large carnivores (day vs night) in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County....	182
<u>Figure 6.17.</u> Livestock depredation patterns by large carnivores during day and night in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.....	182
<u>Figure 6.18.</u> Livestock depredation by lion and spotted hyaena (day vs night) in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County....	187
<u>Figure 6.19.</u> Livestock depredation by cheetah during the day in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County .....	187
<u>Figure 6.20.</u> Livestock depredation by leopard and the African Wild dog during the day in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County .....	188
<u>Figure 6.21.</u> Livestock depredation by lion and spotted hyaena during day and night in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County....	188
<u>Figure 6.22.</u> Livestock depredation by large carnivores in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County .....	189
<u>Figure 6.23.</u> Livestock depredation by lion and cheetah relative to NDVI in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.....	190
<u>Figure 6.24.</u> Livestock depredation by large carnivores relative to NDVI in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.....	190
<u>Figure 6.25.</u> Livestock depredation by lion and large carnivores relative to SPI in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County .....	191
<u>Figure 6.26.</u> Livestock depredation by leopard relative to maximum and minimum temperatures in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County .....	192
<u>Figure 6.27.</u> Livestock depredation by cheetah and by large carnivores relative to maximum temperatures in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County .....	192

<u>Figure 6.28.</u> A photograph of kill site when a camel was killed by lions at the Samburu National Reserve .....	193
<u>Figure 6.29.</u> Map of Samburu National Reserve showing land cover in 2018 .....	194
<u>Figure 6.30.</u> Annual economic impact attributed to camels killed by each large carnivore species in Samburu County.....	199
<u>Figure 6.31.</u> Annual economic impact attributed to donkeys killed by each large carnivore species in Samburu County.....	199
<u>Figure 6.32.</u> Annual economic impact attributed to shoats killed by each large carnivore species in Samburu County.....	200
<u>Figure 6.33.</u> Annual economic impact attributed to cattle killed by each large carnivore species in Samburu County.....	200
<u>Figure 6.34.</u> Annual economic impact attributed to livestock killed by each large carnivore species in Samburu County .....	201
<u>Figure 6.35.</u> Combined economic impact implications attributed to livestock killed by large carnivores in Samburu County.....	201
<u>Figure 6.36.</u> Photo of a Samburu lady and her daughter herding shoats.....	203
<u>Figure 6.37.</u> Demographic constitution of respondents in the semi-structured questionnaire survey in Samburu County.....	204
<u>Figure 6.38.</u> Photo of a Samburu herds boy tending to shoats.....	204
<u>Figure 6.39.</u> Perceived large carnivore depredation rates per livestock type in Samburu County .....	205
<u>Figure 6.40.</u> Perceived most problematic predator of livestock in Samburu County .....	206
<u>Figure 6.41.</u> Perceptions, attitudes, tolerance and coexistence with carnivores in Samburu County .....	207
<u>Figure 6.42.</u> Responses of male and female respondents on the prospect of coexistence with large carnivores in the Samburu landscape .....	209
<u>Figure 6.43.</u> Photo of shoats near the Ewaso river bank. Shoats are the most preferred livestock type by the Samburu pastoralist community due to their cheap maintenance and high fecundity rates hence easily sold off for profit.....	209
<u>Figure 6.44.</u> Carnivore conservation workshop at the Kalama Community Wildlife Conservancy in Samburu .....	217
<u>Figure 6.45.</u> Photograph taken of a Samburu herds boy tending to cattle in the dried section of the Ewaso Ng'iro river bed in Samburu County .....	217
<u>Figure 6.46.</u> Photograph of Workshop organizer, Titus Adhola - PhD student, giving the background of carnivore conservation workshop at the start of the workshop.....	218
<u>Figure 6.47.</u> Photograph of workshop participants during plenary session .....	218
<u>Figure 6.48.</u> Photograph of a Samburu elder addressing participants during workshop .....	219
<u>Figure 7.1.</u> Photograph of a lion and lioness at the Samburu National Reserve.....	224
<u>Figure 7.2.</u> Photograph of a spotted hyaena juvenile at a kill site in Soysambu Wildlife Conservancy in Nakuru.....	227
<u>Figure 7.3.</u> Photograph of a dried lion scat with red arrow showing prey bone fragment circled in red.....	228

## **LIST OF ACRONYMS**

**ACK:** Action for Cheetahs in Kenya

**AFRAKEN:** Association of France Alumni in Kenya

**AMU:** Aix-Marseille University

**ANOVA:** Analysis of variance

**BVM:** Bachelor of Veterinary Medicine

**CAVS:** College of Agriculture and Veterinary Sciences

**CNES:** Centre national d'etudes spatiales

**CNRS:** Centre national de la recherche scientifique

**CWC:** Community Wildlife Conservancy

**DNA:** Deoxyribonucleic acid

**DRSRS:** Directorate of Resource Surveys and Remote Sensing

**EC:** European Commission

**ED 355:** Ecole Doctorale - Espaces, Cultures, Societes, AMU

**ESA:** European Space Agency

**EU:** European Union

**FAO:** Food and Agriculture Organization

**GIS:** Geographic Information System

**GLM:** Generalized linear model

**GMES:** Global Monitoring for Environment and Security

**GPS:** Global Positioning System

**GZT:** Grevy's Zebra Trust

**ICPAC:** IGAD Climate Prediction and Applications Centre

**IFRA-Nairobi:** French Institute for Research in Africa-Nairobi

**IGAD:** Intergovernmental Authority on Development

**INQUA:** International Union for Quaternary Research

**IQR:** interquartile range

**IR:** InfraRed

**IUCN:** International Union for Conservation of Nature

**KWS:** Kenya Wildlife Service

**LAMPEA:** Laboratoire méditerranéen de préhistoire Europe Afrique

**MMSH:** Maison méditerranéenne des sciences de l'homme

**MNI:** Minimum Number of Individuals

**NDVI:** Normalized Difference Vegetation Index

**NGS:** National Geographic Society

**NID:** Non Identifiable Specimens

**NIR:** Near-InfraRed

**NISP:** Number of Identified Specimens

**NMK:** National Museums of Kenya

**NRT:** Northern Rangelands Trust

**PCR:** Polymerase chain reaction

**PROBA-V:** Project for On-Board Autonomy – Vegetation

**QQ plots:** quantile quantile plots

**RF:** Rufford Foundation

**RS:** Remote Sensing

**SC:** Soysambu Conservancy

**SD:** standard deviation

**Shoats:** sheep and goats

**SNR:** Samburu National Reserve

**SPI:** Standardised Precipitation Index

**SPOT-VGT:** Système Pour l'Observation de la Terre – Végétation

**STE:** Save the Elephants

**Tukey's HSD:** Tukey's honestly significant difference

**UK:** United Kingdom

**UoN:** University of Nairobi

**US:** United States of America

**USD:** United States of America Dollar(s)

**WMC:** Wildlife Management and Conservation degree programme

**WMO:** World Meteorological Organization

**ZINB:** Zero inflated negative Binomial

**ZIP:** Zero inflated Poisson

## **CHAPTER 1. Introduction.**

### **1.1. Résumé du Chapitre 1: contexte.**

Le Plio-Pléistocène est une période capitale avec la mise en place de la lignée humaine en Afrique, en particulier du genre *Homo* et les phases anciennes de divergence avec les australopithécines. Les paléanthropologistes essaient de comprendre comment l'alimentation a contribué aux différences écologiques entre les espèces et comment elle a influencé les relations évolutives. Le postulat de la chasse chez les anciens hominidés est basé sur le fait que l'association entre outils de pierre et ossements retrouvés dans les sites en grottes (Afrique du Sud) ou en plaine-air (Afrique de l'Est) reflètent une activité de prédateurs. Ceci a conduit à un paradigme de 'L'homme chasseur' qui permet de reconnaître et déterminer la nature humaine, sensu comportement. Au sein des paléocommunautés animales du Quaternaire, les carnivores sont particulièrement importants pour l'étude de l'évolution de la lignée humaine en raison de leurs potentialités à concurrencer et interagir avec les hominidés dans le cadre des stratégies alimentaires car ils sont à la fois des compétiteurs pour les ressources animales (viande, moelle) et fournisseurs de carcasses dans le cadre de charognage. Les modes d'acquisition et temps d'accès aux carcasses sont des problématiques (chasse, charognage primaire, secondaire) qui font l'objet de beaucoup de débats et d'études.

Les savanes actuelles de l'Est Africain (ex. Bassin du Turkana, Serengeti, Amboseli, Ngorongoro...) apportent des modèles utiles pour nous aider à comprendre et reconstruire les environnements passés que les hominidés ont exploités, où ils ont vécu et se sont adaptés. Les études sur l'écologie du charognage dans divers écosystèmes (Ngorongoro et Serengeti en Tanzanie, Maasai Mara au Kenya, Virunga au Congo...) démontrent que les possibilités de charognage offertes par les prédateurs strictement carnivores dans des habitats et des périodes de l'année spécifiques étaient déterminées par la disponibilité des ressources. Ainsi, suite à l'intervention de félins, chasseurs et mangeurs de viande, et avant celle de hyènes, charognards et mangeuses d'os (et de moelle), il existerait une niche spéciale pour les hominidés pour la récupération de carcasse dans des environnements de ripisylves, le long de rivières, durant la fin de la saison sèche.

D'autres études écologiques travaillant sur les facteurs impactant la prédation par les carnivores sauvages, indiquent que la prédation sur le bétail domestique peut être relativement évitée. Les facteurs clés caractérisant ces conflits, tels que les pratiques d'élevage, les établissements humains, les schémas d'élevage et les représailles face à la déprédation du bétail, sont

directement liés aux activités anthropiques et peuvent donc être gérés au moyen de mesures d'atténuation telles que des formes d'élevage raisonnées et une approche communautaire participative accrue dans la gestion et la conservation de la faune sauvage, et des guildes de carnivores.

Notre travail de thèse se concentre sur l'écologie, la taphonomie et la conservation de grands carnivores au Kenya, et désigne un essai s'interrogeant sur les conflits Hommes-Carnivores. La région de Samburu, notre principale région d'étude, est unique dans la mesure où elle héberge six espèces de grands carnivores, commune à l'Afrique de l'Est: lion, léopard, hyène tachetée, hyène rayée, lycaon et guépard. Il s'agit donc d'un 'terrain' idéal pour la mise en œuvre de stratégies communautaires de sensibilisation à la faune sauvage et de conservation visant à atténuer les conflits homme-faune sauvage, par la création et la promotion de zones de gestion de la faune sauvage et de meilleures pratiques d'élevage pour lutter contre la prédation du bétail. Le deuxième site d'étude est la *Soysambu Conservancy* à Nakuru; Il s'agit plutôt d'une zone de contrôle permettant de comparer les données taphonomiques avec celles de Samburu sur les modifications osseuses par les carnivores modernes.

L'objectif général de l'étude est de s'appuyer sur les recherches antérieures néo-taphonomiques et écologiques sur les conflits hommes-carnivores afin de mieux comprendre les déterminants évolutifs, socioculturels et écologiques des dommages causés au bétail par les grands carnivores. Ces connaissances seront utiles pour favoriser la conservation des grands carnivores au Kenya, grâce à une gestion plus éclairée de ces conflits. Les objectifs de l'étude sont les suivants: (1) Évaluer l'écologie de la prédation en documentant les habitudes de consommation des carcasses chez les carnivores modernes (lions, léopards et hyènes tachetées) au moyen d'analyses de désarticulation osseuse, de fréquences des parties squelettiques et de modifications de la surface des carcasses de proies dans deux régions du Kenya de la vallée du Rift (Samburu et Nakuru); (2) de documenter l'impact de la saisonnalité et de l'habitat local sur le régime alimentaire des grands carnivores et les taux de prédation du bétail dans un environnement pastoral de Samburu; (3) de réaliser une étude ethnographique sur les conflits hommes-carnivores dans un milieu pastoral de Samburu; (4) d'utiliser, par l'étude de cas actuel de la consommation de carcasses par trois grands carnivores en tant qu'analogue moderne, pour discuter les concepts clés au cœur des questions paléoécologiques sur le débat entre chasse et charognage dans le Passé.

## **1.2. Summary of Chapter 1: context.**

The Plio-Pleistocene was denoted as a unique period of hominid diversity in Africa that coincided the early phases of divergence of the *Homo* lineage from the australopithecines. Paleoanthropologists have tried to understand how diet contributed to the ecological differences between hominid species and influenced their evolutionary relationships. The postulation of hunting among early hominids was based on the belief that stone tools and bones from old deposits in caves reflected past human predatory activities. This led to the adoption of the hunting paradigm because hunting epitomized the most diagnostic behavioral trait for distinguishing what was human and what was not. Within quaternary animal palaeocommunities studies, carnivorans are particularly important to the study of hominid evolution because they could have impacted on hominid dietary strategies in at least three ways: as potential predators of hominids; as competitors for animal resources (meat and/or marrow); and, as providers of carcasses for scavenging. The timing of hominid vs carnivoran access to carcasses (i.e. hunting vs scavenging) is, however, a subject of much debate.

Modern East African savannas such as the Turkana Basin, Serengeti, Amboseli, and Ngorongoro Crater serve as the primary model to reconstruct the palaeoenvironments that early hominids would have needed to survive in and adapt to. Past studies on the ecology of scavenging in the Ngorongoro and Serengeti ecosystems (Tanzania), Maasai Mara (Kenya) and Virunga National Park (Democratic Republic of Congo), showed that scavenging opportunities enabled by strictly flesh-eating predators in specific habitats and times of the year could be determined by resource availability. After felids defleshed carcasses and prior to the intervention of bone crunching hyenas a theoretical scavenging niche was open for hominids in riverine settings at the end of the dry season.

Globally, several ecological studies that have assessed factors which influence depredation by wild carnivores indicate that, livestock depredation is to some extent preventable, and that key factors characterizing the conflict landscape such as livestock husbandry practices, human settlement, herding patterns and retaliation to livestock depredation, are directly linked to anthropogenic activities, and therefore have the potential to be managed through mitigation measures such as attentive forms of husbandry, ecological restorations of carnivore wild prey habitats, and an increased participatory community approach in the management and conservation of wildlife.

This PhD study focusses on the ecology, taphonomy and conservation of large carnivores in Kenya with a goal of seeking practical strategies to mitigate human-carnivore conflict. Samburu County, the main study site is unique in the sense that it hosts populations of the six large carnivore species found in Eastern Africa, namely; lion, leopard, spotted hyaena, striped hyaena, wild dog and cheetah; and is therefore an ideal surrogate, for implementation of community wildlife awareness and conservation strategies towards mitigation of human-wildlife conflict, through creation and promotion of wildlife management areas and better husbandry practices to deal with livestock depredation. The second study site - Soysambu Conservancy in Nakuru, was a control study site for comparing taphonomic data with that from Samburu on bone modifications by modern carnivores.

The general aim of the study was to build upon previous neotaphonomic and ecological research on human-carnivore conflict, in order to better understand the evolutionary, sociocultural and ecological determinants, of livestock damage caused by large carnivores, and to use this knowledge promote the large carnivore conservation in Kenya, through a more-informed management of human-carnivore conflict. The study objectives were: (1) To assess the ecology of predation by documenting carcass consumption patterns by modern carnivores (lion, leopard and spotted hyaena) through analyses of bone disarticulation patterns, skeletal part frequencies and surface modifications on prey carcasses across two Kenyan landscapes (Samburu and Nakuru) in the rift valley. (2) To document the impact of seasonality and local habitat on large carnivore diet and livestock depredation rates across a Samburu pastoralist landscape. (3) To conduct an ethnographic study on human-carnivore conflict in a Samburu pastoralist landscape. (4) To use the current case study of carcass consumption by three large carnivores as a modern analogue to complement on key concepts central to palaeoecological questions about the hunting-scavenging debate.

### **1.3. Palaeo-ecological perspective of the human-carnivore conflict.**

The Plio-Pleistocene was denoted as a unique period of hominid diversity in Africa that coincided the early phases of divergence of the *Homo* lineage from the australopithecines. Paleoanthropologists have tried to understand how diet contributed to the ecological differences between hominid species and influenced their evolutionary relationships. The postulation of hunting among early hominids was based on the belief that stone tools and bones from old deposits in caves reflected past human predatory activities. This led to the adoption of the hunting paradigm because hunting epitomized the most diagnostic behavioral trait for distinguishing what was human and what was not (Gifford-Gonzalez, 2018; Turner and Anton, 1997; Dart, 1954; Brain, 1981; Russell, 2012; Lewis, 1997; Tunnell, 1990; Tappen, 1995).

In the 1970s, the South African scientist Bob Brain came across the skull of an early hominid child in a cave at Swartkrans, with clear indentations by a set of canines, most likely those of a leopard (Brain, 1981). This incident presents one of the earliest evidences in prehistory on the predation on man by carnivores (Brain, 1981; Kruuk, 2002).

Within palaeocommunities, according to Brain, (1981); Lewis, (1997); Blumenschine, (1986a,b, 1988, 1989); Potts, (2003, 1988); Potts *et al.*, (1983); Turner, (1990); Marean, (1997); Russell, (2012); Behrensmeyer *et al.*, (2000); Stiner, (1994); Marean and Frey, (1997); Klein, (1999); Parkington, (1981); Schoville and Otárola-Castillo, (2014); Tunnell, (1990); Tappen, (2001); Leslie, (2016); Mwebi, (2013); Werdelin and Solounias, (1991); Pobiner, (2007), carnivorans are particularly important to the study of hominid evolution because carnivorans potentially could have impacted on hominid dietary strategies in at least three ways: as potential predators of hominids; as competitors for meat and/or marrow; and, as providers of carcasses for scavenging. The timing of hominid vs. carnivoran access to carcasses is, however, a subject of much debate (e.g. Potts, 1988, 2003; Binford, 1981; Bunn, 1982, 1986; Bunn *et al.*, 1988; Russell, 2012; Binford *et al.*, 1988; Blumenschine, 1988). Changing ideas about hominid dietary behavior coupled with palaeocommunity research have led to viewing carnivorans not just as competitors and predators, but as species contributing to the structure of resources available to hominids (e.g. Blumenschine, 1986a,b, 1989; Marean, 1997; Kruuk, 1972a; Pobiner, 2007; Russell, 2012; Gidna *et al.*, 2014; Leslie, 2016; Werdelin and Solounias, 1991; Mwebi, 2013; Lewis, 1997; Tunnell, 1990; Tappen, 1995, 2001; Schoville and Otárola-Castillo, 2014; Goswami and Friscia, 2010; Gittleman, 1989; Turner and Anton, 1997).

#### **1.4. Ecological perspective of the human-carnivore conflict.**

On a global scale, large carnivores have experienced catastrophic declines as a result of human activities, notably hunting, retaliatory killing and habitat loss (Kruuk, 2002, 1972b; Woodroffe *et al.*, 2005; Winterbach *et al.*, 2013; Treves *et al.*, 2006; Treves and Karanth, 2003). In East Africa, large carnivores have been particularly affected by pastoralism as increased stocking rates have led to significant habitat loss, and increased retaliatory killings by pastoralists following livestock depredation events (Ogada *et al.*, 2003; Dickman, 2005, 2008, 2010; Woodroffe *et al.*, 2007; Cotterill, 2013; Frank, 2010; Kissui, 2008a,b; Mwebi, 2007, 2013).

Livestock are particularly vulnerable to wild carnivore depredation because, a decreased risk of predation in a human-mediated environment, has led to a degeneration of their anti-predatory abilities (Zohary *et al.*, 1998; Boitani and Powell, 2012). Livestock depredation causes serious damage to local economies, and tends to reinforce negative attitudes towards conservation initiatives and wild carnivores (Romañach *et al.*, 2007; Inskip and Zimmerman, 2009; Kruuk, 1976b). These perceptions can have strong emotional and political consequences, ultimately resulting in the persecution of carnivores (Kellert *et al.*, 1996; Clarke, 2012; Schaller, 1972; Boitani and Powell, 2012; Kingdon and Hoffman, 2013; Cotterill, 2013; Dickman, 2010; Suryawanshi *et al.*, 2013; Boast, 2014; Patterson *et al.*, 2004; Romañach *et al.*, 2007; Marker *et al.*, 2003a,b; Balme and Hunter, 2004; Marker, 2003; Lindsey *et al.*, 2005b; Fanshawe *et al.*, 1991; Rasmussen 1996; Woodroffe and Ginsberg, 1998; Holekamp *et al.*, 1993; Hofer and Mills 1998; Wagner, 2006; Hofer, 1998a; Rieger, 1979a; Osborn and Helmy, 1980).

The majority of ecological carnivore research have concentrated on individual species rather than on whole assemblages or guilds of carnivores present within a landscape. A lot of information is still needed on carnivore habitat requirements; adaptation to, and tolerance of human encroachment; food habits/local diet; and, interactions with other guild members (Boitani and Powell, 2012; Kruuk, 2002; Valeix, 2011). Carnivores help to structure an ecosystem through their impact on prey, on each other, and on the vegetation (Ray *et al.*, 2005). Therefore, the removal of a carnivore species from an ecosystem may have far-reaching and un-anticipated impacts on a habitat landscape (Sodhi and Ehrlich, 2010). Consequently, it is paramount to conserve and manage natural landscapes; and to evaluate the anthropogenic impact on the full assemblage of carnivores and their prey (Boitani and Powell, 2012; Winterbach *et al.*, 2013; Goswami and Friscia, 2010; Gordon and Prins, 2008).

### 1.5. Problem statement and justification.

Modern East African savannas serve as the primary model for the palaeoenvironments of early hominids (Tappen, 1995). East African savannas such as in the Turkana Basin, Serengeti, Amboseli, and Ngorongoro Crater have been used particularly often to model the ecological situations that early hominids would have needed to survive in and adapt to (e.g. Behrensmeyer and Boaz 1980; Blumenschine 1986a,b, 1988, 1989; Russell, 2012; Schaller and Lowther, 1969; Sinclair *et al.*, 1986; Potts *et al.*, 1983; Bunn, 1986; Monahan, 1996; Stiner, 1994; Marean and Frey, 1997; Klein, 1999; Parkington, 1981; Schoville and Otárola-Castillo, 2014).

There is a long tradition of neotaphonomic research in palaeontology and archaeology that is intended for building models of the bone accumulating and modifying behaviours of prehistoric biological actors (e.g., Binford, 1981; Domínguez-Rodrigo and Piqueras, 2003; Domínguez-Rodrigo, 2001; Blumenschine, 1995; Selvaggio and Wilder 2001; Selvaggio, 1994a,b; Behrensmeyer and Boaz, 1980; Gidna *et al.*, 2014). This established wisdom has led to a large body of actualistically based, neotaphonomic research on various terrestrial vertebrate carnivores; work that characterizes the bone accumulating and, modifying behaviors of those animals (e.g. Gidna *et al.*, 2013, 2014, 2015; Mwebi, 2013; Stiner, 1994; Klein and Cruz-Urbe, 1984; Haynes, 1983; Brain, 1981; Bunn, 1983; Dart, 1954; Hill, 1979, 1989; Mills and Mills, 1977, 1978; Skinner *et al.*, 1980; Sutcliffe, 1970; Fourvel, 2012; Kruuk, 1972a; Yravedra *et al.*, 2014; Fosse *et al.*, 2009; Domínguez-Rodrigo and Pickering, 2010; Stiner *et al.*, 2012; Domínguez-Rodrigo 1997a, 1999; Domínguez-Rodrigo and Barba, 2005, 2006; Pobiner, 2007; Fernández-Jalvo and Andrews 2016; Delaney-Rivera *et al.*, 2009).

Studies of this type focus variously on patterns of: skeletal part representation; the intra-skeletal and intra-bone distributions of feeding related damage; tooth mark morphology and frequency (often by type, e.g., scores, pits and punctures); and prey mortality distribution. Such neotaphonomic research have been conducted with intent of interpreting and reconstructing hominid interactions with other fauna in both archaeological and palaeontological contexts (e.g., Domínguez-Rodrigo and Pickering, 2010; Domínguez-Rodrigo and Barba, 2005, 2006; Pickering *et al.*, 2011; Mwebi, 2013; Gidna *et al.*, 2013, 2014, 2015; Blumenschine, 1986a,b; Fosse *et al.*, 2009; Pobiner, 2007; Fourvel, 2012).

Several ecological studies have looked into the factors which could reduce depredation by wild carnivores (e.g. Ikanda and Packer, 2008; Ogada *et al.*, 2003; Woodroffe *et al.*, 2007; Dickman, 2005, 2008, 2010; Kissui, 2008a,b; Mwebi, 2007, 2013; Frank, 2010; Blackburn *et al.*, 2016; Ghoddousi *et al.*, 2016; Cotterill, 2013; Suryawanshi *et al.*, 2013; Boast, 2014; Patterson *et al.*, 2004). These studies indicate that, livestock depredation is to some extent preventable, and that key factors characterizing the conflict landscape; such as livestock husbandry practices, human settlement, herding patterns and retaliation to livestock depredation, are directly linked to human behaviours, and therefore have the potential to be managed.

The Samburu landscape, our main study site is a very dynamic ecosystem with people, livestock and wildlife moving in search of resources. For many generations, Samburu pastoralists have practiced attentive forms of husbandry associated with minimal losses to depredation, through use of cattle bomas, herders, guarding dogs, and high levels of human activities around the bomas (Ogada *et al.*, 2003; Woodroffe *et al.*, 2005; Mwebi, 2013). However, despite valiant efforts to minimize livestock depredation, through attentive husbandry methods; livestock still constitutes a considerable proportion to wild carnivore diets (Woodroffe *et al.*, 2005; Suryawanshi *et al.*, 2013; Gervasi *et al.*, 2014; Sangay and Vernes, 2008; Johansson *et al.*, 2015; Kruuk, 2002).

Samburu County is unique in the sense that it hosts populations of the six large carnivore species found in Eastern Africa, namely; lion, leopard, spotted hyaena, striped hyaena, wild dog and cheetah; and is therefore an ideal surrogate, for implementation of community wildlife awareness and conservation strategies towards mitigation of human-wildlife conflict, through creation and promotion of wildlife management areas and better husbandry practices to deal with livestock depredation.

The second study site, the Soysambu Conservancy in Nakuru, was a control study site for comparing taphonomic data with that from Samburu on bone modifications by the three modern carnivores: lion, leopard and spotted hyaena. The ecological component of the study involved all the six large carnivore species found in Samburu: The lion, leopard, spotted hyaena, cheetah, African wild dog, and Striped hyaena due to their tendency to cause intense conflict, as well as their conservation concern.

Evidence gathered from past research on human-carnivore conflict (e.g. Inskip and Zimmerman, 2009; Ikanda and Packer, 2008) indicates that in a landscape where humans and wild carnivores live side by side, livestock depredation can never be totally eradicated; at best, it can only be minimized to a tolerable minimum. While perceived impacts of large carnivores on livelihoods drive negative attitudes; positive attitudes towards predators may potentially deteriorate over time if conflicts are not addressed, which could undermine the conservation efforts being operated in an area (Boitani and Powell, 2012).

To this end, conservation and the management of human-carnivore conflict, would therefore benefit from a better understanding of key evolutionary, socio-cultural and ecological determinants, of actual livestock damage caused by large carnivores, and the threat of damage that affected people perceive (e.g. Boitani and Powell, 2012; Suryawanshi *et al.*, 2013). This will better facilitate the process of working towards a consensus to enhance the tolerance of large carnivore presence in a pastoralist dominated landscape. My PhD study built upon previous neotaphonomic and ecological research on human-carnivore conflict. Complementary datasets on carnivore tooth puncture marks and NISP and MNI values from hyaena den sites were made available to this study courtesy of Dr. Jean-Baptiste Fourvel's PhD study in 2012 and Dr. Ogeto Mwebi's PhD study in 2013.

#### **1.6. Null Hypotheses:**

1. Large carnivore species type does not influence tooth mark size.
2. Prey size class does not influence tooth mark size.
3. Prey skeletal region does not influence tooth mark size.
4. Prey size class does not influence large carnivore prey preference.
5. Large carnivore species type does not influence carnivore scat morphometry.
6. NISP values do not influence MNI values at carnivore kill sites and den sites.
7. Climatic variables do not influence livestock depredation patterns by large carnivores in Samburu County.
8. Local habitat does not influence livestock depredation patterns by large carnivores in Samburu County.
9. Perceived and actual rates of livestock depredation by large carnivores in Samburu County are dissimilar.
10. Economic losses due to livestock depredation per large carnivore species in Samburu County are dissimilar.

### **1.7. General study aim:**

To build upon previous ecological research on human-carnivore conflict, to better understand the evolutionary, socio-cultural and ecological determinants, of livestock damage caused by large carnivores, and to use this knowledge promote the large carnivore conservation in Kenya through a more-informed management of human-carnivore conflict.

### **1.8. Study objectives:**

1. To assess carcass consumption patterns by African large carnivores (lion, leopard, spotted hyaena, striped hyaena and brown hyaena) at kill sites and den sites in Kenya, Djibouti and Namibia.
2. To assess African large carnivore (lion, leopard, spotted hyaena) scat morphometry in Samburu County.
3. To assess prey size class preference by African large carnivores.
4. To document the impact of climatic variables (rainfall, NDVI, SPI, maximum and minimum temperatures) and local habitat on livestock depredation by large carnivores (lion, leopard, cheetah, spotted hyaena, striped hyaena and African wild dog) across a Samburu pastoralist landscape.
5. To conduct an ethnographic study on human-carnivore conflict in Samburu County.
6. To assess the economic impact of livestock depredation by large carnivores in Samburu County.
7. To use the current case study of carcass consumption by modern African large carnivores and ethnographic study of a modern East African pastoralist community as a modern analogue to complement the hunting-scavenging debate.

## CHAPTER 2: Literature review.

### 2.1. Résumé du Bilan de la Littérature.

L'ordre des Carnivores présente une grande diversité évolutive, écologique, morphologique et taxinomique, avec une apparition à la fin du Paléocène (environ 56 Millions d'années). Les carnivores s.l., constituent des modèles parfaits pour étudier des facteurs de convergences et d'éco-morphologie, dans le cadre de modèles macro-évolutifs. Ils sont ainsi un des ordres zoologiques les plus étudiés et les plus distribués dans le monde actuellement. En effet, ils sont très diversifiés, composés de 13 familles actuelles regroupant plus de 280 espèces vivantes, soit le quatrième plus riche groupe en espèces parmi les ordres de mammifères modernes. Même si un des caractères diagnostique des Carnivores est le couple (supérieur et inférieur) des dents carnassières qui, dans ce groupe, a été modifié en lames tranchantes (dents sécodontes) pour couper efficacement la viande, on assiste à une grande diversification de formes et régimes alimentaires leur permettant d'occuper un large éventail de niches écologiques comprenant des carnivores stricts tels que les chats et les belettes, ainsi que des généralistes, insectivores, omnivores et même herbivores stricts tels que le panda géant. La diversité spécifique varie beaucoup suivant les clades actuels, depuis les clades mono-spécifiques (Nandiniidae, Ailuridae et Odobenidae) jusqu'aux douzaines de taxons chez les Mustelidae, et des taxons terrestres ou d'eau douce dépassant le nombre d'espèces des Pinnipèdes marins. Leur écologie est également très diverse, depuis des formes diurnes, crépusculaires ou nocturnes; des coureurs, grimpeurs, fouisseurs, nageurs (eau douce et marin); des mangeurs de viande, et d'ossements, des insectivores, piscivores, herbivores ou omnivores...L'étendue de leur distribution géographique et environnementale est considérable, aquatique à terrestre, se trouvant sur tous les continents et écosystèmes, présent sur les pôles, les déserts et hautes montagnes en passant par les forêts tropicales.

Les sociétés humaines ont globalement exprimé des opinions et des émotions très diverses concernant la présence de carnivores dans leur environnement. Ainsi, les espèces de carnassiers ont pu être soit pourchassées et éliminées dans certaines régions, soit faire l'objet d'une certaine vénération et restaurés dans leur milieu dans d'autres. Ils sont également à redouter en raison des pertes liées à la prédation du bétail, mais aussi sur les hommes eux-mêmes, et globalement pour une compétition entre mangeurs de viande, pour les ressources animales (gibier). Ils peuvent être appréciés dans le sens où l'homme entretient une relation extraordinaire avec certains carnivores, au point que les humains ont domestiqué les chats et les chiens notamment

pour qu'ils deviennent des animaux aux fonctions diverses (défenses, compagnie...). Le public voit généralement les grands carnivores différemment des petits carnivores, et différentes cultures ont des attitudes distinctes vis-à-vis de communautés de carnivores, attitudes renforcées sur des expériences, et des récits, variés au cours du temps, sur de nombreuses générations. Par conséquent, la relation entre les carnivores et les humains est un peu 'douce-amère' et intègre une longue histoire de compétition, de prédation, de peur de l'inconnu, de fascination et de beauté, qui implique qu'ils soient largement célébrés, utilisés ou commentés sous des aspects culturels tels que la littérature, l'art, l'héraldique et la mythologie.

Les carnivores sont depuis longtemps concernés et impliqués dans les histoires taphonomiques des assemblages osseux archéologiques dans un large éventail de contextes chronologiques, géographiques et environnementaux. Leurs actions incluent à la fois la création et les modifications de ces assemblages osseux, destruction primaire des os de carcasses prédatées par les carnivores mais aussi consommation secondaire de parties squelettiques précédemment rejetées par des groupes humains. L'évaluation des degrés de compétition entre carnivores et hommes est un sujet central en archéozoologie, par exemple sur des ossements rejetés par l'homme en déterminant les séquences et superpositions des marques, avec des implications comportementales tant pour l'homme que pour des carnivores. Bien que beaucoup d'informations aient été apportées sur les agents modificateurs de l'os, et d'autres processus taphonomiques spécifiques au cours du siècle dernier, les questions concernant les relations entre les assemblages osseux et l'écoéthologie des espèces modernes font encore actuellement l'objet de recherches et d'application paléoécologiques actives.

Ces questions ont trait à des problèmes intéressant les paléanthropologues ; par exemple est ce que les premiers hominidés ont pu occuper certains habitats plus propices à la chasse ou à la récupération de la viande provenant de carnivores, et comment les caractéristiques taphonomiques des assemblages d'os fossiles sont en corrélation avec les niveaux variables de prédation et de pression de récupération sur les espèces-proies. Dans cette perspective, la revue des études consacrée à ce sujet, portera sur l'histoire taxonomique et évolutive, ainsi que sur l'écologie et la biologie des membres de certaines familles de carnivores : les Hyénidés (hyènes tachetées, brune et rayées), les Félidés (lions, léopards, guépards) et les Canidés (chien sauvages ou lycas), en insistant sur leurs relations avec l'homme et les implications de ces mêmes relations, à la fois passées (paléoécologie) et actuelles (écologie) dans le contexte des stratégies pratiques pour atténuer les conflits homme-carnivore.

## **2.2. Summary of literature review.**

The mammalian order Carnivora has a broad evolutionary, ecological, morphological, and taxonomic diversity, with a fossil record spanning the Paleocene. This makes it an ideal model clade for studying convergence and eco-morphology, macro-evolutionary patterns, and life history evolution. For this reason, the order Carnivora is without doubt, one of the most important and widely studied groups of mammals. The order is remarkably diverse taxonomically, and is composed of 13 extant families with over 280 living species, making it the fourth most speciose of modern mammalian orders. Even though the diagnostic character for Carnivora is the carnassial pair which in this group have been modified as shearing blades for effective slicing of meat, member taxa have diversified to occupy a wide range of ecological niches that include strict carnivores such as the cats and weasels, as well as generalists, insectivores, omnivores, and even strict herbivores such as the giant panda. Species diversity varies markedly among the major extant clades, from the monospecific Nandiniidae, Ailuridae and Odobenidae to the dozens of mustelid species, and with terrestrial–freshwater taxa outnumbering the marine Pinnipedia. Carnivoran ecological diversity embraces diurnal, crepuscular and nocturnal forms; cursors, climbers, diggers, swimmers (freshwater and marine); and flesh eaters, herbivorous forms, insect eaters, piscivores and omnivores. The breadth of their geographic and environmental range spans land to water, all continents, from pole to pole, from deserts to high mountains to rainforests.

Globally, humans have expressed diverse opinions and wide ranging emotions concerning carnivore presence or their lack thereof within specific landscapes. As a result, carnivores could be indifferently persecuted in some parts of the world, while in other parts they are passionately being restored. Carnivores are also feared due to the potential losses to livestock depredation, ability to predate on humans, and competition with man for both food and resources. They are also revered in the sense that man has an extraordinary relationship with carnivores to the extent that humans domesticated cats and dogs to become household pets. The public views large carnivores differently from small carnivores, and different cultures have different attitudes towards different assemblages of carnivores. Attitudes may be based on accounts of experiences across many generations. Consequently, the relationship between carnivores and humans is somewhat bitter-sweet, and incorporates a long history of competition, predation, fear of the unknown, fascination and beauty. Therefore, it only seems natural that carnivores are widely celebrated in human cultural facets such as literature, art, heraldry and mythology.

Carnivores have been implicated in the taphonomic histories of archaeological bone assemblages in a broad range of geographic and environmental contexts. Carnivore destruction can include both primary destruction of bones encountered from carcasses preyed upon by carnivores, and secondary consumption of skeletal portions previously discarded by human foragers. Evaluating the levels of carnivore competition for human-discarded bone can be a powerful tool for assessing the degree to which carnivores have overprinted hominid behavioral signals. Although much has been learned about specific bone-modifying agents and other taphonomic processes over the past century, questions about the relationships of bone assemblages to the ecology of living animals are still a matter of active ongoing palaeoecological research. Such questions relate to problems of interest to paleoanthropologists, such as whether early hominids might have found some habitats more favorable than others for hunting or scavenging meat from carnivore kills, and how taphonomic features of fossil bone assemblages correlate with varying levels of predator and scavenger pressure on prey populations. To this end, the literature review for this PhD study highlights on the taxonomic and evolutionary history, ecology and biology of members of the carnivore families, Hyaenidae (spotted, brown and striped hyaenas), Felidae (lion, leopard, cheetah) and Canidae (African wild dog), their relationships with man, and the implications of those very relationships both in the past (palaeoecological) and present (ecological) within the context of human-carnivore conflict mitigation.

### 2.3. Carnivore evolution, ecology and conservation.

The placental mammal order Carnivora has a broad ecological, morphological, and taxonomic diversity, and a fossil record spanning over sixty million years, making it an ideal model clade for studying convergence and eco-morphology, macro-evolutionary patterns, and even life history evolution (Goswami and Friscia, 2010). Evolutionarily, Carnivora is divided into two major branches (*see* Figures 2.1 & 2.2): Feliformia (including cats, linsangs, civets, mongooses, fossas, falanoucs, and hyaenas (Flynn *et al.*, 2000; Wesley-Hunt and Flynn, 2005); and, Caniformia (encompassing dogs, bears, seals, sea lions, walruses, the red panda, raccoons, skunks, weasels, badgers, otters, and wolverines (Wozencraft, 2005; Myers *et al.*, 2008).

The order Carnivora is composed of 13 extant and 2 extinct families descended from a mid-Eocene radiation of primitively meat-eating mammals (Wesley-Hunt and Flynn, 2005; Gittleman, 1989). With over 260 living species, Carnivora is one of the most species-rich clades of mammals (Goswami and Friscia, 2010; Boitani and Powell, 2012). The diagnostic character for Carnivora is the carnassial pair, the fourth upper premolar and first lower molar, which in this group have been modified as shearing blades for effective slicing of meat (Gittleman, 1989; Kingdon and Hoffmann, 2013). Although the shearing carnassials are a synapomorphy for Carnivora, member taxa have diversified to occupy a wide range of ecological niches and include highly carnivorous clades such as the cats and weasels as well as generalists, insectivores, omnivores, and even strict herbivores such as the giant panda (Goswami and Friscia, 2010).

Variation in ecology is strongly reflected in the dentition, so a more omnivorous diet is accompanied by a relative increase in grinding surfaces while a more highly carnivorous diet is reflected in a relative decrease in grinding surfaces and an increase in shearing edges (Van Valkenburgh, 1988, 1989). Carnivores are elusive and require diverse and often sophisticated techniques to get information on their ecology and behavior (Boitani and Powell, 2012). The study of carnivores has a long history, spanning from the early monographs by Murie (1940, 1944), Errington (1943), and Mech (1966), on coyotes *Canis latrans*, minks *Mustela vison*, and wolves *Canis lupus*; the work of Craighead and Craighead (1956) on predator communities; the monographs by Schaller (1967, 1972); and Kruuk (1972a) on tigers *Panthera tigris*, lions and spotted hyaenas; all of which established a strong foundation for modern day research on carnivores.

Today's conservation needs call for evidence based action: explicit evidence showing the need for conservation action, and explicit evidence showing the effectiveness of specific techniques (Boitani and Powell). Key challenges for carnivore conservation include: 1.) Many carnivore species such as tiger, wild dog, lion and cheetah are being threatened with extinction unless urgent conservation measures are taken to save these very charismatic carnivores; 2.) Ecological functions of carnivores within communities are poorly understood, putting the ecological integrity of communities in danger as carnivore populations become low; 3.) Co-existence of carnivores with humans, especially large carnivores, depends on developing strategies to deal with livestock predation, a complex issue that involves the integration of biological, social and economic aspects; 4.) Carnivore guilds, resource partitioning, niches, competition, intra-guild predation and mutualisms are yet to be exhaustively understood; 5.) The basic natural histories are unknown for many species, especially in developing countries. New techniques in remote sampling offer possibilities for obtaining basic information on the most elusive carnivores in remote locations; and, 6.) The communitywide effects of predation are not fully understood and require further study (e.g. Ray *et al.*, 2005; Kruuk, 2002; Sodhi and Ehrlich, 2010; Boitani and Powell, 2012; Ogada *et al.*, 2003; Dickman, 2008; Woodroffe *et al.*, 2005, 2007; Frank, 2010; Kissui, 2008a,b; Winterbach *et al.*, 2013; Treves *et al.*, 2006; Treves and Karanth, 2003; Románach *et al.*, 2007; Valeix, 2011; Blackburn *et al.*, 2016; Ghoddousi *et al.*, 2016; Cotterill, 2013; Suryawanshi *et al.*, 2013; Boast, 2014; Patterson *et al.*, 2004; Clarke, 2012).

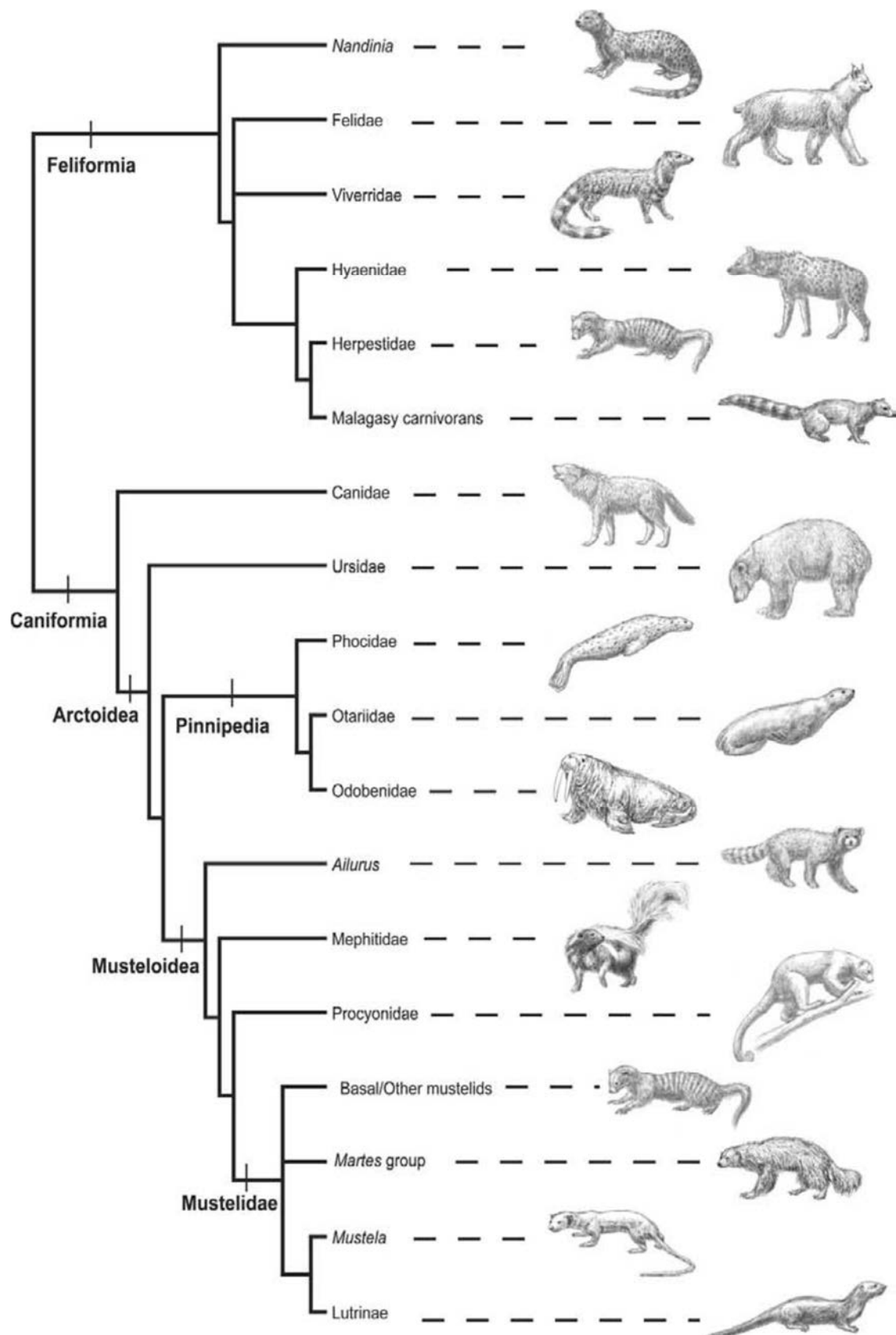


Figure 2.1. Diagrammatic summary of the molecular phylogeny of major clades of living Carnivora (Wesley-Hunt and Flynn, 2005).

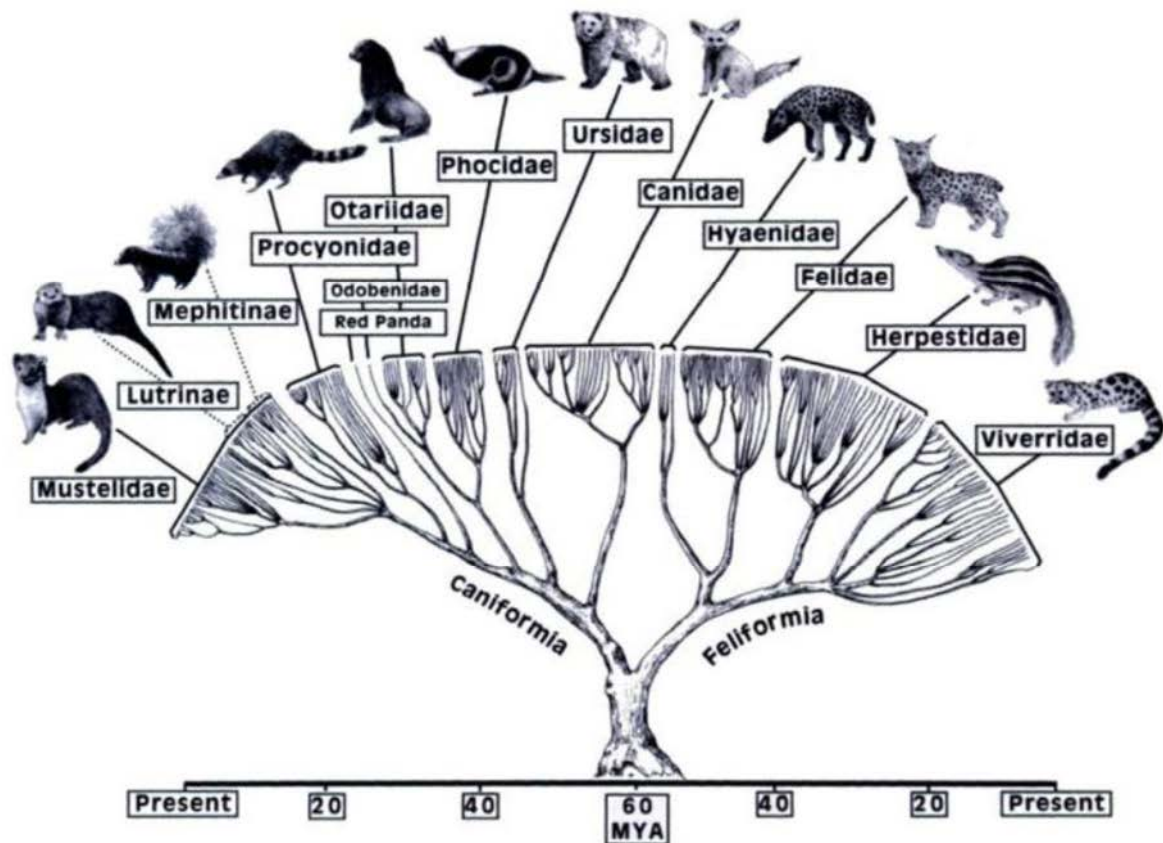


Figure 2.2. An evolutionary “super tree” of the carnivores showing the evolutionary relationships between the living species of the order Carnivora and is based on the combination of 177 separate, smaller phylogenetic trees. The distance of a branching point from the branch tips suggests the estimated age of each evolutionary divergence, as indicated by the scale below the tree (Binida-Emonds *et al.*, 1999).

#### 2.4. Carnivores and humans.

Humans evolved with the large carnivores as competing predators and occasionally as prey (e.g. Brain, 1969, 1981; Lewis, 1997; Kruuk, 2002, 1972a; Gittleman, 1989; Turner and Anton, 1997). In the ‘*Anthropocene*’ characterized with an ever burgeoning human population, high premium has been placed for more natural habitat with demands for natural resources spinning out of control (Dirzo *et al.*, 2014). Consequently, the geographic range of most carnivores is shrinking, their populations fragmented as they get persecuted for one reason or another (Gittleman, 1989; Kruuk, 2002, 1972a,b). The lion and cheetah for example, have captured the imaginations of many a tourist, to the extent that it feels ‘magical’ visiting Africa’s reserves to ‘spot’ these cats in their natural environment, thereby contributing greatly through tourism; to the economies’ of these African countries (Ray *et al.*, 2005; Clarke, 2012).

Yet the majority of people do not realize how vulnerable these very charismatic species are. Carnivores tend to exist at low densities and in small populations, making them blueprints for local extinction (Boitani and Powell, 2012; Kingdon and Hoffmann, 2013).

Humans elicit mixed reactions concerning carnivores. In many parts of the world carnivores are persecuted, while in other parts they are being restored. Thus human societies remain interested in carnivores for one reason or another, and science serves society's interest through numerous carnivore studies (e.g. Gittleman, 1989; Boitani and Powell, 2012; Kruuk, 2002, 1972a, 1986; Schaller, 1967, 1972). Carnivores are both feared and revered by man; feared due to the damage they may do to livestock, ability to predate on humans, and competition with man for both food and resources; revered in the sense that man has an extraordinary relationship with the animals as pets, and exploits them in several ways (Kruuk, 2002). Indeed, carnivores such as lions, wild dogs and hyaenas are highly social and have highly complex social behaviours and capabilities, to the extent that humans domesticated wolves to become dogs *Canis familiaris*, with which they have since co-evolved (Boitani and Powell, 2012). The public views large carnivores differently from small carnivores, and different cultures have different attitudes towards different assemblages of carnivores. Rural residents tend to harbor more negative attitudes towards large carnivores than urban dwellers, and these attitudes seem not to be based on recent experience (Kruuk, 2002; Gittleman, 1989; Boitani and Powell, 2012; Clarke, 2012; Patterson, 1907).

Attitudes may be based on accounts of experiences across many generations. The relationship between carnivores and humans is therefore bitter-sweet, and incorporates a long history of competition, predation, fear of the unknown, fascination and beauty (Boitani and Powell, 2012; Kruuk, 1972a, 2002; Schaller, 1967, 1972a; Turner and Anton, 1997; Clarke, 2012; Patterson, 1907). Carnivores are widely celebrated in literature, in art, in heraldry, in mythology and in witchcraft. Mothers have told stories about the big bad wolf and other predators to their children from early history until today. Artful accounts of such danger come from everywhere around the globe, from African villages, to the teeming cities of the modern world (Kruuk, 2002). The instinctive awe, and the conflicting emotions associated with carnivores, have also invaded our sense of aesthetics, and the images of these animals have become touch-stones. To most of us, the sight of a roaring lion or tiger is, despite its danger, a breathtakingly beautiful experience, and the silhouette and music of a howling wolf, will be forever engraved on the mind of a spectator (Kruuk, 2002; Boitani and Powell, 2012; Clarke, 2012).

We use the images or attributes of carnivores, to describe people in everyday English idiomatic expressions, for example; as fearless, or as strong as a lion; the leopard never changes his spots; as fast as the cheetah; as sly as a fox; and, last but not least, many men, young and old, do find themselves whimsically ‘charmed’ by the nifty, sultry, cat-like footwork of the *femme fatale*, also known as ‘*the art of the cat walk*’ and occasionally make ‘*cat-calls*’ (no pun intended).

## **2.5. Carnivores and their prey base.**

Majority of the Carnivora species eat meat to a greater or lesser extent, and they will prey on other animals at some time or other (e.g. Gittleman, 1989; Kruuk, 1972a,b, 1986, 2002; Goswami and Friscia, 2010; Kingdon and Hoffmann, 2013). Although ‘carnivore’ means meat eater, members of the carnivore have diets that span an entire spectrum. Some are strict carnivores (many felids and mustelids), many scavenge, have some level of omnivory (canids to most ursids and procyonids), or are insectivorous (some mongooses and canids), and giant pandas *Ailuropoda melanoleuca* are strictly vegetarian. The diet of the four extant species of hyaenids includes many more food categories than one would expect of such a small group, with their specializations ranging from wildebeest to termites, from melons to carrion (Kingdon and Hoffmann, 2013). For predatory carnivores, hunting strategies include ambush, stalking, chasing and hunting as individuals and/or in groups (Boitani and Powell, 2012; Goswami and Friscia, 2010; Kruuk, 2002, 1986, 1972a). These family-specific trends are further refined in the subfamilies, where the similarities between species are even greater. For instance, the large and mostly meat-hunting family of mustelids also includes a subfamily of nine badgers, which almost all feed on invertebrates and vegetation (Neal and Cheeseman, 1996), and there is another subfamily of 13 otters, which subsist on fish, frogs or crabs (Kruuk, 1995).

Not only are there differences between families in the kinds of prey or plants they select, they also vary in the degree of specialization. This is important, because specialization *per se* can affect an animal’s vulnerability to environmental change. One can quantify specialization from the number of major food categories that an animal consumes (Kruuk, 2002, 1995). High specialization implies dependence on few resources, so a specialist has less to fall back on when these resources get depleted (Kruuk, 2002). One problem with such comparisons is that, one can describe specialization only in the broadest of terms, because actual food selection is difficult to quantify in the face of differences in food availability, which have to be assessed (Caro, 1994; Kruuk, 2002).

We often use words such as omnivore, opportunist, generalist and specialist. But these labels have no absolute values, and they may mean different things to different people. The Eurasian badger *Meles meles*, for instance, may be highly focused in its food selection in any one area, concentrating on earthworms in northwest Europe (Kruuk, 1989), on rabbits in southern Spain (Kruuk, 2002) and on olives in northern Italy (Kruuk and *de Kock*, 1981). There is no doubt that in each of these areas badgers are highly specialized compared with the other predators around. Nevertheless, their specializations are different in different places (Kruuk, 2002).

However, despite inadequate terminology, we can recognize that some species rely on many more different prey categories than others. For instance, a cheetah on an African savannah kills almost only antelopes out on open grassland (Caro, 1994), but a similarly sized leopard in the same area is much more diverse in its tastes. It eats those same antelopes, but it also takes smaller mammals, and birds, snakes and carrion (Bailey, 1993). It takes them in the open as well as in dense bush or between rocks. Similarly, along European streams a mink will eat small mammals, frogs, fish, birds and insects, but along those very same banks, an otter will feed almost only on fish and frogs (Sidorovich *et al.*, 1998, 2003). In all such situations, one species is clearly much more focused than the other, and, therefore, we have a broad comparative indicator of specialization. The terminology serves to suggest that, a particular predator may be dependent upon few or many prey categories in any one area, and that distinction is useful (Kruuk, 2002).

As predators on other vertebrates at some time or other (even when not most of the time), many carnivores have been, and could still be potential competitors of our own species, of the hunter and the farmer; often or at least occasionally, the larger carnivores in particular may take very big vertebrate prey, which is also the main focus of human hunting and livestock interest. Furthermore, people themselves are potential prey (Kruuk 2002; Gittleman, 1989). Human-sized prey forms part of the diet of the larger canids, of the bears, of spotted hyaenas and of the large cats. Conflict between man and carnivore, therefore, is almost inevitable, because of dietary specializations and vulnerability to predation. Both carnivore and mankind may play the role of competitor, of predator or of prey in this game (Kruuk, 2002, 1995, 1980, 1989, 1986; 1972a; Brain, 1969, 1981; Clarke, 2012).

The composition of the carnivore diet is directly relevant to the interaction between the animals and humans, and, provides part of the ecological background for our own behaviour in relation to carnivores; for instance, it is possible to deduce from studies of carnivore diet what are the kinds of species that are vulnerable to predation (Riney, 1957; Putman, 1984; Bothma and le Riche, 1984, 1986; Kruuk, 1972a,b, 1976a, 1980, 2002; Davison *et al.*, 2002). Diet is the result of foraging and hunting behaviour, and it is the outcome of the predators' interactions with prey (Riney, 1957; Putman, 1984; Kruuk, 2002; Mills, 1984a,b).

Carnivores forage optimally when they are able to predate upon the largest suitable prey species they can safely kill; thus for each carnivore species there is a modal mass (and spread of taxa) of prey eaten by each population. In addition, diet varies according to individual and species prey preferences, local prey species assemblages, temporal availability of prey, and presence of intra-guild competitors (Macdonald and Loveridge, 2010). To this end, we therefore need an understanding of hunting behaviour, in order to describe the effects of carnivores on prey individuals and populations, and to help to understand the animals' significance to mankind (Kruuk, 2002). Quantifying wild carnivore diets is crucial to understanding predator ecology and the influence that predators have on their prey populations (Radloff and Du Toit, 2004; Owen, 2008; Berg, 2003; Davidson *et al.*, 2013; Bothma and le Riche, 1984, 1986, 1994; Kruuk and Turner, 1967; Ogara *et al.*, 2011; Davison *et al.*, 2002).

Advances in GPS technology has allowed noninvasive carcass observations and faecal/scat analysis to gain increasing knowledge on large mammalian carnivores diet (Bacon *et al.*, 2011; Tambling *et al.*, 2012), and has also permitted to study the spatial distribution of kills providing important information for predator-prey relationships (De Boer *et al.*, 2010). Across ecosystems, comparisons of large mammalian carnivore diet have now provided a good understanding of the preferred prey weight range of several carnivore species (Hayward and Kerley, 2005; Hayward, 2006; Hayward *et al.*, 2006a,b), but local studies are still needed to unravel the role of environmental factors and prey availability (Davidson *et al.*, 2013; Bothma and le Riche, 1994; Mills, 1984a,b; Marucco *et al.*, 2008). Known biases resulting from differential digestion, however, require information on food passage rates (Hiscocks and Bowland, 1989), while the possible role of faeces/scat in scent-marking (Kingdon and Hoffman, 2013), may be ecologically and behaviourally important.

## **2.6. Carnivores and their key habitat requirements.**

Previous research on the habitat ecology of carnivores has focused too much on the environmental variables, that predict carnivore presence or density, and not on variables with direct links to carnivore fitness (Boitani and Powell, 2012). Habitat cannot just be a geographical description of an area or piece of land, certain conditions must be present for a species to survive and to reproduce (Boitani and Powell, 2012; Begon *et al.*, 1990). Habitat occurs at multiple temporal and spatial scales; at the 1<sup>st</sup> order, habitat selection scale of the persistence of the species, equivalent to the species niche; the 2<sup>nd</sup> order, growth of local populations and seasonal and annual ranges of individuals; 3<sup>rd</sup> order, short term use of sites by individuals and social groups; and, at the 4<sup>th</sup> order scale, where individuals make microscale foraging or selection decisions (Mayor *et al.*, 2009).

It is important to note that the presence of animals in an environment, does not define habitat because presence alone, does not consider survival and reproduction. Thus environments where animals can occur, but where potential for survival is low and reproduction absent, are sink habitats, and environments with sufficient resources to support high survival and reproduction are source habitats (Garshelis, 2000; Pulliam, 2000; Hirzel *et al.*, 2002; Soberon, 2007; Begon *et al.*, 1990). A sink habitat can be critical to a species if residents of a sink habitat emigrate to a source habitat when a source population is low for reasons other than habitat (Boitani and Powell, 2012; Begon *et al.*, 1990). Environments where members of a species could occur, but presently do not, are potential habitats. Similar to the fundamental niche, measuring a potential habitat well in field studies is almost impossible (Boitani and Powell, 2012). A habitat is of high quality if individuals can experience high survival and reproduction and, thus the population has the potential for a high growth rate (Boitani and Powell, 2012; Begon *et al.*, 1990).

Most ecosystems have multiple predator species that not only compete for shared prey, but also pose direct threats to each other. Predation and competition, are key drivers that shape community structure and function, strongly affecting the distribution, population dynamics, and behavior of interacting species (Chase *et al.*, 2002; Chesson and Kuang, 2008; Hopcraft *et al.*, 2010; Boitani and Powell, 2012; Estes, 1996; Kingdon and Hoffman, 2013).

These drivers combine most spectacularly within the same guild in the mammalian Carnivora, where some of the largest terrestrial predators share similar resources and space. These intraguild interactions are key drivers of carnivore community structure, with ecosystem-wide cascading effects (e.g. Palomares and Caro, 1999; Linnell and Strand, 2000; Ritchie and Johnson, 2009; Vanak *et al.*, 2013; Boitani and Powell, 2012; Estes, 1996). Large mammalian carnivores are keystone components in ecosystem functioning, not only because of their role in driving trophic cascades (e.g. Estes, 1996; Sodhi and Ehrlich, 2010; Schmitz *et al.*, 2004; Steneck and Sala, 2005; Elmhagen *et al.*, 2010; Terborgh and Estes, 2010; Prugh *et al.*, 2009), but also because of their top-down competitive effects on sympatric carnivores (e.g. Linnell and Strand, 2000; Caro and Stoner, 2003; Ritchie and Johnson, 2009). These antagonistic interactions between multiple species of sympatric predators go beyond ‘eating and being eaten’ (Johnson, 2010), because subordinate carnivores live under the risk of interference competition and intraguild killing (e.g. Holt and Polis, 1997; Donadio and Buskirk, 2006).

Classic ecological theory based solely on predator-prey interactions may thus be inadequate to understand trophic dynamics in many ecological systems (Elmhagen *et al.*, 2010; Johnson, 2010). Indeed, the behavioral games that predators play to coexist, can be as important as those between predators and prey (Johnson, 2010). Many terrestrial ecosystems have more than two species of large mammalian carnivores competing for multiple prey species (Woodroffe and Ginsberg, 2005). More importantly, subordinate carnivores are not the main prey for dominant carnivores, although they may be killed as an extreme form of interference competition (Palomares and Caro, 1999; Donadio and Buskirk, 2006).

Some of the most diverse and complex terrestrial assemblages of large carnivores in the world occur in African savannas, with up to seven species of large carnivores continentwide; lion, leopard, spotted hyena, striped hyaena, brown hyaena, cheetah and African wild dog. Interference competition among these species is well documented in the literature (Creel and Creel, 2001; Winterbach *et al.*, 2013; Kruuk, 1972a; Kingdon and Hoffman, 2013). For example, both cheetahs and wild dogs suffer negative consequences from competition with lions and spotted hyenas. These include reduced access to high-resource areas, reduced food intake due to kleptoparasitism, direct harassment, and increased mortality of cubs and adults due to intraguild killing (Kruuk, 1972a; Winterbach *et al.*, 2013; Durant, 1998, 2000; Durant *et al.*, 2004; Creel and Creel, 2001; Webster *et al.*, 2012; Kingdon and Hoffman, 2013).

Within a landscape where prey has an aggregated distribution, predators can take advantage of the spatial autocorrelation of prey density and intensify their search effort in areas of high prey density by using area-restricted search behavior (Smith, 1974; Kareiva and Odell, 1987). In African arid and semi-arid savannas, large herbivores tend to aggregate around scarce water sources/waterholes to access drinking water, and to complement forage consumption in the dry season, when forage quality and water content is low (De Leeuw *et al.*, 2001; Western, 1975).

The regular need to access drinking water constrains the ability of herbivores to range far from water, and surface water sources constrain herbivore distribution in the dry season (Redfern *et al.*, 2003, Smit *et al.*, 2007, Thrash *et al.*, 1995, Valeix *et al.*, 2009, 2010; Western, 1975). As the dry season progresses, rain-fed, non-permanent surface water sources become depleted, forcing most herbivores to concentrate in the immediate vicinity of the few remaining permanent sources of drinking water, resulting in high levels of animal aggregation near water sources at the peak of the dry season (Chamaillé-Jammes *et al.*, 2007, 2008, 2009; Weir and Davison, 1965; Davidson *et al.*, 2013). Waterholes have therefore been identified as one of the key habitat features that determine the dispersion of prey; thereby influencing the spatial ecology and movement patterns of terrestrial predators (Valeix *et al.*, 2009b).

Surprisingly, very little is known about the effect of variability in annual rainfall on the use of water sources by herbivores (*but see* Chamaillé-Jammes *et al.*, 2008, 2009; Valeix *et al.*, 2007, 2009b, 2010, 2011). In effect, suitable habitats are dictated by the dispersion of key habitat features such as waterholes (Valeix *et al.*, 2010). Additionally, predators move differently when they are close to, or far from these key habitat features (Valeix *et al.*, 2009a; Valeix, 2011; Davidson *et al.*, 2013).

An ideal carnivore habitat therefore, is one that has a rich distribution and abundance of prey, in addition to, possessing environmental characteristics that facilitate capture of prey (Boitani and Powell, 2012; Begon *et al.*, 1990; Valeix, 2011). Quantifying the availability or abundance of prey across large spatial scales for most carnivore species is difficult. This is the main reason why surrogates, such as vegetation type or land-cover classifications from remote sensing are often used (Boitani and Powell, 2012).

Hierarchical analyses of habitat selection by Amur tigers *Panthera tigris altaica* for the five main prey species available in the Russian far east showed that it was the distribution of their main prey, not vegetation communities per se, that limited tiger habitat (Miquelle *et al.*, 1996, 1999). Explicitly linking habitat selection by tigers to their ungulate prey made the case for controlling one of the main ecological reasons driving carnivore population decreases *i.e.* poaching of ungulate prey (Miquelle *et al.*, 1999; Chapron *et al.*, 2008).

Because many carnivores are threatened or limited by human activity, many studies include the biotic interactions with humans as an important influence on carnivore habitat (e.g. Estes, 1996; Thurber *et al.*, 1994; Mladenoff *et al.*, 1995; Jones, 2000; Dickinson *et al.*, 2005; Cushman *et al.*, 2009; Gibeau *et al.*, 2002; Carroll and Miquelle, 2006; De Azevedo and Murray, 2007a,b). Thus humans reduce habitat, changing the relationship between fundamental and realized niches of carnivores in a landscape (Boitani and Powell, 2012). Conceptually, reducing conflict with humans would restore great amounts of ‘potential’ habitat for many carnivore species (e.g. Boitani and Powell, 2012; Ogada *et al.*, 2003; Woodroffe *et al.*, 2007; Clarke, 2012; Dickman, 2005, 2008, 2010; Kissui, 2008a,b; Mwebi, 2007, 2013; Frank, 2010; Blackburn *et al.*, 2016; Ghoddousi *et al.*, 2016; Cotterill, 2013; Suryawanshi *et al.*, 2013; Patterson *et al.*, 2004).

## **2.7. Ecological reconstructions and taphonomy.**

The ecology of humans in respect to interactions with other species and the landscape, and the consequences to both humans and animals, are major themes in zooarchaeology (Gifford-Gonzalez, 2018; Reitz and Wing, 2008). Habitats and specific animal populations thought to be pristine today, unmodified by human activities at any time in the past, may actually, have had a substantial impact from human activities (e.g. Branch *et al.*, 2005; Broughton, 2004; Builth, 2006; Mainland, 2008; Mannino and Thomas, 2001; Peacock, 1998; Uchiyama, 2006).

Humans are not the only agents of environmental change. Environments may be altered by climate change, tectonic activity, tsunamis, plant and wildlife diseases, insects, storms, fires, and landslides, among the host of natural disasters that have an impact on ecosystems with or without human initiative. Landscape changes initiated either by people (anthropogenic) or by so-called natural processes (non-anthropogenic) can be small or large, local or global (Gifford-Gonzalez, 2018; Reitz and Wing, 2008; Russell, 2012).

There has been a general perception among many ecologists and geologists that the pre-domestication Holocene environment as a primeval, pristine, baseline against which to measure environmental changes of the past century. This perspective presumes that hominids were either so much a part of nature that they lived in harmony with it, or that they were technologically incapable of causing much harm (Reitz and Wing, 2008). The major exception to this perspective is the question of megafaunal extinctions at the end of the Pleistocene for which humans are not implicated as drivers of those extinctions (Miller *et al.*, 2005). The biological research of the late twentieth century, gradually generated an ever larger body of data that points towards environmental change in the Holocene (Russell, 2012; Miller *et al.*, 2005). In some cases, the change was not of human agency and in others it was (Luff and Bailey, 2000; Mannino and Thomas, 2001; Gifford-Gonzalez, 2018; Russell, 2012).

Studies of former environmental conditions have several goals. One of these is to reconstruct earlier environments by demonstrating stasis or change in that environment compared to present-day attributes. Such changes may be viewed as stresses with two broad sources of that stress: environmental change and human behavior (Reitz and Wing, 2008). Environmental change can result in changes in community composition independent of human predation (Miller *et al.*, 2005). Stresses that are the result of human action are also environmental changes to which both human and nonhuman populations, and communities must respond (Gifford-Gonzalez, 2018; Russell, 2012; Luff and Bailey, 2000).

Should the stress become too great, particularly in the case of climate change, individual animals or entire populations and communities may shift their range to a more favorable setting, essentially following their preferred habitat by shifting their distribution patterns (Luff and Bailey, 2000; Mannino and Thomas, 2001; Miller *et al.*, 2005; Western and Behrensmeyer, 2009; Gifford-Gonzalez, 2018; Russell, 2012). An important source of evidence, therefore, is the presence (or absence) of indicator species based on present-day biogeography (Peters and Pollath, 2004). Most biological communities do not have precise spatial boundaries. They are collections of populations with similar, but not identical, requirements (Reitz and Wing, 2008). As a generalization, small animals have smaller home ranges, tend to have more specific ecological requirements, and are better environmental indicators than are larger animals, which often feed and reproduce over a wider area. Animals with specialized niches are also more vulnerable to environmental change (Peters and Pollath, 2004; Gifford-Gonzalez, 2018; Russell, 2012).

Reduced to its simplest form, the most likely causes for variation are that the environment changed, or that human behavior changed. It is necessary to distinguish between environmental change per se to which humans responded, and human-induced change. Environmental change could be traced to people altering the environment, including the animals, or it could be that the climate changed without human intervention. The change in resource use may also be an entirely cultural consequence of economic or political developments, such as a new cultural group emigrating into the area, or the sudden and/or unexpected invention of a new technology. Such associations provide a basis for reconstructing past environments and populations (Reitz and Wing, 2008; Gifford-Gonzalez, 2018; Russell, 2012).

Reconstructions based on biogeographic evidence are strengthened by the addition of data from environmentally-sensitive isotopes and incremental growth structures in trees, vertebrates, and invertebrates, as well as long-term trends in body size, age-class frequencies, reproduction, and recruitment (Mannino and Thomas, 2001; Marelli and Arnold 2001; Miller *et al.*, 2005). Accurate reconstructions of ancient community ecology depend on how closely fossil assemblages match species richness and relative abundances in the original living communities (Western and Behrensmeyer, 2009). Many taphonomic and methodological biases relating to morphology, body size, and life habit can affect the presence or absence of taxa and their relative abundance in fossil assemblages (Behrensmeyer *et al.*, 2000; Kidwell, 2007).

Vertebrates and shelly invertebrates have durable remains that can accumulate over long periods of time, raising questions about how such remains record properties of the original community, especially during periods of marked population and habitat change (Behrensmeyer *et al.*, 2000; Kidwell, 2007). Data quality issues have been addressed through studies of living populations and their death assemblages in marine invertebrates (Kidwell, 2007; Tomasovych and Kidwell, 2009) and terrestrial vertebrates (Behrensmeyer *et al.*, 1979; Hadly, 1999; Terry, 2008). These “*live:dead*” studies show that single-census death assemblages can approximate ecological snapshots but typically include durable remains representing varying intervals of accumulation, or time averaging. Time averaging usually inflates species richness relative to live samples, but under stable population and environmental conditions can accurately represent rank abundances of the dominant species in shelly invertebrate assemblages (Kidwell, 2007; Tomasovych and Kidwell, 2009).

Taphonomic studies of bones in modern ecosystems (neotaphonomy) have been championed by Brain (1967, 1969, 1981) as well as a number of other researchers, that include: the work of Hill (1975, 1980; Hill and Behrensmeyer, 1984), Gifford (Gifford and Behrensmeyer, 1977; Gifford *et al.*, 1981), Yellen (1977), Behrensmeyer (Behrensmeyer, 1978, Behrensmeyer *et al.*, 1979; Behrensmeyer and Boaz, 1980; Behrensmeyer, 1993), Haynes (1985, 1988), Bunn (Bunn, 1981, 1982, Bunn *et al.*, 1988), Blumenschine (1989), Domínguez-Rodrigo (Domínguez-Rodrigo, 1996, 1997a, 1997b, 1999, 2001; 2008, 2009, 2012; Domínguez-Rodrigo *et al.*, 2007a,b, 2009, 2012; Domínguez-Rodrigo and Piqueras, 2003; Domínguez-Rodrigo and Musiba, 2010); and Tappen (1995, 2001); Selvaggio (1994a,b).

Brain (1967, 1969, 1981) pioneered using modern bone assemblages to build a body of comparative information that could be used to interpret taphonomic processes affecting faunal remains in the paleoanthropological record. His original research inspired other neotaphonomic studies that have been used to formulate scavenging vs. hunting models for early hominid subsistence strategies. A major strength of his research has been the actualistic observations and experiments that he conducted to understand taphonomic cause and effect. Other controlled experimental studies on taphonomic processes, have also contributed to information that can be brought to bear on the past (Shipman, 1981; Marean *et al.*, 1992, Marean, 1997).

Through such actualistic research, paleontologists and paleoanthropologists have built a large body of information on processes that modify bones and leave identifiable traces, allowing us to decode some of the patterns in the fossil record and to distinguish non-human from human damage features. This research has also resulted in a huge leap in understanding of what happens to bones in the post-mortem environment and the realization that different processes can result in similar end-products. The bones themselves, their size, shape and strength, exert definitive though not exclusive control on which body parts, and which bone portions, are most likely to survive to become fossils (Behrensmeyer, 1978, 2007).

Carnivores have been implicated in the taphonomic histories of archaeological bone assemblages in a broad range of geographic and environmental contexts (Assefa, 2006; Bartram and Marean, 1999; Blumenschine, 1988, 1995; Brain, 1981; Chase *et al.*, 1994; Domínguez-Rodrigo *et al.*, 2009, 2007a, 2007b; Marean *et al.*, 1992; Monahan, 1996; Mondini, 2002; Potts, 1988; Marean and Spencer, 1991; Blumenschine and Marean, 1993; Binford *et al.*, 1988; Gidna *et al.*, 2013, 2014, 2015; Tunnell, 1990; Selvaggio, 1994a,b; Yravedra *et al.*, 2011; Gifford *et al.*, 1981; Mwebi, 2013). Carnivore destruction can include both primary destruction of bones encountered from carcasses preyed upon by carnivores, and secondary consumption of skeletal portions previously discarded by human foragers. Low-density elements and portions of bone, such as long-bone epiphyses, retain an abundance of bone grease distributed within cancellous bone that is highly attractive to carnivores (Binford, 1978; Blumenschine, 1988; Lyman, 1985). The abundances of skeletal elements in faunal assemblages subjected to carnivore destruction are thus expected to correlate positively with bone density. This is not always the case (e.g. Carlson and Pickering, 2004; Pickering and Carlson, 2002), and it has been suggested that the absence of a correlation in situations of undoubted carnivore interaction with a bone assemblage may relate to the use of inaccurate bone density data, or a violation of the conditions required for a correlation analysis (Lam and Pearson, 2005). Alternatively, a weak correlation between bone survivorship and bone density may reflect local ecological factors such as the availability of consumable bone, and intensity of carnivore competition (Faith *et al.*, 2007).

Evaluating the levels of carnivore competition for human-discarded bone can be a powerful tool for assessing the degree to which carnivores have overprinted hominid behavioral signals (Faith and Behrensmeyer, 2006; Faith *et al.*, 2007). Although much has been learned about specific bone-modifying agents and other taphonomic processes over the past century, questions about the relationships of bone assemblages to the ecology of living animals remain unanswered. How faithfully do surface bone assemblages represent the vertebrate species richness, population abundances, and habitat structure of an ecosystem? How stable are the taphonomic features of a bone assemblage, and how is ecological change reflected in these assemblages? Such questions relate to problems of interest to paleoanthropologists, such as whether early hominids might have found some habitats more favorable than others for hunting or scavenging meat from carnivore kills (Blumenschine, 1989, 1986b; Potts, 2003), and how taphonomic features of fossil bone assemblages correlate with varying levels of predator and scavenger pressure on prey populations (Behrensmeyer, 2007; Tóth *et al.*, 2014).

Western and Behrensmeyer (2009) reported a high level of fidelity between modern bone assemblages, and living populations based on a 40-year study of the Amboseli ecosystem, in southern Kenya. Relative abundance of fifteen herbivorous species recorded in the bone assemblage, accurately tracks the living populations through major changes in community composition and habitat over intervals as short as 5 years. Their aggregated bone sample provided an accurate record of community structure time-averaged over four decades, proving that bone surveys can provide a useful method, of assessing population changes and community structure for modern vertebrates. To that end, the results of the Amboseli study help in laying the groundwork for integrating paleobiological, and contemporary ecological studies across evolutionary and ecological time scales.

## **2.8. Human-carnivore conflict.**

Conflicts between humans and carnivores due to livestock depredation have occurred since prehistory and evolution of humans (e.g. Kruuk, 2002, 1972a; Gittleman, 1989; Goswami and Friscia, 2010; Turner and Anton, 1997; Brain, 1969, 1981; Lewis, 1997; Blumenschine, 1986a,b, 1988; Potts, 1988; Turner, 1990; Marean, 1997; Clarke, 2012; Gifford-Gonzalez, 2018; Russell, 2012). Carnivores evolved hunting the wild ancestors of today's domestic animals, and the process of domestication has made these domestic animals vulnerable by stripping them of much of their anti-predator behavior, alertness and fleetness, and often placing them in landscapes to which they are not adapted. Due to this vulnerability, humans through the millennia have developed diverse strategies to protect their valuable stock (Boitani and Powell, 2012; Goswami and Friscia, 2010; Kruuk, 2002, 1986; FAO, 2009).

Nonetheless for a variety of socio-economic, historical, and practical reasons, these techniques are often not used, resulting in many conflicts with humans due to livestock depredation (Boitani and Powell, 2012; Ogada *et al.*, 2003; Suryawanshi *et al.*, 2013). These conflicts fuel the bulk of the negative attitudes that some human groups hold against carnivores, and absorb large amounts of conservation resources; as a result, human-carnivore conflict presents a significant barrier to carnivore conservation worldwide. Therefore, making livestock husbandry practices compatible with carnivores is imperative (Boitani and Powell, 2012; Ogada *et al.*, 2003; Breitenmoser *et al.*, 2005; Baker *et al.*, 2008; Woodroffe *et al.*, 2005, 2007).

Livestock depredation occurs on every continent and in every habitat where domestic animals and carnivores occur together (e.g. Boitani and Powell, 2012; Ogada *et al.*, 2003; Breitenmoser *et al.*, 2005; Baker *et al.*, 2008; Linnell *et al.*, 1996; Kaczensky, 1999; Knowlton *et al.*, 1999; Woodroffe *et al.*, 2005; Frank, 2010; Blackburn *et al.*, 2016; Ghoddousi *et al.*, 2016; Cotterill, 2013; Suryawanshi *et al.*, 2013; Inskip and Zimmerman, 2009; Treves *et al.*, 2006; Treves and Karanth, 2003; Kruuk, 2002; Patterson *et al.*, 2004). The extent of depredation, however and the species involved, vary greatly (Boitani and Powell, 2012; Inskip and Zimmerman, 2009). Livestock depredation by large carnivores and their retaliatory killings by humans is a worldwide conservation concern (Woodroffe *et al.*, 2005; Treves *et al.*, 2006; Treves and Karanth, 2003; Boitani and Powell, 2012).

The most basic character leading to the potential for conflict is the size ratio between the carnivore and livestock. Small stock such as sheep and goats (hereafter referred to as '*shoats*'), are vulnerable to depredation by more carnivore species than are large livestock such as cattle, donkeys, camels and horses; and juveniles are vulnerable to more carnivores than the adults (Boitani and Powell, 2012). Being aware of the community structure of the carnivore guild in any area is a vital first step in planning mitigation strategies for the various life-cycle stages of the different livestock species (Vanak *et al.*, 2013; Boitani and Powell, 2012). As progress is made with large carnivore recovery, old conflicts will likely return, as carnivores reappear within an ecological community. Reappearance will require continual readjustments to husbandry and management strategies, as the necessary mitigation measures are tailored for the specific species combinations (Boitani and Powell, 2012; Suryawanshi *et al.*, 2013; Ogada *et al.*, 2003).

Kaczensky (1999), Baker *et al.* (2008), Inskip and Zimmerman (2009), Suryawanshi *et al.* (2013) and Ogada *et al.* (2003) have shown that even for a given carnivore-livestock combination, depredation is still highly variable in both space and time. Landscape, pasture characteristics, age and sex of the carnivores, availability of wild prey, season, use of diverse husbandry methods, all affect levels of depredation. Livestock die of a wide range of other factors, including starvation, disease, accidents, or are stolen. Dead livestock are often found sometime after death by carnivores who are facultative scavengers, especially in extensive ranching operations, making the cause of death hard to objectively identify (Boitani and Powell, 2012).

Signs of presence at a kill can be related to depredation or scavenging. Accordingly, a crucial first step in addressing depredation is to document the extent to which depredation actually occurs, and to identify the carnivores responsible (Suryawanshi *et al.*, 2013; Ogada *et al.*, 2003; Inskip and Zimmerman, 2009; Patterson *et al.*, 2004). Documenting the extent of depredation: (1.) assists in determining the costs and benefits of addressing depredation against other mortality factors (Moberly *et al.*, 2004; De Azevedo and Murray, 2007a, b); and, (2.) is crucial for ensuring effective operation of potential compensation systems (e.g. MacLennan *et al.*, 2009; Naughton-Treves *et al.*, 2003).

Identifying the species of the responsible carnivore is crucial for targeting mitigation or lethal control activities (Boitani and Powell, 2012; Suryawanshi *et al.*, 2013; Ogada *et al.*, 2003; Inskip and Zimmerman, 2009; Bowland *et al.*, 1992; Ciucci and Biotani, 1998; Patterson *et al.*, 2004). Although experienced fieldworkers and technicians may be able to identify the carnivore species responsible for some kills in areas of sympatry, visual separation is impossible for many cases. Genetic methods that can identify species on the basis of DNA, extracted from a carnivore's saliva left in a bite wound, provides a powerful tool for identifying responsible species objectively (Ernest and Boyce, 2000; Williams *et al.*, 2003; Williams and Johnston, 2004; Blejwas *et al.*, 2006; Sundqvist *et al.*, 2008).

Furthermore, the ability to identify sex and individual identity using salivary DNA provides a powerful tool for determining whether problem individuals exist (Linnell *et al.*, 1999). Although these methods are expensive, they are rapidly becoming quicker and cheaper (Boitani and Powell, 2012). In some cases, the extent of depredation has been highly controversial and hard to quantify because livestock are free-ranging (Boitani and Powell, 2012; MacLennan *et al.*, 2009). Enormous potential exists for widespread social conflict surrounding the uncertainty of cause of death in livestock, especially when many animals are simply missing (Linnell and Brøseth, 2003). Therefore, documenting such losses is paramount. Rigorous and standardized methods are especially important in cases where compensation may be paid, because the consequences of the identification have economic and legal implications for the livestock producer (Wobeser, 1996). Mitigating depredation requires understanding the ecology of predation (Linnell *et al.*, 1996). At its most basic, depredation occurs because carnivores eat other animals, and they do not differentiate between wild and domestic animals (Kruuk, 2002; Boitani and Powell, 2012; Linnell *et al.*, 1996).

The ecology of predation has been documented by Linnell *et al.* (1996) as a set of six specific, sequential steps: (1) searching for and locating an animal; (2) identifying this animal as potential prey; (3) approaching the animal closely enough to attack; (4) attacking the animal and establishing physical contact with it; (5) killing it; and, (6) consuming it. Depredation is basically similar, with the exception that the prey may not be consumed fully, due either to surplus killing (Kruuk, 1972b), or to the high risk of disturbance at the kill by a livestock guardian (Boitani and Powell, 2012).

From the perspective of mitigation, opportunities exist at every step to interrupt the progression. Humans have sought new ways to protect their livestock since prehistory, providing thousands of years of human experience (Boitani and Powell, 2012). Mitigation measures that hold the most promise focus on two broad categories: those focused on carnivores (e.g. lethal control or non-lethal removal); and, those focused on livestock (husbandry practices). Addressing livestock depredation inevitably requires use of both approaches (Bangs *et al.*, 2005), though the relative use of each varies greatly with circumstances.

Little attention has been given to traditional skills of coexistence, most of which have been lost as societies have transitioned to market economies (Western *et al.*, 2015). In East Africa, pastoral communities held a mixed and varying view of species, depending on the perceived threat, utility and symbolism (Clarke, 2012, Roque de Pinho, 2009; Brown-Nunez and Jonker, 2008; Goldman *et al.*, 2010). On balance, wildlife was abundant because its benefits in complementing livestock production greatly outweighed losses. There is however, little information in literature on the ecological and behavioural basis of coexistence (*but see* Hazzah *et al.*, 2009; Western, 2012; Cotterill, 2013). Losses were seen as the inevitable cost of living with wildlife, because of the many material and cultural values that were derived from wildlife. These ranged from food, to medicines, clothing, housing, weapons, environmental indicators and totems (Western, 1997). Pastoral communities in particular saw wildlife as co-habitants of their living space and foraging range; and communities used an array of techniques for averting conflict when possible and managing, deterring and controlling it when necessary. Above all an intimate knowledge of animal movements and behaviour was crucial to sharing living space with minimum threat and loss (Western, 1997, Western *et al.*, 2015).

Techniques for containing conflict ranged from seasonal migrations to daily herding and husbandry practices that limited threatening contact. Other techniques include, the protection of herds through vigilance, routing patterns, aggregating herds, collective guarding, night corralling, and ritual deterrents (Western, 1997; Ogada *et al.*, 2003). As a last resort, threatening animals were pursued and killed, continually reinforcing the fear that high-threat species had of humans. Personal responsibility for avoiding and deterring predator attacks on livestock was reinforced by group sanctions to prevent carnivores from becoming habitual killers and attacking livestock of fellow herders (Western, 1997; Western *et al.*, 2015). With the assumption of wildlife control by the state, and prohibitions against traditional uses and deterrence, wild animals lost the many customary values they held, and were simply regarded as government cattle (Western, 1997; Clarke, 2012). Human-wildlife conflict rose steeply once government took responsibility for wildlife protection and problem animal control, leading to the loss of traditional knowledge, and the skills for coexistence and tolerance of wildlife (Western, 1997; Western *et al.*, 1994, 2015). The erosion of traditional values raises the spectre of wildlife being viewed entirely negatively (Akama *et al.*, 1995), leading to growing intolerance and deepening human-wildlife conflict. The negativity can, however be offset where tourism and other new wildlife values contribute significantly to livelihoods and welfare (Prins *et al.*, 2000; Githaiga, 1998; Western and Nightingale, 2004; Waithaka, 2004, 2012; Homewood *et al.*, 2009; Glew *et al.*, 2010).

Nevertheless, development of tourism and other wildlife-related enterprises and programmes is more feasible in pastoral areas than in agro-pastoral or crop farming situations due to high human populations and incompatible land use practices (Western *et al.*, 1994, 2015). Turning wildlife from a liability into an asset reduces the perception that the conservation interests of the state are at odds with primary livelihoods of communities (Western *et al.*, 2015). Devolving the rights and responsibilities for biodiversity conservation from national to local levels calls for resuscitating the skills and incentives for making wildlife an important component of livelihoods, based on maximizing the benefits, and minimizing the costs and conflicts. Paradoxically, such devolution draws the focus of conservation back to the skills and methods of coexistence traditionally residing in communities which is not available to, or considered by national agencies and Non-governmental organizations (Western, 1997; Western *et al.*, 1994, 2015; Clarke, 2012). The passage of a new Wildlife Act in 2013, in line with the Kenya Constitution 2010, explicitly devolves wildlife management responsibilities to county governments, landowner associations and their representative bodies.

## **2.9. Evolutionary history, taxonomy, ethology, ecology and species account for each of Africa's seven largest mammalian carnivore species under focus of PhD study.**

### **2.9.1. The lion.**

#### **2.9.1.1. Taxonomic and evolutionary history.**

The earliest record of the lion *Panthera leo* is at Laetoli in Tanzania during the Pleistocene (Turner and Anton, 1997); however, the first definite lions are from Olduvai, Bed 1 (Tanzania) 2mya which is also in line with the molecular evidence (Werdelin *et al.*, 2010). The subsequent fossil history of lions is well known, with dispersal out of Africa across Eurasia and into North (and possibly South) America (Burger *et al.*, 2004; Yamaguchi *et al.*, 2004). Lions became extinct in the Americas and large parts of Asia at the end of the latest glaciation; and further range contraction occurred in historic times (Werdelin *et al.*, 2010).

Lion taxonomy has long been controversial (*see* Ellerman, *et al.*, 1953; Smithers, 1975; Meester *et al.*, 1986; Turner and Anton, 1997; Werdelin *et al.*, 2010; Kingdon and Hoffman, 2013; Bothma and Walker, 1999); to that end, until more data from a broader range of fossil lions have been studied, the question of whether lions conform better to a one-species or a multiple-species model must remain open (Werdelin *et al.*, 2010; Bertola *et al.*, 2011; Kingdon and Hoffman, 2013).

#### **2.9.1.2. Morphology and identification.**

The lion is the largest of Africa's carnivores, and second largest member of the family Felidae (after the Tiger), standing as much as 1.25m at the shoulder (Kingdon and Hoffman, 2013); but food intake and genetics play a major role in determining the actual size of a lion, and therefore it varies in size from region to region (Bothma and Walker, 1999). The body is muscular and deep-chested; the head is relatively short-muzzled, and round-faced with prominent whiskers and white chin (Rudnai, 1973; Kingdon and Hoffman, 2013); the base of each whisker, is visible as a dark spot and the majority of vibrissae are organized into 4 – 5 horizontal rows on either side of the muzzle (Kingdon and Hoffman, 2013). The random spots found above the top row of whiskers act as 'fingerprints' that distinguish individuals (Pennycuick and Rudnai, 1970).

Ears are relatively small and round, and often scarred; backs of the ears black in sharp contrast to the remainder of the body (Rudnai, 1973; Sunquist and Sunquist, 2002); eyes vary from pale yellow to dark brown; dorsal pelage ranges from pale gold to amber, with pale or white inner limbs and ventral surface (Kingdon and Hoffman, 2013). Young animals are spotted with rosettes that fade at maturity (Schaller, 1972). Some adults retain vestigial spots on abdomen and legs (Kingdon and Hoffman, 2013).



*Figure 2.3. Photograph of a lion at the Samburu National Reserve. Photo credit: Titus Adhola.*

The adult male is easily distinguishable from a female by a mane of longer hair covering the head, neck, chest, elbows and occasionally belly (Kingdon and Hoffman, 2013; Schaller, 1972). Considerable variation occurs in the extent of mane coverage with ‘maneless’ prime-aged male common in some regions (Kingdon and Hoffman, 2013). A secondary function of the mane may be protection of the head and neck region during fights (Sunquist and Sunquist, 2002; Nowak, 2005). Mane colour varies from platinum to black, and is often patchy with lighter hair surrounding the face (Kingdon and Hoffman, 2013). Variation in mane characteristics occurs both within and between populations (West and Packer, 2002; Gnoske *et al.*, 2006; Kingdon and Hoffman, 2013). Limbs are heavy and muscular, ending in large padded feet; all digits are equipped with sharp, retractable claws (Schaller, 1972; Sunquist and Sunquist, 2002). The tail is thick, muscular and tapered, and just over half the length of head and body (Kingdon and Hoffman, 2013). Tail tip has tuft of long, dark or black hairs concealing a horny spur present in some animals (Schaller, 1972).

Sexual dimorphism in lions is quite pronounced in terms of size as well as pelage (Kingdon and Hoffman, 2013); adult males are typically nearly twice as large as adult females (Bothma and Walker, 1999). Females have two pairs of nipples, very rarely three (Ewer, 1973).

Lion dentition is typically felid (Kingdon and Hoffman, 2013). Melanistic forms of the lion are extremely rare (Guggisberg, 1961; Kingdon and Hoffman, 2013; Sunquist and Sunquist, 2002; Schaller, 1972); and only one instance has been recorded of body colouring sufficiently dark to be regarded as melanistic (Mazak, 1964; Kays and Patterson, 2002); one reason for this may be that the preferred habitats of the lion are open grassy plains or savannah, where a black animal the size of a lion would be extremely conspicuous; an undesirable trait in a predator that relies largely on concealment in approaching its prey (Rudnai, 1973).

Very pale lions are known from some regions in Botswana and Tanzania (Kingdon and Hoffman, 2013). The ‘white lions’ from Timbavati Game Reserve in the Limpopo Province of South Africa and from Kruger National Park (McBride, 1977; Robinson and de Vos, 1982; Smuts, 1982) are not albinos (*but see* Sunquist and Sunquist, 2002); the eyes retain the normal yellow pigment as opposed to the pink – red colour observed in albinos (Cruickshank and Robinson, 1997).

#### **2.9.1.3. Distribution range.**

Lions formerly occurred across most of the African continent, except in equatorial forest and the inner regions of the Sahara (Kingdon and Hoffman, 2013). From North Africa, their range extended outside of the African continent, ranging through south-west Asia, west into Europe and east to India (Guggisberg, 1961; Sunquist and Sunquist, 2002; Schnitzler, 2011). Today, lions are only found in sub Saharan Africa (Kingdon and Hoffman, 2013; Guggisberg, 1961; Nowell and Jackson 1996; Cuzin, 2003; Sunquist and Sunquist, 2002); and in the Gir Forest of north western India (Sunquist and Sunquist, 2002; Kingdon and Hoffman, 2013; Kinnear, 1920). In general, Lions have undergone dramatic range retraction at the limits of the historical distribution (Kingdon and Hoffman, 2013). According to Ray *et al.*, (2005) lions have lost some 83% of their historical range in Africa. There is strong evidence that no resident lion populations remain in Gabon, Congo, Côte d’Ivoire and Ghana (Henschel, 2009; Henschel *et al.*, 2010).

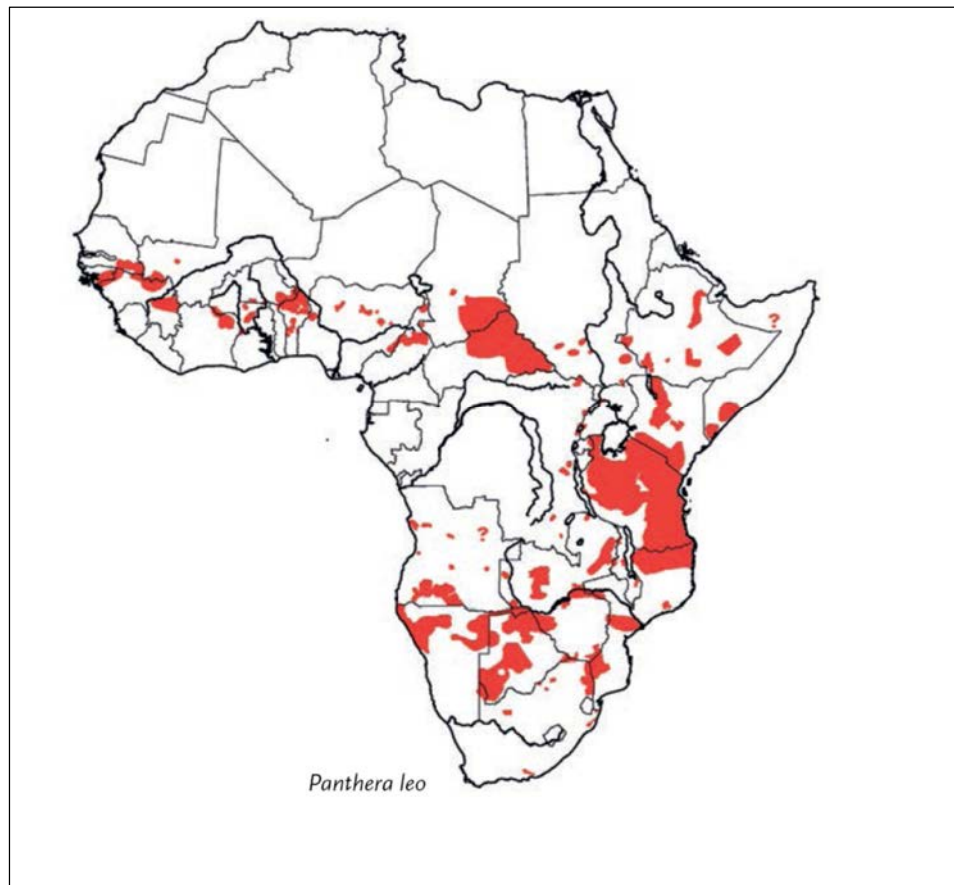


Figure 2.4. Current distribution range of the lion in Africa according to Kingdon and Hoffman, 2013.

#### 2.9.1.4. Social and reproductive behavior.

The lion is the only cat that lives a predominantly social life (Schaller, 1972; Guggisberg, 1961; Kingdon and Hoffman, 2013; Rudnai, 1973; Bothma and Walker, 1999; Sunquist and Sunquist, 2002). The pride is a fission–fusion society (Schaller, 1972; Packer *et al.*, 1990) such that lions spend most of their time in smaller subgroups or alone. Prides change in terms of membership (composition) and size from year to year (Schaller, 1972). The females in a pride are always close genetic relatives with rare exceptions (*see* Owens and Owens, 1984; Smuts, 1978).

Resident males are almost never related to the pride females (except in small, isolated populations) (Packer *et al.*, 1991). Females usually remain in their mothers' pride, but they will also disperse if their fathers are still resident when they reach sexual maturity and incoming males often evict sub adult females along with the sub adult males (Bertram, 1973, Hanby and Bygott, 1987; Stander, 1991). In either case, dispersing females may establish a new pride on the edge of their natal territory and neighbouring prides thus may also be closely related (Packer and Pusey, 1987; Packer *et al.*, 1991; Spong *et al.*, 2002).

Young males are either evicted by incoming adult males, or leave when they begin to reach maturity (Kingdon and Hoffman, 2013); while large coalitions often move directly into adjacent prides (Pusey and Packer, 1987), leaving the pride can be the beginning of a long nomadic phase that can last in excess of two years (Kingdon and Hoffman, 2013). Nomadism and pride membership are not mutually exclusive, and a nomad may become a resident, and vice versa, but each category implies a vastly different way of life; a pride usually occupies a defended area of limited size, which is sometimes called a territory, while a nomad occupies an undefended range (Bothma and Walker, 1999). Nomadic male behaviour differs from that of residents; nomads abstain from roaring to evade detection by resident lions (Grinnell and McComb, 2001) and they rely largely on scavenging for food (Kingdon and Hoffman, 2013). Nomadic males thus often display poor body condition, although they become more proficient at capturing large prey as they grow older and stronger (Schaller, 1972; Kingdon and Hoffman, 2013).

Pride structure can be understood only if the adult males are considered separately from the females (Schaller, 1972). The females and their young are the focus of the pride; the pride usually occupies a limited area, but there are also nomads of both sexes who wander widely (Bothma and Walker, 1999; Kingdon and Hoffman, 2013). The size of the pride's range is related to the size of the pride, and the ranges of various prides may overlap (Bothma and Walker, 1999). The lion's pride size varies from area to area according to the availability of prey (Schaller, 1972; Bothma and Walker, 1999; Kingdon and Hoffman, 2013).

In terms of size of the pride, Wright (1960) tallied 347 groups in East Africa and derived an average of 6, not including solitary individuals. Mitchell *et al.*, (1965) found that the average group size in Zambia was four to five with a maximum of fifteen. Ranges often overlap with those of neighbouring prides, although each pride maintains a core area for its exclusive use, and males may be resident with more than one pride (Schaller, 1972). Both sexes defend the territory, with males ranging more widely, and females defending the core area against other groups of females including those with whom they may share resident male (Kingdon and Hoffman, 2013). The apparent primary benefit of sociality in both males and females is to reproduction (Kingdon and Hoffman, 2013). Nomadic males appear to be constantly on the lookout for vulnerable prides where they can defeat the resident males (Schaller, 1972; Kingdon and Hoffman, 2013); larger coalitions are more successful in such competitions, and solitary males have very little hope of gaining access to females (Bygott *et al.*, 1979).

During a successful pride takeover, the incoming males dispatch the offspring of their predecessors either through infanticide or eviction (Bertram, 1975; Packer and Pusey, 1984; Pusey and Packer, 1994); while this improves the males' reproductive success, it represents a huge loss of investment for females (Kingdon and Hoffman, 2013); by living in groups and pooling their offspring, females improve their chances of protecting their offspring from new males (Packer *et al.*, 1990). After the loss of offspring during a pride take over, pride females immediately become oestrous again (Bertram, 1975). A pride takeover by new males can be chaotic; roaring, chasing and fighting may precede the actual event, followed by an orgy of mating (Kingdon and Hoffman, 2013); one account reports 157 copulations over a 55-hour period (Schaller 1972).

Sociality also enables females to protect their territories from neighbouring prides (McComb *et al.*, 1994). Solitary females, while consistently better fed than their social neighbours, rarely succeed in raising offspring or maintaining a satisfactory core territory, and constant conflict with neighbouring prides and strange males is the main cause for their increased mortality (Packer *et al.*, 1990). Territory boundaries are maintained by roaring, urine-marking and patrolling (Kingdon and Hoffman, 2013). Roaring also allows lions to locate distant pride-mates (Schaller, 1972). Lions do make excursions beyond their ranges, with average recorded daily walking distances of up to 40km per day (Eloff, 2002).

Intruders usually retreat at the sight or sound of residents, and actual fights are rare (Kingdon and Hoffman, 2013). The lethal teeth and claws of opponents make it likely that even a successful competitor will not emerge unscathed, and consequently lions have evolved a number of behavioural mechanisms that enable them to avoid fights (Kingdon and Hoffman, 2013; Schaller, 1972; Bothma and Walker, 1999). When confronted with a challenge from a larger male group, outnumbered resident males sometimes abandon their pride rather than fight, often fleeing the territory with their successors in hot pursuit (Kingdon and Hoffman, 2013). However, coalition numbers may not be the only factor in male success (Schaller, 1972); ownership of a pride probably confers an advantage, as does the possession of larger or darker manes (West and Packer, 2002; Kingdon and Hoffman, 2013).

Although the resident males father all cubs born during their tenure, many coalitions show dominance relationships, and generally only two males in a given coalition succeed in fathering offspring (Packer *et al.*, 1991). Owing to the fact that mating is shared at all by males, may in itself reflect the inability of a dominant male to monopolize more than one oestrous female if more than one are available at the same time (Schaller, 1972; Kingdon and Hoffman, 2013). Indirectly, females may also exercise some choice over the paternity of their offspring in spite of established male dominance hierarchies (West and Packer, 2002). In contrast to males, female lions exhibit no signs of dominance hierarchies and their reproduction is remarkable for its even distribution (Packer *et al.*, 2001).

#### **2.9.1.5. Feeding ecology, foraging behaviour and competition.**

Lions are primarily terrestrial (Sunquist and Sunquist, 2002); and their tawny pelage allows them to camouflage with the background in grassland savannah settings, thus allowing them to approach their prey undetected (Kingdon and Hoffman, 2013). Even though vegetation is understood to be the main type of stalking cover (Kingdon and Hoffman, 2013 Sunquist and Sunquist, 2002); hunting lions also utilise termite mounds, gullies, riverbanks and other features of the terrain to gain ground undetected towards a potential prey (Sunquist and Sunquist, 2002; Schaller, 1972); in the absence of the cover of vegetation; lions are known to improvise and utilise the cover of darkness to approach prey (Sunquist and Sunquist, 2002). Lions have also been observed to capitalise, and use the cover of approaching storms to actively hunt potential prey, temporarily distracted during such weather events (Sunquist and Sunquist, 2002; Sunquist *et al.*, 2014).

Strong forearms and heavily muscled limbs enable short, powerful bursts of speed (Schaller, 1972). Powerful jaws, huge canines and canine-like upper outer incisors facilitate the immobilization of prey by a strangling bite, while the remaining teeth are adapted to slicing meat (Kingdon and Hoffman, 2013; Schaller, 1972; Bothma and Walker, 1999). The greater size of the males assists them in capturing larger prey, as well as in monopolizing carcasses, and imposing themselves upon females (Schaller, 1972). As the largest of Africa's carnivores, lions are well equipped to scavenge from other predators (Sunquist and Sunquist, 2002; Kingdon and Hoffman, 2013).

Unpredictable prey availability and hunting success mean that lions are not guaranteed to a daily prey capture; however, a distensible stomach enables them to gorge when meat is available and to wait several days before feeding again (Kingdon and Hoffman, 2013). Lions are specialists of medium- and large-sized ungulates (from dik diks *Madoqua* spp. to the African buffalo *Syncerus caffer* and eland *Tragelaphus* spp.), but are also known to eat rodents, hares, birds and reptiles (including tortoises), as well as occasionally taking down larger prey like giraffes *Giraffa camelopardalis*, hippopotamus *Hippopotamus amphibius*, rhinoceros, and elephant *Loxodonta africana* (Brain *et al.*, 1999; Matipano, 2004; Schaller 1972; Kingdon and Hoffman, 2013). Porcupines and baboons *Papio* spp. have weapons to which lions respond with caution (Schaller 1972).

Besides typical prey items, lions have been recorded preying on other carnivores, including spotted hyaenas, leopards, cheetahs, black-backed jackals *Canis mesomelas*, bat-eared foxes *Otocyon megalotis*, civets *Civettictis civetta*, ratels *Mellivora capensis*, caracals *Caracal caracal*, banded mongooses *Mungos mungo*, white-tailed mongooses, *Ichneumia albicauda* and zorillas *Ictonyx striatus* (Pienaar, 1969; Eloff, 1984; Stander, 1992a; Hunter, 1998a). Carnivores are typically left uneaten when killed (Kingdon and Hoffman, 2013). However, infanticidal lions and lionesses may eat cubs after killing them (Schaller, 1972; Hunter, 1998a); and lions that find dead cubs sometimes eat them (Schaller, 1972).

Other recorded prey items include: Nile crocodiles *Crocodylus niloticus*, chimpanzees *Pan troglodytes* and other primates, cape fur seals *Arctocephalus pusillus*, pangolins, armadillo *Orycteropus afer*, ostrich *Struthio camelus* and ostrich eggs, and even fish from shallow water (Schaller, 1972; Stander, 1992a; Pienaar, 1969; Tsukahara 1993; Busse, 1980; Bodendorfer *et al.*, 2006; Stander, 1992b; Bridgeford, 1985; Kingdon, 1977; Kingdon and Hoffman, 2013). Man occasionally becomes a prey item in lion diet; and cases of habitual man eaters have been widely documented (*see* Patterson, 1907; Kruuk, 2002; Clarke, 2012).

Hunting is generally opportunistic, and occurs mostly at night (Schaller, 1972; Stander, 1992a; Mills and Biggs, 1993) although ambushing prey at waterholes becomes more frequent during the day in dry seasons (Kingdon and Hoffman, 2013). In general, lions hunt in areas where prey is easy to capture rather than areas where prey is more abundant (Hopcraft *et al.*, 2005). Cooperative hunting is more common in harsh habitats, when the hunting success of a solitary animal is low, and when tackling large prey (Packer and Ruttan, 1988).

Lions throughout Africa will cooperate when hunting larger prey and the additional bulk of the males become handy during such instances when tackling and knocking down large prey (Kingdon and Hoffman, 2013; Schaller, 1972; Funston *et al.*, 1998, 2001). Females capture the majority of small- to mid-sized prey (Schaller, 1972; Kingdon and Hoffman, 2013). Once the prey is subdued, males dominate all other lions at a kill, while females tend to feed alongside the sub adults and cubs (Schaller, 1972; Sunquist and Sunquist, 2002).

Feeding is a messy affair, and evidence of cooperation quickly disappears (Kingdon and Hoffman, 2013; Rudnai, 1973). Prey is either consumed at the site of the kill or dragged to cover, with larger prey usually being consumed on the spot (Kingdon and Hoffman, 2013). The belly is ripped open, and the intestines, internal organs, muscle, bones and skin are consumed (Van Valkenburgh, 1996). Hunting success rates vary among regions, presumably dictated by numerous ecological constraints (Sunquist and Sunquist, 1989). Lions primarily obtain their food by hunting, but scavenging can be a major source of food intake in habitats or at times when lions can regularly find freshly dead animals (Kingdon and Hoffman, 2013). When large migratory herds are out on the treeless, open Serengeti plains, many die naturally, others are killed by spotted hyaenas and every carcass is readily located by descending vultures or hyaena calls (Schaller, 1972).

Lions scavenge opportunistically from all other predators including hyaenas (spotted, brown & striped), cheetahs, leopards and African wild dogs as well as from other lions (Schaller, 1972; Kingdon and Hoffman, 2013; Rudnai, 1973; Sunquist and Sunquist, 2002; Bothma and Walker, 1999; Packer *et al.*, 1990). Males are particularly persistent scavengers of spotted hyaena kills (Kruuk, 1972a; Schaller, 1972; Kingdon and Hoffman, 2013). Spotted hyaenas occasionally supplant lions from their kills, particularly when they greatly outnumber lions (Kruuk, 1972a; Schaller, 1972); and when adult male lions are absent (Cooper, 1991; Bothma and Walker, 1999); but typically wait until lions abandon the carcass and then move in to consume the bones and scraps of skin that the lions cannot eat (Schaller, 1972; Kingdon and Hoffman, 2013). Lions prefer to drink water daily (Sunquist and Sunquist, 2002; Schaller 1972), but they can survive from the moisture obtained from fresh carcasses (Schaller, 1972). Lions conserve energy and resources by spending a large proportion of each day asleep (Rudnai, 1973; Kingdon and Hoffman, 2013). Being sensitive to the heat of the day, they are primarily nocturnal (Kingdon and Hoffman, 2013).

Panting is common only after exertion or a large meal (Schaller 1972). Other efforts to stay cool include lying on their backs and exposing their stomachs to the breeze (Sunquist and Sunquist, 2002). Tree climbing is not uncommon, especially in younger animals, and allows them to take advantage of breezes as well as to avoid flies (Fosbrooke, 1963; Guggisberg, 1961). Lions often rest on high points, including termite mounds, and remain alert to feeding opportunities and intruding strangers (Kingdon and Hoffman, 2013). As the largest of Africa's predators, the adult lion has no actual predators of its own although young are still vulnerable (Kingdon and Hoffman, 2013). Leopards, spotted hyaenas and African wild dogs will kill lion cubs when the opportunity arises, but the greatest threat comes from other lions (Schaller, 1972). Infanticide by incoming males is common, and females will also kill the cubs of unfamiliar lions (Kingdon and Hoffman, 2013). Adult lions can be severely injured while attempting to subdue prey, (Schaller, 1972; Kingdon and Hoffman, 2013). African buffalo even attack and kill non-hunting lions, and are a significant factor in adult mortality (Kissui and Packer, 2004).

#### **2.9.1.6. Relationship with man and the ensuing conservation challenges.**

The conservation status of the lion is currently classified as Vulnerable (VU) by the International Union for the Conservation of Nature (IUCN, 2016). Contemporary estimates suggest that the lion's range declined by 80% during the twentieth century (Ray *et al.*, 2005), with fewer than 50,000 lions remaining continent-wide (Kingdon and Hoffman, 2013). Large areas of land are necessary to support lions and their natural prey, and the most important remaining populations are restricted to eastern and southern Africa (Kingdon and Hoffman, 2013; Sunquist and Sunquist, 2002; Bothma and Walker, 1999). The main conservation threats are habitat conversion, loss of prey and conflict with local people (Kingdon and Hoffman, 2013; Kissui and Packer, 2004; Ray *et al.*, 2005). The severe declines witnessed in lion populations in west Africa, in particular, are attributed primarily to the spread of human settlements and agriculture into lion habitat (Bauer and Van der Merwe, 2004). Most human population growth is in rural areas with attendant pressures to convert wildlife habitat to agriculture (Kingdon and Hoffman, 2013). Cases of problem animals have been reported (Woodroffe and Frank, 2005; Bauer, 2003; Bauer and de longh, 2005; Butler, 2000; Packer *et al.*, 2005); and, events of habitual man eating widely documented (*see* Patterson, 1907; Kruuk, 2002; Kingdon and Hoffman, 2013; Clarke, 2012).

Economic incentives for local communities to tolerate lions have been provided by privately owned hunting companies in Tanzania, Mozambique, Zambia and Botswana and by community programmes in Kenya and Zimbabwe (Kingdon and Hoffman, 2013; Frank *et al.*, 2006). However, there is an urgent need to improve and expand these activities owing to the recent emergence among rural communities of putting out poisoned carcasses that are capable of extirpating entire prides (Frank *et al.*, 2006). Studies have shown that intensive monitoring of livestock and improved husbandry practices can reduce losses to lions (Ogada *et al.*, 2003; Patterson *et al.*, 2004; Woodroffe *et al.*, 2005, 2007; Frank, 2010).

International legal trade for lion products is mostly restricted to hunting trophies and skins by hunting companies (Kingdon and Hoffman, 2013). Local markets exist for lion claws and lion fat as talismans and traditional medicine (Kingdon and Hoffman, 2013; Sunquist and Sunquist, 2002). In Guinea and Guinea-Bissau, lion skins are much sought after, and are openly sold in front of international hotels (Kingdon and Hoffman, 2013; Brugière *et al.*, 2005). Hunting for skins is considered the chief threat to the species in some west African countries (Brugière *et al.*, 2005).

## **2.9.2. Leopard.**

### **2.9.2.1. Taxonomic and evolutionary history.**

Defining the evolutionary history of the leopard *Panthera pardus* is a somewhat complex matter because patterns inferred from fossils and from molecular data lack congruence (Pajmams *et al.*, 2018). Fossil evidence supports an African (eastern Africa) origin in the early Pleistocene (Hemmer, 1979; Gittleman, 1989; Turner and Anton, 1997; Werdelin and Lewis, 2005; Werdelin *et al.*, 2010) while molecular evidence suggests a shared ancestry of Asian and African leopards in the middle Pleistocene (Uphyrkina *et al.*, 2001; Wilting *et al.*, 2016). The apparent incongruence between the fossil record (early Pleistocene) and the molecular record (middle Pleistocene) has been interpreted as indication for two independent out-of-Africa dispersal events; with the molecular record being the basis of all modern Asian leopard lineages (Uphyrkina *et al.*, 2001). Pajmams *et al.*, (2018) state that the combined fossil and molecular evidence together support Africa as the most likely place of origin of *Panthera pardus*. Recent molecular evidence suggests eight or nine subspecies worldwide (Miththapala *et al.*, 1996; Uphyrkina *et al.*, 2001), with all continental African leopards classified as *Panthera pardus pardus* (*but see* Kingdon and Hoffman, 2013).

### 2.9.2.2. Morphology and identification.

The leopard is the largest spotted cat in Africa and Asia (Sunquist and Sunquist, 2002). It is a large cat with robust, muscular forequarters, slender hindquarters, relatively short legs and a long tail around two thirds of head and body length. Pelage highly variable in colour and ranges from pale cream, buff-grey, various shades of orange, tawny-brown or dark rufous graduating to white on belly, chest, throat, chin and underside of tail (Kingdon, 1977; Kingdon and Hoffman, 2013). Body is covered with rosettes, each a cluster of small, black spots surrounding a normally unspotted centre darker than the ground colour. Rosettes give way to large, solid black blotches on the distal half of limbs, belly, throat and tail. Tail tip is black with a white underside. Small, solid black spots cover the face and neck. Upper chest often has a distinctive yoke of connected or semi connected elongated black blotches. Front feet are longer and wider than hind. Feet marked with small, black spots that typically thin out towards the digits but may aggregate in dark individuals, giving a dark, almost black appearance (Kingdon and Hoffman, 2013).



*Figure 2.5. Photograph of a leopard at the Samburu National Reserve resting after having killed a domestic cow calf along the banks of Ewaso Ng'iro River within the reserve. Photo credit: Titus Adhola.*

The pattern of rosettes and spots is unique to individuals and useful for individual identification (Kingdon and Hoffman, 2013). Variation in pelage is extensive within populations, although leopards inhabiting forests tend towards dark colouration while those in arid areas are pale (Pocock, 1932; Kingdon, 1977). Melanism is uncommon in Africa (Kingdon, 1977). Black individuals reputedly occur most often in humid, forested habitats and are reported from the Aberdare Mountain ranges, Mount Kenya, the Virunga Mountains, Ethiopia, Zambia, Cameroon and Gabon (Turnbull-Kemp, 1967; Guggisberg, 1975; Kingdon 1977; Ansell, 1978; Jackson, 2002). Sexual dimorphism is marked, with males being invariably larger and heavier than females (Kingdon and Hoffman, 2013; Sunquist and Sunquist, 2002). Its dentition is typically felid (Kingdon and Hoffman, 2013). The canines are large, with sharp points and slightly flattened on the inner side; the cheek teeth are clearly adapted for slicing (Skinner and Chimimba, 2005).

#### **2.9.2.3. Distribution range.**

Leopards are today found in many parts of Africa, the Middle East, Turkey, throughout Central Asia into south western Russia, throughout tropical Asia into northern China and far eastern Russia, and south to Sri Lanka, Peninsular Malaysia and Java (though naturally absent from Sumatra, Borneo and Bali) thereby making it the most widely distributed of the living larger cats (Nowell and Jackson, 1996; Sunquist and Sunquist, 2002; Turner and Anton, 1997).

Like the puma *Puma concolor*, jaguar *Panthera onca* and tiger, the leopard shows a great deal of size variation over its broad geographic distribution; generally, leopards of more open country tend to be larger than those of the forest (Sunquist and Sunquist, 2002). It is widespread throughout Africa with a very wide habitat tolerance; and is the only African felid occupying both rainforest and desert habitats (Kingdon and Hoffman, 2013).

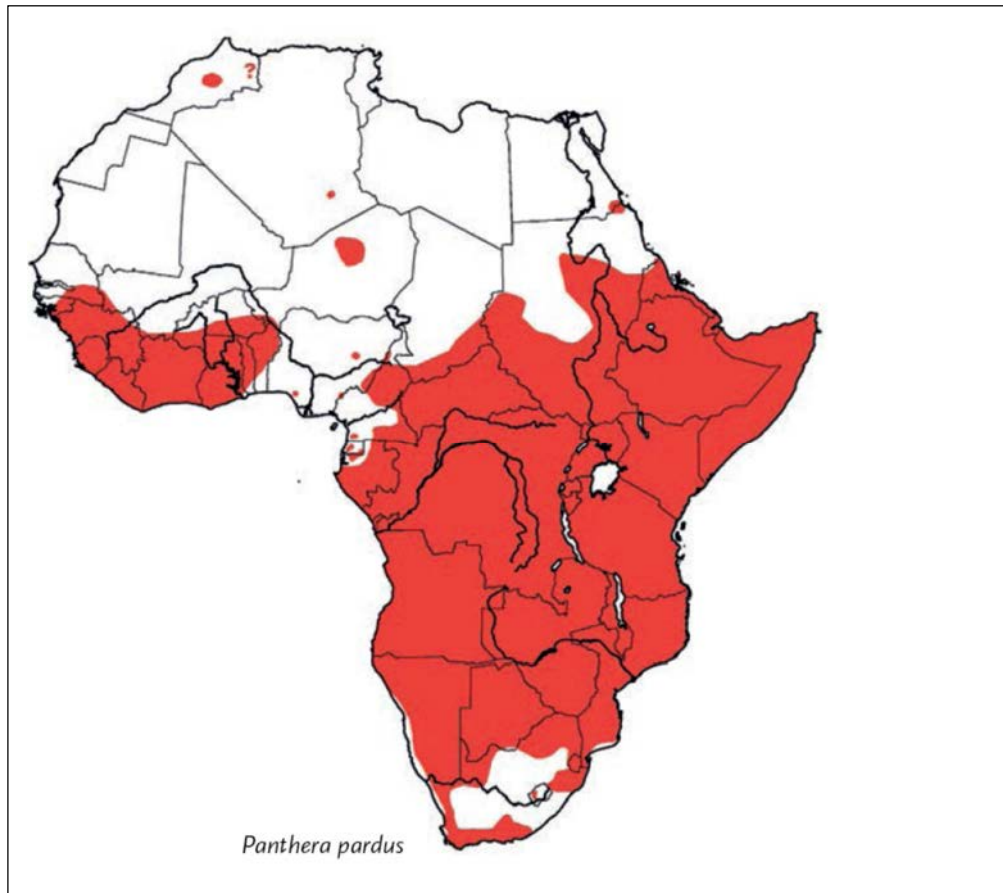


Figure 2.6. Current distribution range of the leopard in Africa according to Kingdon and Hoffman, 2013.

#### 2.9.2.4. Social and reproductive behaviour.

Leopards are solitary and territorial; adults socialize mainly when mating, but familiar non-mating pairs regularly meet and associate briefly without aggression (Kingdon and Hoffman, 2013). Hamilton (1981), Mizutani and Jewell (1998), Bailey, (2005) and Kingdon and Hoffman (2013) state that both sexes maintain enduring home-ranges in which ranges of males being larger and typically overlapping one or more smaller ranges of females (*but see* Marker and Dickman 2005; and, Norton and Lawson, 1985). Range size is broadly correlated with prey availability; where prey availability and hence leopard density is high, ranges are small though high levels of human persecution possibly elevate range size above that predicted by prey availability alone (Marker and Dickman, 2005).

Although territorial adults curtail intrusion by same-sex conspecifics, overlap of home-ranges within sexes is often considerable (*see* Jenny, 1996); leopards do avoid conflict by temporally separating activity in overlapping areas (Stander *et al.*, 1997a). Both sexes scent-mark by cheek-rubbing and spraying vegetation, and by depositing scats and scraping the ground with hind feet (Kingdon and Hoffman, 2013). Scent marks are deposited along frequently used routes including roads, trails and game paths, and along range boundaries (Jenny, 1996; Kingdon and Hoffman, 2013).

Leopards have a limited vocal repertoire (Kingdon and Hoffman, 2013). The most distinctive call, sawing (also called coughing or rasping) carries up to 3km and probably serves a dual function in advertising territorial occupancy and reproductive availability. Sawing is most frequent during peak activity periods at dawn and dusk (Bailey, 2005; Kingdon and Hoffman, 2013). Leopards also make a puffing sound through the nose and lips called chuffing, used as a close-range call during friendly encounters, appeasement or courtship. Leopards growl, snarl, spit and hiss during aggressive encounters and mothers call cubs with a soft grunt (Kingdon and Hoffman, 2013). Scent-marking and vocalizations help in limiting territorial confrontations; however, when they do occur, such encounters are largely demonstrative with typically ritualized feline aggression; on the rare occasions when such encounters escalate, fights are sometimes fatal (Balme and Hunter, 2004; Kingdon and Hoffman, 2013).

Oestrous females show increased rates of vocalization and scent marking, the latter likely associated with elevated sex hormones (Kingdon and Hoffman, 2013). Females sometimes wander far outside their territory during oestrous periods, presumably to locate males (Laman and Knott, 1997; Balme and Hunter, 2004; Bailey, 2005). The mating act itself is usually brief and mating reaches a peak around dawn and dusk; and continues for a few days (Bothma and Le Riche, 1984; Balme and Hunter, 2004). Stander *et al.*, (1997a) observed that overlap between female and male ranges as well as between male ranges facilitates an oestrous female into meeting numerous males (*but see* Laman and Knott, 1997). Even though infanticide has been observed to occur (Scott and Scott, 2003; Balme and Hunter, 2004; Seymour, 2004); female promiscuity in the leopard increases chances of conception and male competition for mates; and possibly reduces the risk of infanticide, by confusing paternity (Kingdon and Hoffman, 2013).

Leopards give birth year round (Hes, 1991; Kingdon and Hoffman, 2013); the oestrous cycle lasts up to 45 days on average (Sadler, 1966), while gestation lasts 90–106 days (Kingdon and Hoffman, 2013). Litters normally comprise 1–3 cubs (Scott and Scott, 2003; Balme *et al.*, 2009). Cubs are denned in thick vegetation, among rocks, tree roots, in caves or aardvark burrows; and are led to kills from weaning (Kingdon and Hoffman, 2013; Le Roux and Skinner, 1989). Adoption of related cubs has been documented (Balme *et al.*, 2012). Cubs reach independence at 7 to 18 months (Balme *et al.*, 2012; Hes, 1991). Dispersal of sub adults is poorly known but females sometimes inherit part of their mother's range while males tend to disperse more widely (Le Roux and Skinner, 1989; Hes, 1991).

Stander *et al.*, (1997a) suggest that mortality among sub adults is high when the population is at ecological carrying capacity, supporting the notion that population regulation is density-dependent. Leopards of both sexes are sexually mature from 2 to 3 years (Hes, 1991; Balme *et al.*, 2009). Longevity in wild leopards is poorly known and it is postulated that adults can probably reproduce until death (Kingdon and Hoffman, 2013).

#### **2.9.2.5. Feeding ecology, foraging behaviour and competition.**

The spotted pelage provides superb camouflage in a wide variety of habitats. Camouflage is important for concealment, mainly from prey but also from predators and competitors (Sunquist and Sunquist, 2002, Sunquist *et al.*, 2014; Kingdon and Hoffman, 2013). Darker colouration in forests and paler in arid, open habitats probably enhances habitat-specific camouflage. Similarly, melanism may confer an adaptive advantage in dark, forested habitat but the rarity of specimens in Africa suggests any gain is insignificant (Kingdon and Hoffman, 2013). The bright white underside of the tail tip is held high by females with young cubs as a signal to follow (Schaller 1972). The ears are flattened and the pale ear patch is displayed during aggressive or defensive interactions to emphasize warning (Kingdon and Hoffman, 2013). The Leopard is a tremendous climber (Hopwood, 1947; Kingdon, 1977; Turner and Antón, 1997); and will retreat to a tree when threatened and haul kills to avoid kleptoparasitism (Kingdon and Hoffman, 2013). This behaviour, combined with a broad and diverse diet, and very wide habitat tolerance, enables them to successfully compete with larger carnivores (Mills and Biggs, 1993; Sunquist and Sunquist, 2002). Kingdon (1977) and Bailey (2005) have recorded the composition of leopard diet to include at least 92 species in sub-Saharan Africa, ranging from arthropods to adult male common eland *Tragelaphus oryx*.

Several studies suggest that diet composition is chiefly determined by local prey availability and therefore varies from one locality to another (Kingdon 1977; Bailey, 2005; Hayward *et al.*, 2006a; Mills and Biggs, 1993; Radloff and Du Toit, 2004; Balme *et al.*, 2007; Mills, 1984; Bodendorfer *et al.*, 2006; Stander *et al.*, 1997a; Norton *et al.*, 1986; Stuart and Stuart, 1993; Henschel *et al.*, 2005, 2011; Sunquist and Sunquist, 2002, Sunquist *et al.*, 2014; Kingdon and Hoffman, 2013). Leopards are capable of predating on elephant, black rhino *Diceros bicornis* and giraffe calves and hauling their carcasses up trees (Blake, 2004; Stevenson-Hamilton, 1947; Scott and Scott, 2003). Primates such as gorillas *Gorilla* spp., bonobos *Pan paniscus*, and chimpanzees feature in rainforest leopard diet (Hoppe-Dominik, 1984; Zuberbühler and Jenny, 2002; Hart *et al.*, 1996; Ray and Sunquist, 2001; Boesch, 1991; Schaller, 1963; Watson, 1999; Fay *et al.*, 1995; D'Amour *et al.*, 2006; Henschel *et al.*, 2005, 2011).

Primates are less important to savanna leopards (Kingdon and Hoffman, 2013). East and southern African savanna leopards regularly kill baboons and vervet monkeys *Chlorocebus pygerythrus*, but overall occurrence of primates in their diet is minimal (Norton *et al.*, 1986; Radloff and Du Toit, 2004). On rare occasions, other carnivores do fall prey to the leopard's dietary taste and include, cheetah, hyaena and a host of the smaller carnivore species (Standar *et al.*, 1997a; Wilson, 1976; Estes, 1991).

Leopards are occasionally cannibalistic, mostly of cubs but sometimes other full grown adults which could be partially or wholly consumed (Balme and Hunter, 2004; Hes, 1991; Charsley, 1977; Steyn and Funston, 2006; Henschel *et al.*, 2005). Livestock losses to leopards vary widely, depending on availability of natural prey and husbandry practices (Kingdon and Hoffman, 2013; Patterson *et al.*, 2004; Mizutani, 1993, 1999; Stander *et al.*, 1997b; Henschel, 2003). Leopards occasionally kill people as prey (Kruuk, 2002; Turnbull-Kemp, 1967; Malbrant and Maclatchy, 1949; Games and Severre, 2002; Kingdon and Hoffman, 2013; Bothma and Walker, 1999).

Leopards kill opportunistically around the clock but forage mainly at night, early morning and late afternoon (Norton and Henley, 1987; Zuberbühler and Jenny, 2002; Hes, 1991, Sunquist and Sunquist, 2002; Bailey, 2005; Hayward *et al.*, 2006; Balme *et al.*, 2007). Leopards forage alone, including females with large cubs that are usually left behind (Sunquist and Sunquist, 2002; Kingdon and Hoffman, 2013). Hunting strategy varies with prey species and habitat type (Kingdon and Hoffman, 2013).

Scavenging occurs; and leopards do appropriate kills from competitively inferior carnivores such as cheetahs, lone spotted hyaenas and jackals (Hunter, 1998a). Forest leopards scavenge the remains of the crowned eagle *Stephanoaetus coronatus* and chimpanzee kills (Kingdon and Hoffman, 2013). The lion is the only African carnivore that is individually capable of killing a healthy adult leopard; however, other large, group-living carnivores such as African wild dogs and hyaenas (spotted or brown) working in concert occasionally kill leopards (Kingdon and Hoffman, 2013). Pairs or groups of adult male baboons have killed leopards, usually in self-defence (Marais, 1939; Cowlshaw, 1994). Intra-specific (leopard vs leopard) clashes account for significant mortality in some populations; young animals are especially vulnerable to predation from lions; and, unattended cubs could potentially be killed by lions, cheetahs and hyaenas (spotted/brown/striped) (Kingdon and Hoffman, 2013).

#### **2.9.2.6. Relationship with man and the ensuing conservation challenges.**

The conservation status of the leopard is currently classified as Vulnerable (VU) by the International Union for the Conservation of Nature (IUCN, 2016). Leopards are at risk mainly from habitat conversion and intense persecution, especially in retribution for real and perceived livestock loss (Ray *et al.*, 2005); estimates of such retributive killings by pastoralists are however poorly reported (Kingdon and Hoffman, 2013). Leopards occasionally kill people as prey; in self-defence or sometimes as habitual man-eaters (Kruuk, 2002; Turnbull-Kemp, 1967; Malbrant and Maclatchy, 1949; Games and Severre, 2002; Kingdon and Hoffman, 2013; Bothma and Walker, 1999). Leopards are surprisingly resilient and persist where other large cats cannot, albeit at lower densities (Martin and *de* Meulenaer, 1988; Marker and Dickman, 2005; Henschel, 2008). Outside protected areas, tourism can offset livestock losses to leopards and foster their conservation (Stander *et al.*, 1997a; Kingdon and Hoffman, 2013).

In intact African rainforest, the principal threat to leopards is probably competition with human hunters for prey (Henschel *et al.*, 2011); the tremendous volume of wild meat harvests denudes forests of prey and may drive localized extinctions (Wilkie *et al.*, 2000; Ray, 2001; Henschel, 2009). The impact of trophy hunting on populations is unclear; but overhunting (legal and illegal combined) of males may diminish female reproductive output (Kingdon and Hoffman, 2013); Balme and Hunter (2004) suggested that elevated turnover of males due to human hunting gave rise to increased rates of infanticide and reduced rates of conception. Illegal killing of leopards is poorly quantified, but occurs widely (Kingdon and Hoffman, 2013).

Skins and teeth (canines) are still widely traded domestically in some southern, central and west African countries where parts are used in traditional rituals and sold openly in villages and cities (Henschel and Ray, 2003; Ray and Quigley, 2001; Gross, 1998; Papini, 2004; Tishken, 2006; Sunquist and Sunquist, 2002, Sunquist *et al.*, 2014; Kingdon and Hoffman, 2013). In Guinea and Guinea-Bissau, leopard skins are valued for traditional ceremonies, and as trophies by a wealthy urban middle class and tourists; skins are openly sold in front of international hotels in Conakry, Guinea, and hunting for skins is considered the chief threat to the species in the two countries (Brugière *et al.*, 2005).

### **2.9.3. Cheetah.**

#### **2.9.3.1. Taxonomic and evolutionary history.**

The cheetah *Acinonyx jubatus* is historically recorded in Africa, Asia, and the Near East; it is now largely confined to isolated populations in Africa (Turner and Anton, 1997). The cheetah was initially included in the subfamily *Acinonychinae* (Wozencraft 1993); but with the emergence of recent molecular evidence, it is now included in the *Puma* lineage along with the Puma (cougar/mountain lion/panther) and Jaguarundi (eyra cat) *Puma yagouaroundi*, which diverged some 6.7 mya (Johnson *et al.*, 2006; Johnson and O'Brien, 1997, Bininda-Emonds *et al.*, 1999, Mattern and McLennan, 2000; Sunquist *et al.*, 2014; Hemmer, 1978; Adams, 1979; Nowak, 2005). Cheetah-like felids once ranged across Asia, Africa and North America in the Pleistocene (Kurtén, 1968; Turner and Anton, 1997).

Two extinct species, the giant cheetah *Acinonyx pardinensis* and the smaller *Acinonyx intermedius*, have been found in the Pleistocene of Eurasia, as well as fragmentary remains of unknown species in Africa; while in North America, two cheetah-like species, *Miracinonyx stuederi* and *Miracinonyx trumani*, have been described from the late Pleistocene (Turner and Anton, 1997; Kingdon and Hoffman, 2013). For many years it was uncertain whether similarities between *Acinonyx* and *Miracinonyx* were due to convergent evolution or common descent (Kingdon and Hoffman, 2013; Adams, 1979). Recent work involving ancient DNA indicates that *Puma* and *Miracinonyx* are more closely related than either is to *Acinonyx* (Barnett *et al.*, 2005).

The word *Acinonyx* is derived from the Greek word *akaina* (a thorn) and *onyx* (a claw), referring to the non-retractable claws. The species name, *jubatus* (Latin), refers to crest or mane seen in young and certain adults (Kingdon and Hoffman, 2013). With no clear cut collective agreement, a number of sub-species have been listed (*see* Allen, 1939; Smithers, 1975; Krausman and Morales, 2005; Ellerman and Morrison-Scott, 1951; Charruau *et al.*, 2011; Menotti-Raymond and O'Brien, 1993; Pocock, 1927; Hills and Smithers, 1980; Van Aarde and Van Dyk, 1986; Kingdon and Hoffman, 2013; Turner and Anton, 1997). A colour variant of the cheetah known as the 'king cheetah', was initially thought to be a new species of cheetah (*see* Pocock, 1927; Kingdon and Hoffman, 2013; Van Aarde and Van Dyk, 1986).

### **2.9.3.2. Morphology and identification.**

The cheetah is described as a medium-sized, spotted felid, with a tall, slender build, long, thin legs, a deep, narrow chest, and a long tail measuring about half the head and body length. The head is rounded, muzzle short, with small, rounded ears, set far apart and black when viewed from behind. A characteristic lachrymal or 'tear streak' extends from medial corner of eye to upper lip just behind canines. The tail is also spotted, with the spots on the distal third coalescing into black rings; the tip of the tail is white. The spot patterning on the face and chest differs among individuals and is a useful feature for field identification; variations in coat patterns have been used to reveal family resemblances (Caro and Durant, 1991).



*Figure 2.7. Photograph of a cheetah at the Samburu National Reserve. It was on the prowl along with two other cheetahs (possibly siblings) looking for possible prey near an airstrip within the reserve. Photo credit: Titus Adhola.*

The fur is short and coarse, except for an erectile crest of greyish hair on the nape and shoulders. It has front feet with five digits; and hindfeet with four. Males are heavier than females and have larger chest girths. Females usually have six pairs of nipples, in contrast to the three or four pairs in other large cats (Kingdon and Hoffman, 2013). The cheetah's claws are shorter and straighter than the claws of other cats; and there are no claw sheaths for the claws to pull back into, so even when they are retracted, the claws are easy to see. This accounts for the common misconception that cheetahs have non-retractile claws like a dog (Sunkist *et al.*, 2014).

The dental formula is typically felid; the canines are short, sharp and rounded, not as long as in other felids where they are used for severing the spinal cord (Kingdon and Hoffman, 2013). The antero-internal cusp, which is well developed in other felids, is barely in evidence, represented by a small knob; its reduction allows the jaws to close tightly (Pocock, 1916b; Ewer, 1973; Skinner and Chimimba, 2005). Melanistic and white Cheetahs do occur in the wild (Wrogemann, 1975; Sunkist and Sunkist, 2002).

#### **2.9.3.3. Distribution range.**

The cheetah is widely, but sparsely, distributed from Senegal to Somalia and south to South Africa, with small, isolated populations existing in Morocco, Algeria and Egypt (Myers, 1975; Nowell and Jackson, 1996; Sunkist and Sunkist, 2002). Cheetahs from the Sahara are considerably lighter in colour than those in sub-Saharan Africa (Dragesco-Joffé, 1993). Outside of the African continent, extremely small fragmented populations of Asiatic cheetahs survive in central Iran and possibly Pakistan (Farhadinia, 2004; Kingdon and Hoffman, 2013). The animals occur in the foothills and dry water-courses of desert massifs, where prey is more common than on the flats (Farhadinia and Hemami, 2010).

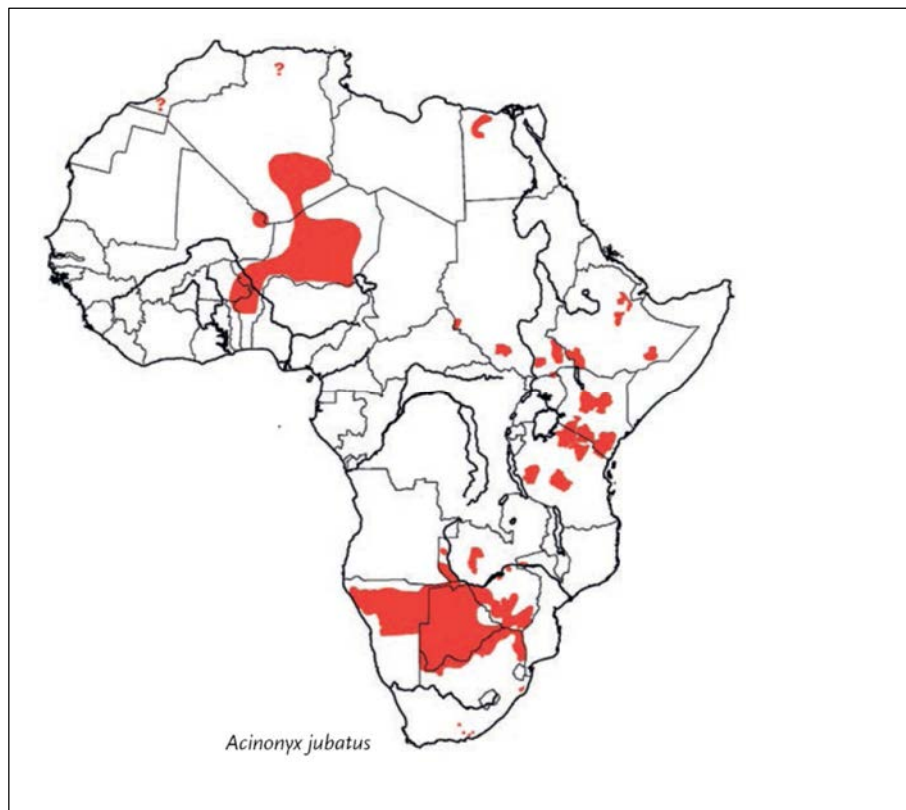


Figure 2.8. Current distribution range of the cheetah in Africa according to Kingdon and Hoffman, 2013.

#### 2.9.3.4. Social and reproductive behaviour.

All segments of the cheetah population show variation in grouping patterns. Females mostly live alone, unless they have dependent cubs (McLaughlin, 1970; Frame, 1984; Turner and Anton, 1997). Males live in small permanent coalitions of two or three (rarely four) animals throughout their lives, whereas others live alone (Kingdon and Hoffman, 2013). Most of these coalitions are composed entirely of littermates; with a few exceptions of unrelated males (*see* Kingdon and Hoffman, 2013; Caro, 1994). A male cheetah, or group of male cheetahs, maintain(s) close proximity to a single female, or to a mother and her cubs, when she is in oestrus (Kingdon and Hoffman, 2013; Hunter and Skinner, 2003); such associations may account for observations of larger documented group sizes (Graham, 1966; Eaton, 1970). In addition to prey availability and intra-sexual range overlap (with male cheetahs showing more intra-sexual range overlap than females); cheetah density and home-range size may be governed by additional factors such as anthropogenic perturbation (Marker *et al.*, 2008).

Coalitions of males are more likely to obtain a territory than are singletons probably because of coalitions' numerical advantage in fights (Kingdon and Hoffman, 2013). Fights over territories are an important source of mortality as males are more likely to die inside or on the immediate borders of territories than outside them, and many males die on territories at the time they are occupied (Caro, 1994).

Coalitions are more likely to displace residents from a territory than singletons; the latter usually acquire territories by taking over a vacancy. The key benefit of being a coalition member is that it gives a male a greater chance of acquiring a territory (Kingdon and Hoffman, 2013). In Serengeti National Park, more females are sighted on active territories than are found outside territories or on those that are not occupied; thus territories are female '*hotspots*' (Caro, 1994). When combatants are killed in these clashes, it is usually by a suffocating bite to the throat (Hunter and Skinner, 1995); low-level aggression is sometimes observed at small- and intermediate-sized kills, and males may fight over a female in oestrus, occasionally leading to fatal outcomes (Caro, 1994).

The reasons that female cheetahs and all other felids except female lions live alone is poorly understood (Kingdon and Hoffman, 2013). In Serengeti, 43% of Cheetah litters are multiply sired and not only by members of the same coalition (Gottelli *et al.*, 2007). Matings are rapid, lasting less than a minute, and in the wild very few copulations have been witnessed (Kingdon and Hoffman, 2013). Females breed throughout the year (Laurenson *et al.*, 1992) and are induced ovulators (Wildt *et al.*, 1981); non-mating induced ovulation appears rare (Brown *et al.*, 1996). Females are capable of reproduction in the wild at approximately two and a half to three years (Caro, 1994; Kelly *et al.*, 1998; Durant *et al.*, 2004).

Cubs are born in the shelter of long grass, tall or thick vegetation, marshes, underbush, or among rocks or kopjes. Females often eat the afterbirth (Kingdon and Hoffman, 2013). Mothers return to the lair to nurse cubs for 6–8 weeks, during which time they regularly carry cubs to new lairs (Frame and Frame, 1980), before cubs accompany their mother on hunts from 3–4 months (Laurenson, 1993). Mothers capture food for their cubs, and some of these prey items are then released again allowing cubs to pursue and subdue prey, which probably facilitates acquisition of hunting skills (Kingdon and Hoffman, 2013). Although playful cubs sometimes spoil their mother's hunting attempts, overall effects on hunting success are thought to be minimal (Caro, 1995).

After leaving their mother, littermates remain as a sibling group mostly within their natal range for approximately six months, but females split from the group at around time of first oestrus (Kingdon and Hoffman, 2013). Males disperse out of their natal range, probably to avoid inbreeding, while females are the more philopatric sex, with their ranges overlapping those of their mothers by as much as 60% (Caro, 1994). Infanticide has not been witnessed in cheetahs (Hunter and Skinner, 2003). Cheetahs have few vocalizations (Caro, 1994). They growl during antagonistic interactions at kills, and when females are approached too closely by males; spitting and hissing may accompany lunging during such encounters. Mothers and cubs yip, a high-pitched bleat, when trying to find each other (Caro, 1994; Kingdon and Hoffman, 2013).

#### **2.9.3.5. Feeding ecology, foraging behaviour and competition.**

Cheetah holds the record of being the fastest land mammal, and is able to achieve a top speed of about 70 miles an hour (113 km/hr) over short distances while hunting down prey (*see* Kingdon and Hoffman, 2013; Sunquist *et al.*, 2014) The hunting method of a high-speed chase does not lend itself to cooperative action, and the number of cheetahs in a given area is therefore likely to be fairly small. This fact, together with the need for territorial separation, may in large part explain the wide geographic range of the cheetah, achieved at an early date and maintained over a considerable period of time (Turner and Anton, 1997; Durant *et al.*, 1988). Prey consists principally of small- to mid-sized ungulates, usually weighing less than 40 kg: however, body weights of prey have a large range, from the calves of African buffalo and giraffes to ground-living birds and small mammals, including hares, porcupines, rats and guineafowl (Pienaar, 1969; Kingdon and Hoffman, 2013).

Blesboks *Damaliscus pygargus*, Impalas *Aepyceros melampus*, Thomson's Gazelles *Eudorcas thomsonii* and Grant's Gazelles *Nanger granti*, and Springboks *Antidorcas marsupialis* are significantly preferred, whereas prey outside this range are generally avoided. The preferred prey species offer minimal injury risk and their small size means cheetahs can bolt down their meat before kleptoparasites arrive, without risking losing too much food (Kingdon and Hoffman, 2013). Throughout its range, young animals are taken in preference to adults, especially in the case of larger species such as common wildebeests (Pienaar, 1969; Sunquist *et al.*, 2014). Cheetahs select ungulate prey that are alone or in small groups, in high vegetation, less vigilant, on the edge of the herd, and far from nearest neighbours (FitzGibbon, 1990).

Males take larger prey than females by virtue of their larger size and by hunting in coalitions (Hunter, 1998a; Caro, 1994). Cheetahs are sometimes injured during hunts, though fatal injuries are rare (Kingdon and Hoffman, 2013). On very rare occasions, cheetahs will scavenge or return to abandoned kills (Pienaar, 1969, Caro, 1982, 1994, Stander, 1990; Hunter, 1998a). Cheetahs hunt by sight, and mainly by day, during times when competitors are less active (Schaller, 1972; Cooper *et al.*, 2007). In the Sahara, most hunting takes place during the cooler night time hours, or shortly after dawn (Dragesco-Joffé, 1993; Wacher *et al.*, 2005); night-time hunting has also been recorded in Namibia (Standar, 1990) and in the Serengeti (Schaller, 1972).

Prey are pursued over short distances. Smaller prey are tripped or knocked over using a rapid swipe of the front paw. Medium- to large sized prey are usually pulled off balance by hooking with the dew-claw and pulling backwards (*see* Londei, 2000); larger prey may also be tackled by climbing onto the prey's haunches and toppling it. Large prey are suffocated or strangled by the cheetah clamping the throat with its jaws, which takes time to achieve, with the cheetah's large nasal passages allowing rapid inhalation to continue (Schaller, 1972; Kingdon and Hoffman, 2013).

Smaller prey are either grabbed by the muzzle, or killed with a bite to the skull or back of the neck (Cooper *et al.*, 2007; Kingdon and Hoffman, 2013). Prey are either eaten at the site of the kill, or dragged to nearby shelter. Cheetahs usually require time to recover following a chase, sometimes up to a full hour (Caro, 1994). They feed rapidly, usually selecting the meat off the ventral surface first (Kingdon and Hoffman, 2013); however, bone consumption at kills has been recorded (Brain, 1981; Phillips, 1993).

Cheetahs make little attempt to defend their kills from larger predators and kleptoparasites such as lions, leopards, spotted hyaenas, brown hyaenas, striped hyaenas, African wild dogs, baboons, and vultures. As a consequence, cheetahs avoid hunting in areas where these predators are present (Schaller, 1972; Caro, 1994; Durant, 1998; Hunter *et al.*, 2007a,b; Rostro-Garcia *et al.*, 2015; Mills *et al.*, 2004). In Namibia, the Cheetah is an important predator of livestock on both commercial and communal farms (Marker, 2003). Adult Cheetahs are relatively immune from predation although occasional cases of predation by lions, spotted hyaenas and leopards have been reported (Kingdon and Hoffman, 2013). However, predation on cubs may be extremely high (Laurenson, 1994; Hunter *et al.*, 2007b; Mills and Mills, 2014).

#### **2.9.3.6. Relationship with man and the ensuing conservation challenges.**

The conservation status of the cheetah is currently classified as Vulnerable (VU) by the International Union for the Conservation of Nature (IUCN, 2015). Habitat encroachment and reduction in ungulate prey, stemming from cultivation and direct exploitation, are responsible for most of the massive reduction in range (Kingdon and Hoffman, 2013; MacDonald and Loveridge, 2010; Sunquist *et al.*, 2014). Direct persecution still occurs in most areas where cheetahs exist outside of protected areas, such as in Namibia, where the overwhelming majority of its populations live on farmland; and their numbers have drastically reduced over the past two decades due to eradication and removal from farms due to being perceived as a threat to livestock (Marker *et al.*, 2003b).

Domestic fur trade remains prevalent in some parts, such as north-east Africa (Kingdon and Hoffman, 2013). Majority of cheetah deaths are human induced (Marker, 2003; Marker *et al.*, 2003b). Management strategies that reduce livestock losses, have proved successful and cost-effective at mitigating losses of livestock to cheetahs outside protected areas (Marker, 2003; Marker *et al.*, 2003b; Kingdon and Hoffman, 2013; Kruuk, 2002; Woodroffe *et al.*, 2005; Winterbach *et al.*, 2013; Treves *et al.*, 2006; Treves and Karanth, 2003; Ogada *et al.*, 2003; Dickman, 2008; Woodroffe *et al.*, 2007; Cotterill, 2013; Frank, 2010; Kissui, 2008a,b; Mwebi, 2013; Románach *et al.*, 2007; Inskip and Zimmerman, 2009; Kruuk, 1972b; Kellert *et al.*, 1996; Boitani and Powell, 2012).

Sporadic reintroductions of captive-born individuals have been attempted in areas of South Africa but have largely failed due to inability to hunt wild ungulates and predation from lions; in contrast, wild-to-wild translocations of cheetahs in South Africa and Namibia have successfully re-established populations (Hofmeyr and Van Dyk, 1998; Hunter, 1998a,b).

#### **2.9.4. African wild dog.**

##### **2.9.4.1. Taxonomic and Evolutionary history.**

Extant African wild dog *Lycaon pictus* are known only from sub-Saharan Africa with fossil evidence of early forms of *Lycaon* identified in Africa from 3 to 2 mya (Kingdon and Hoffman, 2013). However, fossil evidence of *Lycaon* from the late middle Pleistocene also exists from localities outside of sub-Saharan Africa and includes a *Lycaon* specimen from Israel (Stiner *et al.*, 2001) and possibly *Lycaon*-like fossils in Europe (Kurtén, 1968). Recent analyses of morphological and molecular genetic data strongly support *Lycaon* as a distinct genus associated with the wolf-like canids, which include species in the genus *Canis* (wolves, coyotes, jackals, domestic dog) and *Cuon* (the Asian dhole *Cuon alpinus*) (Clutton-Brock *et al.*, 1976; Van Gelder, 1978; Wayne and O'Brien, 1987; Girman *et al.*, 1993; Tedford *et al.*, 1995; Wayne *et al.*, 1997; Girman *et al.*, 2001; Girman and Wayne, 1997). The combination of molecular evidence (Wayne *et al.*, 1997) and a review of palaeontological evidence (Rook, 1994) suggests that *Lycaon* may be the sister taxon to the wolf-like canids and one of its most basal lineages (Kingdon and Hoffman, 2013).

##### **2.9.4.2. Morphology and identification.**

The African wild dog is a large, but lightly built, canid, with long, slim legs, large, rounded ears and remarkably pungent scent. Colouration of pelage is distinctive but highly variable, with combination of irregular black, yellow-brown and white blotches on back, sides and legs (Kingdon and Hoffman, 2013; Creel *et al.*, 2004). Each animal's pelage colouration is unique, and this can be used to identify individual animals. Colouration of head and tail more consistent: almost all dogs have yellow-brown head with black 'mask', black ears and black line following sagittal crest, and white tip to tail. Length of pelage varies regionally, but hair is generally very short on limbs and body but longer on neck, sometimes giving a shaggy appearance at the throat. Four digits on each foot, all with claws, and pads of middle two fused proximally. Females have six to eight pairs of nipples. Males are larger than females (McNutt and Gusset, 2012; Kingdon and Hoffman, 2013). The teeth are adapted to holding and slicing and show a much lesser function of grinding than in some other canids (Kingdon and Hoffman, 2013).



*Figure 2.9. Photograph of a pair of African wild dogs resting in a thicket in Samburu, Kenya. Photo credit: Titus Adhola.*

The outer upper incisors are larger than the central ones, heavily built and recurved; they wear to sharp edges to assist the short, sharp-pointed canines in holding prey. The outer incisors in the lower jaw are less well developed. The back portion of the lower first molar is sectorial, adding to the slicing ability of the carnassial mechanism. The crushing function is performed by the second upper molar and the lower second and third molars that are less developed than the remainder of the teeth (Skinner and Chimimba, 2005; Kingdon and Hoffman, 2013).

African wild dogs in East Africa are smaller than those in southern Africa and were originally believed to represent distinct sub specific populations. African wild dogs in north-east Africa also tend to be predominantly black with small white and yellow patches, while dogs in southern Africa are more brightly coloured with a mix of brown, black and white (Kingdon and Hoffman, 2013). However, on the basis of genetic analysis, no subspecies are currently recognized (Girman and Wayne, 1997; Girman *et al.*, 2001).

#### **2.9.4.3. Distribution range.**

The African wild dog is endemic to Africa; formerly distributed throughout sub-Saharan Africa, from desert (Lhotse, 1946) to mountain summits (Thesiger, 1970). In North Africa occurred as disjunct populations in southern and southwestern Algeria; there are no confirmed records from Libya, but they persisted (as vagrants) in Egypt until the late 1800s (Osborn and Osbornová, 1998).

Probably absent only from lowland rainforest and the most arid deserts (Schaller, 1972). The species is virtually eradicated from West Africa, where populations survive in Niokolo-Koba National Park in Senegal and in the protected areas complex between Niger, Benin and Burkina Faso (Lamarque, 2004; Kingdon and Hoffman, 2013).

African wild dogs are similarly greatly reduced in central Africa, where the only surviving populations are known in Central African Republic and Chad. In north-east Africa they survive in good numbers only in parts of Ethiopia and S Sudan. The largest populations remain in southern Africa and parts of East Africa. African wild dogs are known, or presumed, to be extinct, or near-extinct, in Burundi, Cameroon, Congo, Côte d'Ivoire, Democratic Republic of Congo, Eritrea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Nigeria, Rwanda, Sierra Leone, Swaziland, Togo and Uganda (Fanshawe *et al.*, 1997; Woodroffe *et al.*, 2004; Kingdon and Hoffman, 2013).

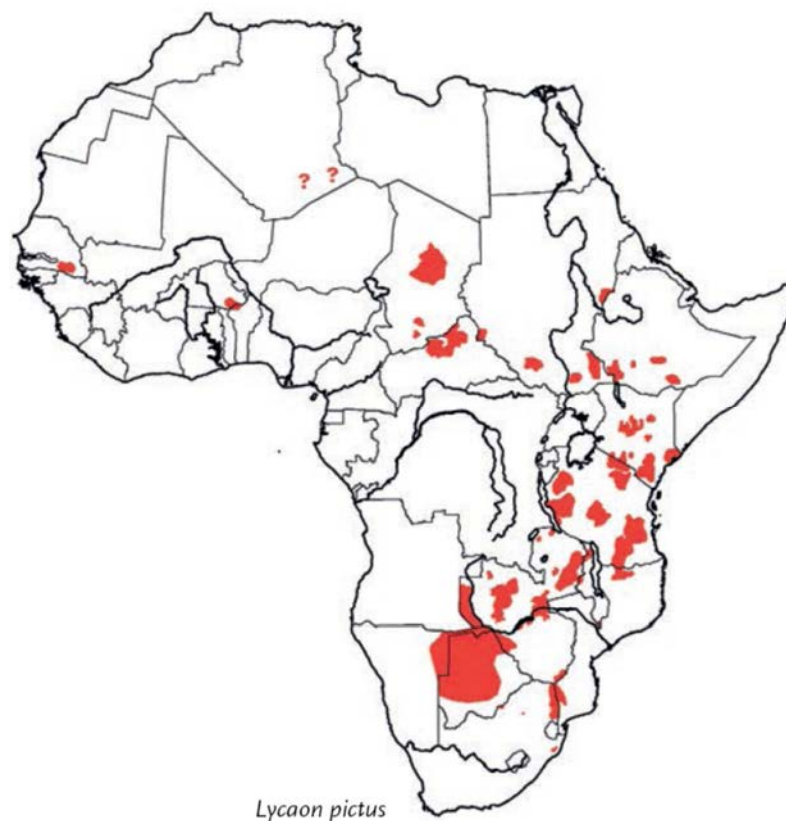


Figure 2.10. Current distribution range of the African wild dog in Africa according to Kingdon and Hoffman, (2013).

#### **2.9.4.4. Social and reproductive behaviour.**

African wild dogs are intensely social animals, spending virtually their entire lives in close association with other dogs (McCreery, 2000). They are obligate social breeders that live in a close kin-related pack. A pack, defined by its potential for reproduction, is rarely static in membership for extended periods. Rather, pack membership typically changes throughout the year due to relatively high rates of mortality, dispersal and high variance in reproductive success. By definition a pack may be as small as a pair, but packs with fewer than four adults often dissolve or extinguish following unsuccessful attempts to rear pups through to one year (Kingdon and Hoffman, 2013).

Pack size varies between populations and also within populations over time (Woodroffe *et al.*, 2004). Packs greater than 30 adults and yearlings have been recorded in the comparatively large remaining populations in Botswana and Tanzania (Kingdon and Hoffman, 2013). In the past, much larger, but very rare aggregations have been reported. In the nineteenth century packs of several hundred dogs were recorded in South Africa (Cumming, 1850). In the 1920s an aggregation travelling across Masailand in southern Kenya was estimated in the region of 500 dogs as described by Blixen (1937). Both males and females emigrate from their natal packs in groups, with females typically dispersing a year earlier than males. As with most mammals, males disperse further than females, which often establish reproductive territories that incorporate part of their natal area (McNutt, 1996a).

Packs are formed when small same-sex subgroups (usually full siblings and litter-mates) leave their natal group and join subgroups of the opposite sex from other packs (McNutt, 1996a, McCreery and Robbins, 2001). In a new pack, therefore, the females are typically closely related to one another, but not to the males, and the males are closely related to one another, but not to the females. Offspring produced by the dominant pair are, therefore, typically related to all adults in the pack. In this sense most African wild dog packs represent an extended kin group, within which all dogs are closely related to others in the pack. However, it is not uncommon for packs to have an adult unrelated to any of the others as a consequence of stochastic events affecting subgroup membership among packs in transition, especially adoption of unrelated pups (McNutt, 1996b; McNutt *et al.*, 2008).

Occasionally, new packs form by fission of large packs, with some of the original founders of both sexes emigrating together in a secondary dispersal event. In such situations pups might remain with the natal pack or join the secondary dispersal group, irrespective of the whereabouts of their parents. The priority of access to meat in favour of the youngest animals (and reinforced by the dominant pair) has implications for social structure. Older males that had been designated as dominant have been recorded being replaced, after serious fighting, by young males (Creel and Creel, 2002). The susceptibility of adults to coercion (notably to regurgitate meat) by very young animals, and a tendency for adult males from the youngest cohorts to achieve dominant status has been called the ‘youth first protocol’ (Burrows, 2004).

African wild dogs have large home-ranges for their body size across habitats. However, these ranges vary widely between habitats probably affected by prey density and availability (Kingdon and Hoffman, 2013). During the 3 – 4 months while feeding young pups at a den, packs are confined to relatively small areas, but the rest of the year a pack ranges widely within their much larger territory. Pups are born in an underground den that they use for the first three months of life. Such dens are usually those of aardvark *Orycteropus afer*, and are often enlarged and modified by porcupines or spotted hyaenas. Dens may also take the form of small caves or other suitable structures in rocky formations. The mother is confined to the den during early lactation, and is reliant on other pack members to provision her during this time. Pack members feed the mother, and, starting from about four weeks of age, the pups by regurgitating solid pieces of meat. Some pack members also ‘baby-sit’ the pups, and chase predators off while the remainder of the pack is away hunting. These adults sometimes join the pups in begging for food when the provisioners return (Kingdon and Hoffman, 2013; MacDonald and Sillero-Zubiri, 2004).

Annual age-specific adult mortality is generally quite high for African wild dogs compared with other large carnivore species (range 20 - 57%), but it varies with other demographic characteristics such as fecundity, litter-size and pup survival among populations. Pup mortality during the first year of life is relatively high, and averages around 50% in most populations. However, mean litter-size and variance in pup survivorship vary widely among populations. Juvenile survival has been shown to be an important variable in a population’s long-term growth and stability (Creel *et al.*, 2004).

Although neighbouring African wild dog packs overlap along boundaries, African wild dogs should be considered territorial. They rarely enter other packs' core areas and they defend their ranges infrequently but aggressively, occasionally with fatal consequences, against intruders and unrelated neighbours. The large territories of packs translate into very low population densities typical for the species. Even packs that inhabit protected areas may travel extensively outside reserve borders, where they encounter conflict with human activities and threats such as roads, snares and livestock and game farmers likely to persecute them. African wild dogs of both sexes emigrating from their natal packs may range over extremely wide areas compared with territory sizes (Kingdon and Hoffman, 2013).

Dispersing African wild dogs have been tracked over hundreds of kilometres (Fuller *et al.*, 1992b), a characteristic that could account for the occasional reports of single animals, or single-sex groups from countries such as Uganda, Democratic Republic of Congo and Swaziland, where there have been no resident populations for several decades. It can also account for the occasional re-colonization of formerly occupied habitats such as the Serengeti (Tanzania), Laikipia (Kenya) and Savé Valley (Zimbabwe) (Kingdon and Hoffman, 2013). African wild dogs have a complex communication system, including a number of unique vocalizations (Robbins, 2000), as well as olfactory communication both within and between packs (Van Heerden, 1981). Territory boundaries appear to be predominantly communicated through scent-marking with faecal and urine marks by the dominant pair. Semio-chemical communication is also important in maintaining pack cohesion during hunting in bush habitats. Most vocalizations are for intra-pack communication and are generally high frequency, and relatively low in volume and broadcast quality. Food-begging calls are typically twittering. Whines combine with body postures to suggest an appeasing function and yelps denote the anticipation of food (Kingdon and Hoffman, 2013).

#### **2.9.4.5. Feeding ecology, foraging behavior and competition.**

African wild dogs are cursorial predators that opportunistically hunt medium-sized antelope (Kingdon and Hoffman, 2013). Many of the common prey species are more than twice their size, the average weighing around 50 kg, and may be as large as 200 kg (Creel and Creel, 2002). Wild dogs prey mainly on ungulates, focusing on wildebeest *Connochaetes taurinus*, impala, kudu *Strepsiceros tragelaphus*, gazelles and warthogs *Phacochoerus spp* (Pienaar, 1969; Fanshawe and Fitzgibbon, 1993; Creel and Creel, 1995; McNutt, 1995).

Differences in diet among ecosystems are strongly affected by the relative abundance of these species (Creel *et al.*, 2004). African wild dogs will chase, but rarely kill, larger species, such as eland, roan *Hippotragus equinus* and African buffalo. More typically, calves of these species are targeted when encountered. Small antelopes, especially common duiker *Sylvicapra grimmia*, dikdiks and steenbok *Raphicerus campestris*, are important in some areas (Kingdon and Hoffman, 2013).

African wild dogs also opportunistically capture relatively smaller prey such as small carnivores like bat-eared foxes (Rasmussen, 1996), black-backed jackals (Kamler *et al.*, 2007) or banded mongooses (Creel and Creel, 2002), hares, springhares *Pedetes spp.*, francolins, lizards and even eggs, but these constitute a small proportion of their diet. African wild dogs travel and hunt in packs. Hunts typically take place around the first and last hour of daylight and are preceded by a ‘social rally’ or ‘greet’ believed to alert and collect the pack in anticipation of departure (Kingdon, 1977; Kingdon and Hoffman, 2013).

Occasionally, hunts can begin before dawn or extend after dusk. They commonly also hunt on moonlit nights. Typical capture is as follows: one dog bites and holds the quarry, usually at the flank, and other pack members help pull it to ground and quickly kill it by disemboweling (Kingdon and Hoffman, 2013). In some hunts, usually involving large prey, one pack member may effectively immobilize the prey by biting and holding its nose while others make the kill. Hunts can appear to be highly coordinated events, but in many areas, particularly woodland habitats with dense brush understorey, packs tend to split during hunts with individual dogs opportunistically chasing and often bringing down prey alone (Creel and Creel, 2002).

Although hunting is not necessarily cooperative, feeding at kills, in contrast, is highly coordinated and cooperative. In general, prey is consumed rapidly (Kingdon and Hoffman, 2013). Van Lawick and Van Lawick-Goodall (1970) recorded the consumption of a thomson’s gazelle in 15 minutes – and quietly by the entire pack with several individuals pulling against others to facilitate the rending of the carcass. When pups are travelling with the pack a system of priority of access is given to the youngest first and reinforced by the dominant pair. Otherwise, all members of the pack eat together rapidly and leave a carcass after eating. If they have left pups somewhere, they return to the pups and regurgitate meat to them. Caching of food has also been recorded (Malcolm, 1980). Competition with larger predators has a major impact on African wild dog behaviour and population biology (Creel and Creel, 1996, 2002; Mills and Gorman, 1997).

There is a large degree of dietary overlap between African wild dogs and spotted hyaenas and lions (Creel and Creel, 2002), and the latter two species will steal kills from African wild dogs, particularly in open areas, such as the Serengeti and Ngorongoro Crater, where such kills are easily located (Kruuk, 1972a; Fanshawe and FitzGibbon, 1993). The high metabolic rate of African wild dogs means that prey loss to competitors has the potential to seriously impact their energy balance: a model based on data from Kruger suggested that dogs must spend about 3.5 hours/day hunting in order to meet their energy requirements but would need to increase this to some 12 hours if they lost 25% of their food (Gorman *et al.*, 1998). Despite earlier suggestions (Fanshawe and FitzGibbon, 1993), the benefits of increased group size for the purpose of defending the carcass against kleptoparasites such as spotted hyaenas might be countered by increasing intra-specific competition for food as pack size increases (Kingdon and Hoffman, 2013).

Small groups would probably be particularly vulnerable to kleptoparasitism, because they would not be able to consume enough food before the hyaenas appropriated the kill, and medium-sized groups may, therefore, be most effective to meet energy and nutritional demands (Carbone *et al.*, 1997). As such African wild dogs seem to fare well where interference competition is minimal. However, where spotted hyaena density is high and visibility good, hyaenas can accumulate at kills in sufficient numbers to negatively impact foraging success (Creel and Creel, 2002).

The degree of competition between African wild dogs and lions is less clear, but predation by lions (outside the context of kills) is a principal cause of natural mortality in African wild dogs (Creel and Creel 1996, 2002; Van Heerden *et al.*, 1995; McNutt, 1995). An attempt to reintroduce African wild dogs to Etosha National Park in Namibia failed because they were hunted out by a pride of lions over a period of weeks (Scheepers and Venzke, 1995). Away from kills, spotted hyaenas also occasionally kill dogs of all ages (Ginsberg *et al.*, 1995, Creel and Creel, 2002), and leopards and African rock pythons *Python sebae* have also been recorded killing individuals (Kingdon and Hoffman, 2013).

Competition with larger carnivores could help explain the ranging behaviour of African wild dogs. While larger predators tend to occur at higher densities where prey species are relatively abundant, African wild dogs (like cheetahs) tend to avoid these areas. Because they range in areas of comparatively low prey densities, they tend to occupy ranges effectively requiring greater travel distances during hunting. Naturally wide-ranging behaviour, and a preference for areas with reduced large predator densities, can explain in part why African wild dogs are often found in habitats outside of protected areas. As a result of changes in lion and spotted hyaena populations, some habitats with suitable prey populations can become marginal or completely unsuitable for African wild dogs. In addition to inter-specific competition, adults and pups have been killed in inter-pack clashes. Intra-specific competition caused 69% of known-cause deaths in Selous through conflict within and between packs (Kingdon and Hoffman, 2013; Creel and Creel 1998).

#### **2.9.4.6. Relationship with man and the ensuing conservation challenges.**

The African wild dog is Red Listed as an Endangered (EN) species by the International Union for the Conservation of Nature (IUCN 2012). Studies in several ecosystems have examined the factors that limit wild dog populations, and there are several contemporary reviews of this information (McNutt and Boggs, 1996; Woodroffe *et al.*, 1997; Creel and Creel, 1998, 2002). Like most large carnivores, wild dogs have disappeared from much of their historical range as human populations have expanded, and the dogs are now largely confined to protected areas and their peripheries. Wild dogs were actively destroyed by wildlife managers in most areas until the later part of the twentieth century, due to a perception that their method of killing prey was cruel, and that their cursorial hunting was disruptive for ungulate populations (Lindsey *et al.*, 2005b).

Early in the 1970s, institutionalized culling of wild dogs came to an end, and they are now legally protected in the seven nations that hold substantial numbers (Fanshawe *et al.*, 1991). Snaring and other human-caused deaths remain a substantial force of mortality in some populations (Rasmussen 1996; Woodroffe and Ginsberg, 1998). However, it is not clear that these problems affect wild dogs with greater force than they affect lions and spotted hyaenas, which generally have maintained thriving populations where wild dogs have declined or disappeared (Creel *et al.*, 2001).

African wild dogs are a threat to livestock in some areas, but stock depredation is infrequent compared with the frequency of range overlap with domestic grazers. In and around Masai Mara National Reserve, Kenya, African wild dogs ignored livestock, and data from Samburu and Maasai areas of northern Kenya indicate that they rarely caused problems unless wild prey was severely depleted (Woodroffe *et al.*, 2005). A two-year study of African wild dog depredation of commercial livestock in Zimbabwe found that African wild dogs actually killed approximately half the number of cattle believed by farmers to have been lost representing an actual annual loss of 0.4% of the regional herd (Rasmussen, 1999).

African wild dogs hunting in livestock areas outside Selous Game Reserve, Tanzania, were never observed to kill livestock in six years of observation (Creel and Creel, 2002). Nevertheless, African wild dogs can become a severe problem for small domestic stock (including calves), especially in areas where native prey species populations have been reduced by hunting (Woodroffe *et al.*, 2005). Multiple kills of small stock have been reported from a single attack by packs of African wild dogs in Kenya, Botswana and Namibia (Kingdon and Hoffman, 2013). While pups die almost exclusively from ‘natural’ causes, a substantial proportion of known mortality recorded among adults in studied populations is caused directly by human activity such as road kills and snares, even in some of the largest and best-protected areas (*see* Woodroffe *et al.*, 2007). In addition, African wild dogs originating in protected areas often range outside the boundaries where they encounter high speed vehicles (road kills), guns, snares and poisons (Kingdon and Hoffman, 2013).

### **2.9.5. Spotted Hyaena.**

#### **2.9.5.1. Taxonomic and evolutionary history.**

The spotted hyaena *Crocuta crocuta*, is the sole representative of the genus *Crocuta* (Kingdon and Hoffman, 2013). The fossil history of *Crocuta* is complex, with at least three species present in Africa during the Plio-Pleistocene, in addition to the living one (Werdelin and Lewis, 2005, 2008). These species document morphological changes in the *Crocuta* lineage that suggest a transition from probably solitary scavenging in the Pliocene to the socially versatile, sometime group-hunting species of today (Kingdon and Hoffman, 2013). These changes imply modifications to ecology and behaviour that this species complex went through as it adapted to changes in climate and environment, as well as competition from an increasingly competent hunter and scavenger, *Homo* spp. (Lewis and Werdelin, 1999, 2000).

The spotted hyaena today has a wide distribution in Africa, yet this distribution is only a small remnant of its distribution in the Pleistocene (Kingdon and Hoffman, 2013). At the height of its expansion, the spotted hyaena ranged throughout Eurasia from the Pacific coast of Siberia to the British Isles and throughout those parts of Africa for which a fossil record is known (Werdelin and Lewis, 2005, 2008). The Eurasian forms became abruptly extinct towards the end of the Pleistocene and the range of the modern African species appears to have been contracting ever since. Thus, while there is no immediate cause for alarm, it is worth noting that the spotted hyaena today occupies only a fraction of its former range, with unknown consequences for its viability as a species (Werdelin and Lewis, 2005, 2008; Lewis and Werdelin, 1999, 2000).

No subspecies are currently recognized (Kingdon and Hoffman, 2013). Hollister, (1918), Matthews, (1939a), Werdelin and Solounias, (1996); and, Jenks and Werdelin, (1998) describe individual variation as considerable, and that any non-molecular regional characteristics, if at all existed, are yet to be identified (*but see Rohland et al.*, 2005).

#### **2.9.5.2. Morphology and identification.**

Matthews (1939b), Neaves *et al.* (1980), Cunha *et al.* (2003), and Kingdon and Hoffman, (2013) describe the spotted hyaena as follows: the largest extant hyaena with a strongly built body with muscular neck and shoulders and sloping hindquarters. Pelage colour light brown, beige, sandy or ginger. Prominent spots of variable size and density on neck, shoulder, back, flanks, rump, legs, base of tail and occasionally belly. Spots, initially black or dark brown, may turn light brown and fade with age. Pelage composed of fine underhair and longer, stouter, flat-sectioned bristle hairs. Hair along back of neck and across shoulders is longer, giving appearance of a mane. The tail is thin and ending in long black hair at tip. It has four-toed feet with short, blunt, non-retractable claws and broad and flattened naked pads. It has a characteristic loping gait when running. The sexes are very similar in appearance including sexual organs. Sex determination is however possible through histological (Wurster-Hill *et al.*, 1970; Yost, 1977) and molecular methods (Schwerin and Pitra, 1994).



*Figure 2.11. Photograph of a spotted hyaena scavenging on an eland carcass at the Soysambu Conservancy, Nakuru. Photo credit: Titus Adhola.*

Skinner and Chimimba, (2005) describe the skull as massively built and characterized by high sagittal crest extending backwards beyond occipital condyles. The rostrum is broad; zygomatic arches are robust and sweep out towards the back to provide ample room for the well-developed masseter and temporalis muscles. Kingdon and Hoffman, (2013) describe its dentition as typically hyaenid, although upper first molars are often absent, unlike in the brown hyaena *Parahyaena brunnea* where upper first molars are functional teeth and always present. Lower premolars massive, with rounded central cusps; upper first premolars small, the second and third rounded with high central cusps, while the fourth have distinct protocones on inner edges. Upper canines large, sharp, rounded and slightly recurved; lower canines are stout and recurved. Permanent teeth erupt at about 15 months. Kruuk, (1972a), Lindeque and Skinner, (1984), Van Jaarsveld *et al.*, (1987), and Van Horn *et al.*, (2003) state that wear of mandibular third premolar and cross-section of dentine lines of upper canines; tooth eruption and replacement can be reliably used as indices of age.

### 2.9.5.3. Distribution range.

The spotted hyaena is endemic to Africa, south of the Sahara, although formerly with a geographic range across almost all of Africa and Eurasia (Werdelin and Solounias, 1991). Current distribution is patchy, especially in West Africa, with populations often concentrated in protected areas. More continuous distributions persist over large areas of Chad, Central African Republic, South Sudan, Ethiopia, Kenya, Tanzania, Botswana, Angola, Namibia and parts of South Africa (Kingdon and Hoffman, 2013).

Hofer and Mills (1998) reported the species as extinct in Algeria, where it may have occurred in the Ahaggar and Tassili d'Ajjer, although Kowalski and Rzebik-Kowalska (1991) noted that continued presence in the southernmost regions as still probable. Hofer and Mills (1998) also reported no recent records from Djibouti, Eritrea, Gabon, Gambia and Togo (*but see* Künzelt *et al.*, 2000; Grubb *et al.*, 1998; Henschel and Ray, 2003; Juste and Castroviejo, 1992). There is no confirmed evidence of their occurrence in Egypt, Liberia or Lesotho (Kingdon and Hoffman, 2013).

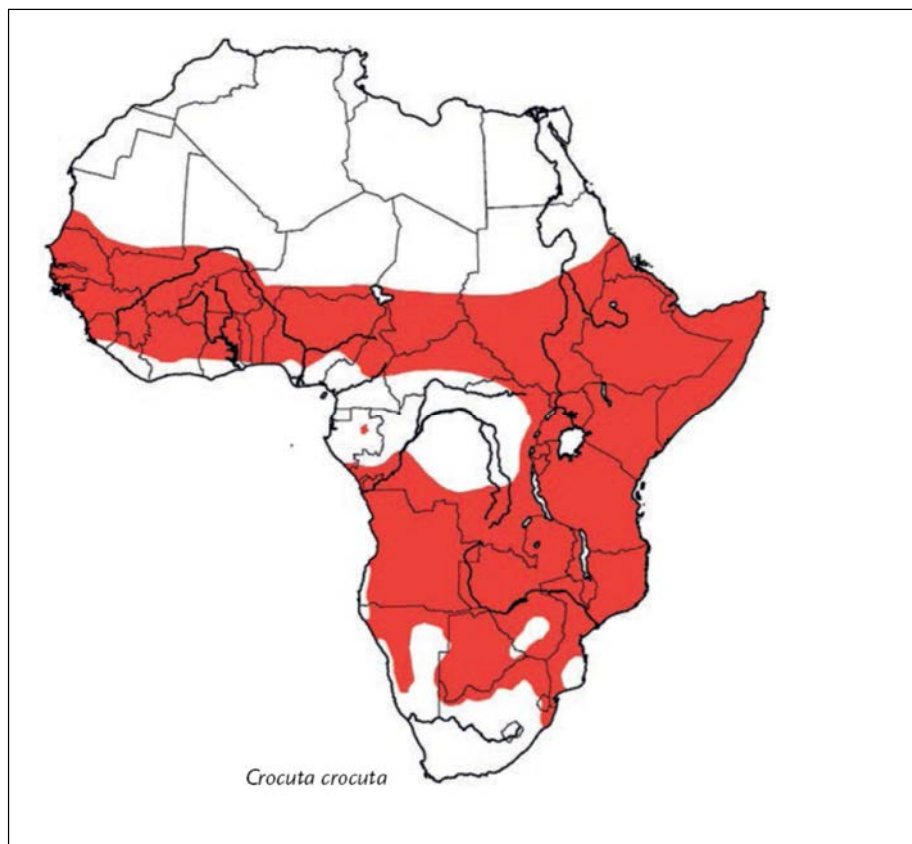


Figure 2.12. Current distribution range of the spotted hyaena in Africa according to Kingdon and Hoffman, (2013).

#### **2.9.5.4. Social and reproductive behaviour.**

The spotted hyaena is regarded as a highly social species that lives in groups (clans) and defends group territories (Kruuk, 1972a). Clans are a ‘fission–fusion’ society, and although clan members often operate independently, there is a high degree of cooperation in the defence of the territory, of food resources and the communal den (Kingdon and Hoffman, 2013). Clan social structure consists of a linear dominance hierarchy amongst adult females, and a separate linear dominance hierarchy amongst immigrant males, all of which are socially subordinate to clan females (Frank, 1986a). The mechanisms by which adult females and immigrant males acquire social status differ (Kruuk, 1972a; Kingdon and Hoffman, 2013; Frank, 1986a).

The most noticeable peculiarity of spotted hyaena is its ‘hermaphroditism’ and the reason why females have an elongated ‘*penis-like*’ clitoris remains a matter of debate (Kingdon and Hoffman, 2013). Passage of the firstborn cub or litter through the clitoris often results in cases of still-birth (Glickman *et al.*, 1992, Frank *et al.*, 1995; Drea *et al.*, 2002). This not only implies a reduction in lifetime reproductive success, but also a positive counter selection pressure to maintain this costly trait (East *et al.*, 1993). One benefit of a penile clitoris might be control over the mechanics of copulation, as this would have favoured selection for active submission by immigrant male and therefore provided the female with a high degree of mate-choice and the benefit of maternal investment being dedicated to offspring sired by high-quality or genetically compatible male (East *et al.*, 1993, 2003; East and Hofer, 2002).

The average number of adults and sub-adults in a clan varies from three in desert and semi-desert areas of southern Africa upto 90 individuals in the savanna areas of East Africa (Kruuk 1972, Hofer, 1998b; Mills, 1990). Territory size and the density of prey inside a clan’s communal territory may limit clan size, unless clan members regularly feed on migratory herds outside their territory (Hofer and East, 1993a, b; Höner *et al.*, 2005). Clans do split if the current clan size exceeds a threshold above which the food base of the territory is insufficient (Mills, 1990), or if a territory in the neighbourhood has become vacant (Holekamp *et al.*, 1993, Höner *et al.*, 2005). Females generally remain in their natal clan (Frank 1986b). When females attain adulthood, they typically acquire a rank immediately below that of their mother, but can significantly decline in social status if their mother(s) die(s) (Smale *et al.*, 1993, Hofer and East, 2003).

Males typically mature at two years of age and disperse from their natal clan, immigrating into another clan at approximately 3 – 4 years of age (Höner *et al.*, 2010). At immigration, they join the immigrant male hierarchy at the lowest rank (Kruuk, 1972a). Because their social status increases as their tenure in the clan lengthens, and as males above them in the hierarchy die or leave the clan, the male hierarchy functions like a social queue (East and Hofer, 2001). Males with long tenure mostly seek to foster amicable relationships with older adult females, whereas recent immigrant males more often do so with younger adult females (Kruuk, 1972a; Mills, 1990). Females aggressively reject unwanted males (Höner *et al.*, 2007).

Genetic paternity analyses have revealed that females exercise a high degree of mate-choice (East *et al.*, 2003, Höner *et al.*, 2007). Younger females mostly reject close advances by longer tenured males, thereby preventing inbreeding with close relatives, such as their father (East and Hofer, 2001; Kruuk 1972). As a result, the offspring of younger females are mostly sired by males that were not clan members when the female was born (Mills, 1990). Breeding takes place throughout the year, with little evidence for seasonality of births (Kruuk, 1972a, Mills, 1990; Holekamp and Smale, 1995; East and Hofer, 2002). The gestation period is approximately 110 days; oestrus is thought to last for one day, and females cycle every 14 days (Matthews, 1939b). Females give birth to litters of one, two or rarely three cubs; triplets typically do not survive, as females normally only lactate through two nipples (Holekamp and Smale 1995; Hofer and East 1997, 2008).

Spotted hyaena clans defend communal territories against encroachment from neighbouring spotted hyaena clans through vocal displays, scent-marking (Gorman and Mills, 1984) and boundary patrols (Kruuk, 1972a). It is the adult females that initiate and lead most cooperative territorial behaviours (Kruuk, 1972a; Mills, 1990; Boydston *et al.*, 2001).

Clan members participate in ritualized greeting ceremonies during which two individuals stand parallel and face in opposite directions, lift their hindlegs nearest to their partners and sniff or lick the anogenital region of the other (Kruuk, 1972a; Mills, 1990). Greetings occur between all ages and both sexes, although greetings between adult females and immigrant males are rare (Frank *et al.*, 1990). Greeting ceremonies are an important element in the maintenance of social status and the formation of alliances with other clan members (East *et al.*, 1993; Kruuk, 1972a; Mills, 1990).

Hofer and East (1993a) state that much of the social life of a clan occurs in the vicinity of the communal den. They intimate that communal dens may be used for years, or den sites may be changed several times within a year; and that, a clan may simultaneously have several communal dens separated by up to 7km. Dens are dug by other species, mostly warthog, aardvark and bat-eared fox and then are modified (Kruuk, 1972a). Cubs excavate underground burrows and adult female enlarge the den entrance (Kruuk, 1972a; Mills, 1990).

The structure of dens does not normally permit the access of adult animals, and cubs must emerge at the den entrance to interact with their mother (Golla *et al.*, 1999). Small underground burrows may protect cubs from predation by lions and non-clan members (Kruuk, 1972a); and may also reduce infanticide by adult female and immigrant male clan members (Hofer and East, 1995; East *et al.*, 2003). Young cubs that emerge from a den due to the presence of a female that is not their mother risk infanticide, and mothers that nurse cubs that are not their own risk compromising the growth and survival of their litter (Kruuk, 1972a; Mills, 1990). Females usually nurse only their own cubs and reject approaches by other cubs; however, exceptions to this rule do occur (East *et al.*, 2009). As there are often several animals present at the communal den, cubs benefit from the vigilance of adults that can alert young to the presence of predators (Kruuk, 1972a). Social interactions at the communal den between cubs and adult clan members play an important role in the integration of juveniles into the dominance structure of the clan (East *et al.*, 1993, Holekamp and Smale, 1993).

#### **2.9.5.5. Feeding ecology, foraging behaviour and competition.**

Contrary to the general belief of being considered as mainly scavengers; the study by Kruuk (1972) showed that spotted hyaenas can be very effective and flexible hunters. They prefer prey within a body mass range of 56 –182kg (Höner, *et al.*, 2005; Hayward, 2006), a dietary niche breadth similar, but not identical, to that of the lion (Höner *et al.*, 2002). In the Serengeti ecosystem and the Ngorongoro Crater, of Tanzania, spotted hyaenas primarily hunt common wildebeests, thomson's gazelles and plains zebras (Kruuk, 1972a; Hofer and East 1993a; Höner *et al.*, 2002, 2005).

In the Masai Mara in southern Kenya, they feed mainly on topis *Damaliscus lunatus* and thomson's gazelles when migratory species are absent. Upon arrival of the migratory herds from the Serengeti national park, they switched to feeding on common wildebeests for about three months, until the migratory animals return to the Serengeti (Cooper *et al.*, 1999). In the Aberdare mountain ranges of Kenya, the dominant prey items are bushbucks *Tragelaphus scriptus*, sunis *Nesotragus moschatus* and African buffalo (Sillero-Zubiri and Gottelli, 1992). The diet of spotted hyaenas in west and central Africa is less well known (Kingdon and Hoffman, 2013).

Spotted hyaenas are known to be very opportunistic in nature depending on the circumstances. They occasionally take larger prey such as giraffes, juveniles of hippopotamuses, elephants and white rhinoceroses *Ceratotherium simum*. They also consume a wide range of small mammal prey, including small carnivores and rodents up to the size of springhares as well as other vertebrate prey (such as birds, fish, reptiles), insects, crabs, snails, ostrich eggs, fruits and the faeces of herbivores, carnivores and omnivores (Hirst, 1969; Pienaar, 1969; Kruuk, 1972a; Bearder, 1977; Cooper, 1990; Henschel and Skinner, 1990a; Mills, 1990; Gasaway *et al.*, 1991; Sillero-Zubiri and Gottelli, 1992; Skinner *et al.*, 1992; Hofer and East, 1993a; Holekamp *et al.*, 1997; Cooper *et al.*, 1999; Di Silvestre *et al.*, 2000; Salnicki *et al.*, 2001; Höner *et al.*, 2002; Breuer, 2005; Bothma and Walker, 1999).

Despite being a highly social carnivore that may live in large groups, individuals hunt mostly on their own or in small groups (Kruuk, 1972a; Gasaway *et al.*, 1989; Mills, 1990; Skinner *et al.*, 1992), although cases of mass killings (glut killings) of prey have been recorded (Kruuk, 1972b). Prey is detected by sight, hearing and odour and carrion by smell, the noise of other carnivores feeding, or by watching vultures descending on a carcass. Adult solitary spotted hyaenas of around 5–6 years of age can be very efficient hunters, and, in the Masai Mara, are responsible for over 75% of hunting attempts on common wildebeest and topi (Holekamp *et al.*, 1997). Spotted hyaenas are active mostly at night, dawn and dusk, but can forage at any time during the day. During hunts, prey may be chased over several kilometres at speeds of up to 60km/h (Hofer, 1998b; Mills, 1990). Spotted hyaenas have been observed to drown prey, such as southern lechwe *Kobus leche* (Child and Robbel, 1975), and even to run down lesser flamingoes *Phoenicopiterus minor* in shallow soda lakes (Brown and Root, 1971).

They are capable of travelling long distances (30 – 80km) in search of prey or water (Eloff, 1964; Tilson and Henschel, 1986; Mills, 1990). Food is cached, mostly in water (Kruuk, 1972a). The spotted hyaena is an efficient scavenger of carrion, including the kills of other spotted hyaenas and other carnivores like lions (Kruuk, 1972a; Henschel and Skinner 1990a; Mills, 1990), although in both Masai Mara (Cooper *et al.*, 1999) and the Ngorongoro Crater (Kruuk, 1972a; Höner *et al.*, 2002), spotted hyaenas obtained most of their annual intake from hunting rather than scavenging. It is also an effective kleptoparasite on other carnivores (Kruuk, 1972a). The proportion of its diet derived from or lost to other predators varies between ecosystems (Kruuk, 1972a; Cooper, 1991; Mills and Biggs, 1993; Höner *et al.*, 2002). Lions usually displace spotted hyaenas at kills, unless spotted hyaena group size is large and male lions are absent (Cooper, 1991; Höner *et al.*, 2002).

Assemblages of bones are often found at spotted hyaena communal dens where all clan offspring are placed, although not to the same degree as in the brown hyaena or the striped hyaena, because spotted hyaenas infrequently carry food back to their young (Kruuk, 1972a; Mills, 1990). A variety of items, mostly long bones or skulls of medium- to large-sized ungulates, have been found in dens; bone assemblages tend to reflect the ungulate fauna in an area (Bearder, 1977; Mills and Mills, 1977; Henschel *et al.*, 1979, Skinner *et al.*, 1986, Lam, 1992; Skinner, 2006).

The only major predators of the spotted hyaena are lions (Kruuk 1972; Schaller, 1972; Mills, 1990; Trinkel and Kastberger, 2005), although they do not generally consume the hyaenas they kill. Leopards occasionally kill individual hyaenas (Bailey, 2005). Other sources of natural adult mortality include violent encounters between conspecifics (Kruuk, 1972a; Henschel and Skinner, 1991), injuries sustained while hunting, and disease (Mills 1990; Hofer and East, 1995; White, 2005). White (2005) described selective litter reduction by mothers via partial litter abandonment, a mechanism of filial infanticide not previously described in this species. Cubs may also starve to death when their mother(s) die (Kruuk, 1972a). Other sources of cub mortality include predation by lions and the collapse of communal dens after heavy rain (Kruuk, 1972a; Mills, 1990; Kingdon and Hoffman, 2013).

#### **2.9.5.6. Relationship with man and the ensuing conservation challenges.**

The conservation status of the spotted hyaena is currently classified as Least Concern (LC) by the International Union for the Conservation of Nature (IUCN, 2015). Although the total world population is relatively large and contains sub-populations that exceed 1000 individuals in several countries, it is declining outside protected areas, largely as a result of human persecution through shooting, trapping and poisoning, some of it officially led or sanctioned (Kingdon and Hoffman, 2013).

Mortality from wire snares set to catch wild herbivores is the most important cause of adult mortality in Serengeti national park, where snares kill around 400 adult hyaenas each year and are responsible for more than half of all adult mortality (Hofer *et al.*, 1993, 1996). Entire clans may be killed by poisoning (Holekamp *et al.*, 1993), and many individuals are killed when hit by vehicles (Kingdon and Hoffman, 2013). Most populations in protected areas in southern Africa, such as Kruger national park in South Africa, Kgalagadi transfrontier park (South Africa and Botswana), Hluhluwe-imfolozi (South Africa) and Etosha national park (Namibia), are considered to be stable, whereas populations in eastern and West Africa, even in protected areas, are considered to be declining because of snaring and poisoning (Hofer and Mills 1998b). The population in the Ngorongoro Crater has significantly increased in recent years (Höner *et al.*, 2005, 2012).

The spotted hyaena may be able to respond rapidly to changing ecological conditions. At the edge of Masai Mara National Reserve, increased human activity during a ten-year period was associated with increased use of daytime resting areas in dense vegetation, and avoidance of areas containing the highest abundance of prey, as these were the areas where intensive livestock grazing by pastoralists was concentrated (Boydston *et al.*, 2003). In some areas, spotted hyaenas may kill domestic livestock, domestic cats, domestic dogs and people (Hofer, 1998b; East *et al.*, 2012). Some native peoples protected it as a valuable scavenger, but others regarded it with superstitious dread (Nowak, 2005); in yet other areas, spotted hyaenas are, or used to be, relied upon to dispose of human corpses (Kingdon and Hoffman, 2013; Nowak, 2005).

Human attitudes and perceptions towards the spotted hyaena in Africa vary from a legal classification as ‘vermin’ (Ethiopia) to fully protected in conservation areas (Kingdon and Hoffman, 2013). There are still countries where farmers may kill hyaenas at their discretion (Hofer and Mills, 1998b). The spotted hyaena is not an important item in the diet of humans (though it is occasionally harvested as a food source in some countries), or an important species for trophy hunters, although it is killed for body parts for traditional medicines and body parts and live hyaenas are used for witchcraft (Kruuk, 1972a; Mills, 1990; Kingdon and Hoffman, 2013). Licensed sport hunting is permitted in several countries, but numbers killed for this purpose are probably small (Kingdon and Hoffman, 2013). Habitat loss and degradation has reduced the habitat available to species that are suitable prey for the spotted hyaena and led to declines in populations (Hofer and Mills, 1998b; Kingdon and Hoffman, 2013).

## **2.9.6. Striped hyaena.**

### **2.9.6.1. Taxonomic and evolutionary history.**

The Striped hyaena *Hyaena hyaena* is allopatric to the brown hyaena (Gittleman, 1989; Kingdon and Hoffman, 2013; Mills, 1990; Werdelin and Barthelme, 1997; Nowak, 2005). Both species are solitary foragers but tend to rest in pairs or groups (Kingdon and Hoffman, 2013). The two species were at least potentially sympatric at times in the past, as both species have been recorded from sites in South Africa. However, a more likely scenario may be that their respective geographic ranges have fluctuated somewhat depending on changes in climate and environment during the Plio-Pleistocene and that they have thus replaced each other in the fossil record without being truly sympatric. While the *Parahyaena brunnea* lineage cannot be followed fully in the fossil record; the *Hyaena hyaena* lineage is more fully documented through the presence of a Pliocene form, *Hyaena makapani*, known from South and East Africa, which is smaller and more gracile than the living species (Toerien, 1952; Werdelin and Lewis, 2005; Werdelin and Turner, 1996).

The number of subspecies of *Hyaena hyaena* were condensed by Pocock to five, based on cranial measurements and pelage characteristics. They included: *Hyaena hyaena barbara* from north-west Africa, *Hyaena hyaena dubbah* from north-east Africa, *Hyaena hyaena syriaca* from Syria, Asia Minor and the Caucasus, *Hyaena hyaena hyaena* from India and *Hyaena hyaena sultana* from Arabia (Pocock, 1934a, b). Rieger (1979a) suggested integrating these into a smaller, north-east African-Arabian group composed of *Hyaena hyaena dubbah* and *Hyaena hyaena sultana* and a larger, north-west African-Asian group comprising *Hyaena hyaena barbara*, *Hyaena hyaena syriaca* and *Hyaena hyaena hyaena*. However, Jenks and Werdelin (1998) noted the inadequacy of available morphological data on variability to characterize each subspecies and that any classification was provisional. To that end, no subspecies are recognized (Kingdon and Hoffman, 2013).

#### **2.9.6.2. Morphology and identification.**

The striped hyaena is a medium-sized carnivore with overall appearance reminiscent of a dog (Kingdon and Hoffman, 2013). It is smaller than the brown hyaena. The muzzle is blunt with a pointed dog-like nose, and head broad with long, pointed ears. The back slopes downward from head to tail. The pelage has black vertical stripes on side, horizontal stripes on legs and a distinctive dark patch (or broad, dark 'stripe') on the throat. Underfur colouration is pale grey or beige; however, some individuals may appear more white. Pelage colouration varies by region and may vary seasonally in colder parts of its range. Ground colour of pelt typically grey to light brown, but may appear strikingly white even within the same population (Pocock, 1934a; Rosevear, 1974; Ilani, 1975; Kingdon and Hoffman, 2013). Longest hairs are up to 200mm long (Rosevear, 1974) and fall along the mid-dorsal line. The black dorsal mane may be held erect, significantly increasing apparent size of the animal (Pocock, 1934a, Kruuk, 1976a, Rieger, 1978). Striped hyaena legs appear thin relative to their length and hindlegs are shorter than forelegs; feet have four toes with short, non-retractable claws (Pocock, 1916a). Tail long with long coarse hairs. Well-developed anal pouch, a slit-like glandular orifice over-arching the anus from either side. Anal pouch may be everted and thus be apparent while pasting or presenting during social encounters (Fox, 1971; Kruuk, 1976a; Rieger, 1978). Mendelssohn and Yom-Tov (1987), state that there is no apparent sexual dimorphism in the striped hyaena in terms of body measurements and weight (*but see* Bothma and Walker, 1999). Its permanent dentition is distinctly carnassial and dental formula typically hyaenid (Rosevear, 1974; Coetzee, 1977).



*Figure 2.13. Photograph of a pair of striped hyaenas scavenging at an elephant carcass (lion kill site) at night in the Samburu National Reserve. The lions were not in the vicinity. Photo credit: Titus Adhola.*

#### **2.9.6.3. Distribution range.**

The striped hyaena has a very large range extending from Africa, north of and including the Sahel, and including much of East and north-east Africa, through the Middle East and Arabian Peninsula, the Caucasus, Turkey, central Asia, and the Indian subcontinent, though not reaching Bhutan or Burma. Across their wide range, current distribution is patchy and most populations are likely composed of isolated small populations (Hofer and Mills 1998a). A total African population estimate of 2450 – 7850 individuals represents roughly half of the total worldwide estimated population (Hofer and Mills, 1998b). Only Burkina Faso, Cameroon, Egypt, Kenya, Morocco and Niger have populations estimated at more than 100 individuals, and, of those, only Egypt and Kenya have estimated populations over 1000 (accounting for 51% of the maximum African population estimate and 82% of the minimum estimate) (Kingdon and Hoffman, 2013). Throughout its range, the striped hyaena occurs at low densities, but is distributed broadly across the landscape. Estimates of striped hyaena abundance are complicated by the remarkably limited amount of information available on the species. This is undoubtedly due to its shy, nocturnal, mostly solitary nature, its apparent affinity for rugged terrain, its generally negative reputation, and frequent confusion with, or lack of differentiation from, the spotted hyaena and aardwolf *Proteles cristatus* where the species overlap (Skinner *et al.*, 1980; Kingdon and Hoffman, 2013; Kruuk, 1976a; Leakey *et al.*, 1999; Wagner, 2006).

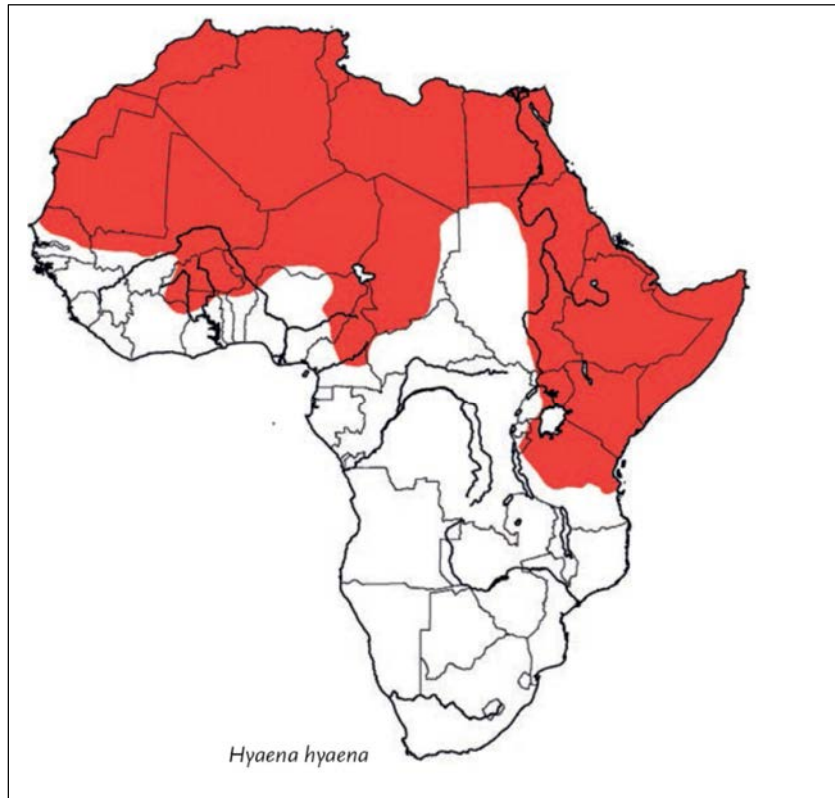


Figure 2.14. Current distribution range of the striped hyaena in Africa according to Kingdon and Hoffman, (2013).

#### 2.9.6.4. Social and reproductive behaviour.

Although generally classified as a solitary species, research in Kenya has shown that striped hyaenas routinely rest in pairs and occasionally in groups of up to four individuals (Wagner *et al.*, 2008). Adult males within a group are typically unrelated or distantly related to other adults in the group. However, full-sibling brother–sister and full-sibling brother–brother pairs were observed within groups (Wagner *et al.*, 2007).

Very little has been recorded regarding direct social interactions outside of captive situations (Kingdon and Hoffman, 2013). Kruuk (1976) did note the meeting ceremony between greeting pairs, which involved mutual sniffing of the face, neck and anal regions. The anal pouch was protruded during sniffing and either both hyaenas were standing or one would lie down while exposing the anal region. Observations in captivity match these field observations (Rieger, 1978).

Descriptions of mating behaviour come from observations in captivity. Males will follow an oestrous female for several days before being allowed to mate (Bothma and Walker, 1999). Litter-sizes in the wild range from 1 - 4 cubs and from 1 - 5 in captivity (Skinner and Ilani, 1979; Rieger, 1981; Wagner *et al.*, 2007). Cubs are reared in dens. Mothers carry food back to the den for their cubs (Kruuk 1976, Davidar 1990). Sexual maturity is reached at 2 - 3 years (Rieger, 1979b). As there are no long-term studies of the species in the wild, longevity has only been reported in captivity at 23 - 24 years (Rieger 1979a; Weigl, 2005).

Striped hyaenas are considerably quieter than spotted hyaenas in terms of both volume and frequency of vocalizations, and are generally silent (Rosevear, 1974). However, Kruuk (1976a) noted that striped hyaenas are more vocal in Israel and their relative silence in East Africa may reflect a behavioural response to avoid dominant carnivores in the region. Vocalizations are similar to those of the spotted hyaena and include whining by cubs before suckling, giggling when frightened, yelling when being chased by conspecifics, lowing in a defensive position, growling when play or food-fighting, and a call by the mother to her cub(s) (Kruuk 1976a; Rieger, 1981).

#### **2.9.6.5. Feeding ecology, foraging behaviour and competition.**

Although sometimes found in small groups of up to four individuals while resting, striped hyaenas appear to be strictly solitary foragers in Africa (Kruuk, 1976a; Wagner *et al.*, 2008). In Israel, however, groups of hyaenas do converge at feeding sites (Kruuk, 1976a; Macdonald 1978; Skinner and Ilani, 1979; Bouskila, 1984), but there is no clear indication of cooperative foraging and relatedness of these observed groups has not been investigated. Foraging activity in Kenya and Tanzania was restricted entirely to night-time except during rain and/or unusually dark and cloudy weather (Kruuk, 1976a; Wagner *et al.*, 2008; *pers. obs.*).

Striped hyaena generally favours open or thorn bush country in arid to semi-arid environments (Rosevear, 1974; Kruuk, 1976a; Rieger, 1978; Leakey *et al.*, 1999; Wagner, 2006) where water is available within a 10 km radius (Rieger, 1979a). Striped hyaenas appear to avoid open desert (such as the central Sahara) and dense thickets and forests (Rosevear, 1974; Rieger, 1979a). While active, the striped hyaena may cross more open areas, but they actively seek out relatively heavy vegetative cover or rocky depressions, particularly large caves, for resting (Rosevear, 1974; Kruuk, 1976b; Rieger, 1979a; Leakey *et al.*, 1999).

Where larger caves are not available, the resting sites used by striped hyaenas are generally not revisited, although they frequently choose sites very close to those used previously (Kruuk, 1976a). Striped hyaenas may remain active in areas frequented by humans, while avoiding them on a temporal scale (Rosevear, 1974; Kruuk, 1976b; Mendelssohn and Yom-Tov, 1987; Wagner, 2006). The diet of the striped hyaena is still a matter of some debate (Kindgon and Hoffman, 2013). However, it has been reported to consume a wide variety of vertebrates, invertebrates, vegetables, fruit and human originated organic wastes (Flower, 1932; Harrison, 1968; Ilani, 1975; Kruuk, 1976a; Macdonald, 1978; Leakey *et al.*, 1999; Wagner 2006). It is known to scavenge off lion and spotted hyaena kills (Kruuk, 1976a; Wagner, 2006; *pers. obs.*) as well as discarded livestock carcasses (Leakey *et al.* 1999; Wagner 2006). Kruuk (1976), Macdonald (1978), Bouskila (1984), Leakey *et al.*, (1999) and Wagner (2006) all found remains of prey items in faecal samples that were likely scavenged.

In many areas, striped hyaenas have also been described as raiding human graves and carrying away bones (Rosevear, 1974; Horwitz and Smith 1988; Leakey *et al.*, 1999), and fruit and vegetable crop raiding is considered a serious problem in Israel (Kruuk, 1976b). The overall reputation of the species, therefore, is that of an omnivorous scavenger (Kindgon and Hoffman, 2013). However, in Laikipia, Kenya, an analysis of faecal bone fragments and hairs indicates that hyaenas regularly consume smaller mammals and birds that are unlikely to be scavenged (Wagner, 2006). This is in agreement with Kruuk's (1976) observations, but previous interpretations of the limited data available (Rosevear, 1974; Skinner and Ilani, 1979; Leakey *et al.*, 1999) often under-emphasized the evidence for active hunting. Striped hyaenas have also been reported chasing hares *Lepus* spp., porcupines, bat-eared foxes, cheetah cubs, dik dik and reedbuck *Redunca* spp. (Kruuk, 1976a; Skinner and Ilani, 1979).

Further, there is strong evidence that small livestock (goats and sheep) and dogs are killed (Rosevear, 1974; Leakey *et al.*, 1999; Kuhn, 2005). Thus, the striped hyaena foraging strategy includes both active hunting and scavenging (Kindgon and Hoffman, 2013). Several studies have inferred diet by combining data from bone collections with analysis of faecal samples (Kerbis-Peterhans and Horwitz, 1992; Leakey *et al.*, 1999), while others have inferred diet from den bone collections alone (Skinner and Ilani, 1979; Kuhn, 2005; Skinner, 2006).

Interactions with other carnivores are best considered in terms of dominance and competition rather than predation. The striped hyaena is subordinate to lions and spotted hyaenas; but outcomes of encounters with cheetahs and leopards are not as predictable; even though adults of those species are likely to dominate striped hyaenas (Kindgon and Hoffman, 2013). Published literature on striped hyaena foraging behaviour in Africa indicates that it is generally a solitary nocturnal forager; for which fruit and vegetable where available, may play a significant part. Striped hyaenas are known to regularly consume insects, invertebrates, small vertebrates and actively hunt small mammals, and ground-nesting and/or ground-feeding birds. In addition, they scavenge off carcasses of larger mammals and this activity appears to account for a significant portion of the bones collected at den sites (Kruuk, 1976a; Skinner and Ilani, 1979; Rosevear, 1974; Leakey *et al.*, 1999; Kuhn, 2005; Wagner *et al.*, 2008; Kindgon and Hoffman, 2013; Skinner, 2006; Mwebi, 2013; Fourvel, 2012; Fourvel and Ogeto, 2011).

#### **2.9.6.6. Relationship with man and the ensuing conservation challenges.**

The striped hyaena's conservation status is classified as Near Threatened (NT) by the International Union for the Conservation of Nature (IUCN, 2015). Humans are responsible the majority of striped hyaena species mortality throughout the evaluated range (Hofer 1998a) and were implicated in 50% of recorded deaths in Laikipia, Kenya (Wagner 2006). Negative perceptions of the species persist throughout its range and collection of human remains ('grave robbing') and incidents of damage to agriculture and livestock perpetuate negative attitudes. Striped hyaenas are very susceptible to accidental or targeted poisoning as they readily accept strychnine-poisoned bait (Hofer 1998a). The population in Niger is apparently declining as a result of officially sanctioned eradication or poisoning and indirectly by habitat destruction through overgrazing and agricultural encroachment (Hofer and Mills, 1998b).

Habitat destruction is also viewed as a threat in Kenya and effective protection is absent as hyaenas are viewed with contempt. Due to the lack of differentiation between the species, striped hyaenas are often killed when spotted hyaenas are the intended target (Wagner 2006). Striped hyaenas are also subject to trade in skins and body parts, mainly for use in traditional medicine. In North Africa, the animal's brain is used as an aphrodisiac and hairs are used as a talisman (Rieger, 1979a; Osborn and Helmy, 1980). In Morocco, where the species is commercially hunted for use in traditional medicine, the population has declined drastically and has withdrawn into the southern mountainous regions (Kindgon and Hoffman, 2013).

In Egypt, striped hyaenas are hunted for utilization of the whiskers and eyeballs as protection from the evil eye and the heart for courage (Osborn and Helmy, 1980). A considerable proportion of striped hyaena populations is known to exist outside of formally protected areas in regions where pastoralism is the norm and the potential for human–carnivore conflict is very high, populations in Egypt and Kenya are exceptionally vulnerable to human population growth, habitat destruction and poisoning. Particular attention should be paid to ensuring the survival of the species in pastoral areas by identifying ways to reduce human–carnivore conflict through promotion of methods that ensure adequate numbers of prey persist and/or methods that reduce livestock killing by carnivores (Kindgon and Hoffman, 2013; Kruuk, 2002; Winterbach *et al.*, 2013; Mwebi, 2013; Románach *et al.*, 2007; Inskip and Zimmerman, 2009; Kruuk, 1972*b*; Kellert *et al.*, 1996; Boitani and Powell, 2012).

### **2.9.7. The brown hyaena.**

#### **2.9.7.1. Taxonomic and evolutionary history.**

The brown hyaena *Parahyaena brunnea* is presently allopatric to the striped hyaena. Even though the two hyaena species were recognized as separate genera by Werdelin and Solounias (1990, 1991) and Wozencraft (1993); both were at least potentially sympatric at times in the past, and at some point included in the same genus as both species have been recorded from sites in South Africa. However, a more likely scenario may be that their respective geographic ranges have fluctuated somewhat depending on changes in climate and environment during the Plio-Pleistocene and that they have thus replaced each other in the fossil record without being truly sympatric. The *Parahyaena brunnea* lineage cannot be followed fully in the fossil record, but given its absence from East Africa after the early Pliocene (*but see* Werdelin and Barthelme 1997), it is most likely a southern African endemic. Fossils from South Africa are known from the early Pleistocene, and all appear to represent the modern species (Werdelin and Turner 1996*b*). There has been controversy regarding the phylogeny and taxonomy of modern hyaenas, but the traditional view, going back to the nineteenth-century discovery of the brown hyaena, was that the aardwolf was basal to the other three species, with brown and striped hyaenas closely related, and the spotted hyaena as their closest relative (Kingdon and Hoffman, 2013).

However, some prominent studies incorporating fossil taxa (Galiano and Frailey 1977, Werdelin and Solounias, 1991) concluded on the basis of morphological data that the genus *Hyaena* as traditionally conceived is paraphyletic, and that the brown hyaena is the closest relative of the spotted Hyaena. This required raising the subgenus *Parahyaena* to the generic level (Hendey, 1974).

#### **2.9.7.2. Morphology and identification.**

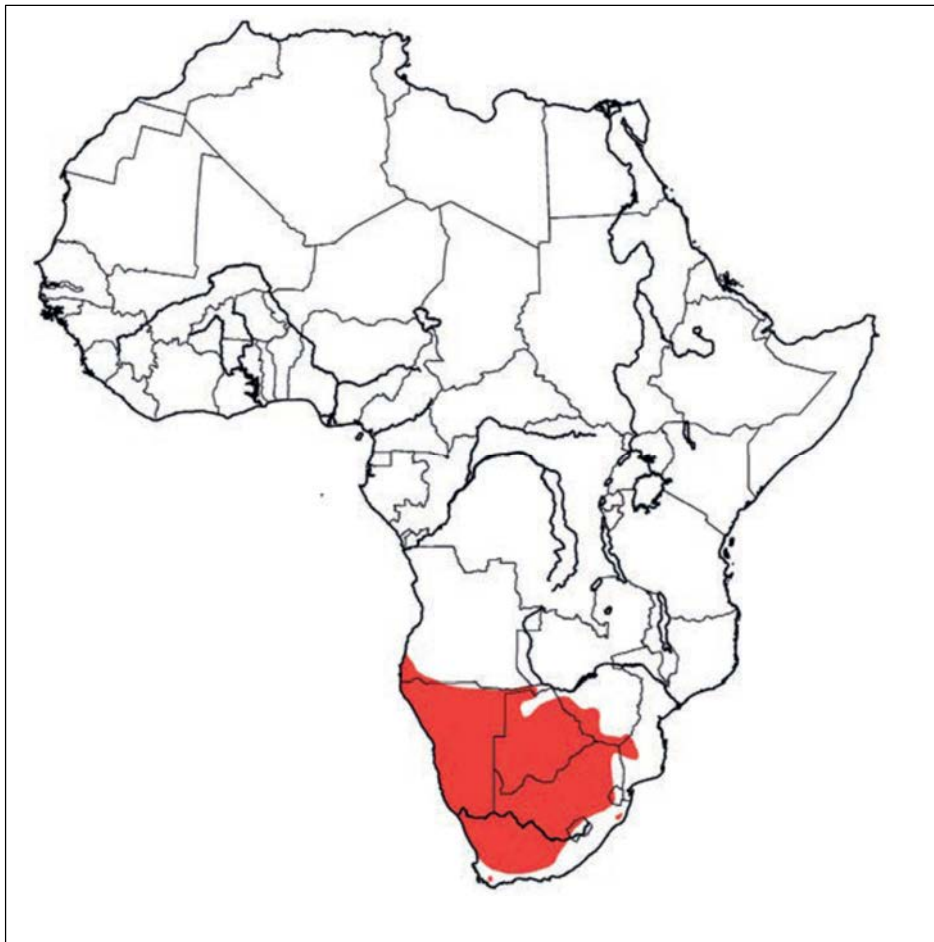
This is the second largest extant hyaenid species after the spotted hyaena. It has a typical hyaena build, being higher at shoulders than at rump, giving appearance of a sloping back. The muzzle is black, forehead lighter, whiskers long and black, and ears long and pointed. The pelage is shaggy, dark brown to black, except around neck and shoulders, which are off-white to tawny-white, as are underparts and insides of limbs. The long hair along the mid-dorsal line can be raised in a conspicuous display (Skinner, 1976; Kingdon and Hoffman, 2013). Close up, body colour is uneven, with darker bands caused by broad black tips of guard hairs lying in juxtaposition. On upper parts of limbs are a series of white bands. The tail is relatively short, dark and bushy and its forefeet much larger than its hindfeet, a feature clearly marked in the spoor and making it possible to distinguish a brown hyaena scat from a spotted hyaena scat. There is a clear difference between male and female reproductive organs, with the testes showing clearly just below the anus, unlike the spotted hyaena. Females have two pairs of abdominal nipples (Skinner and Chimimba, 2005; Kingdon and Hoffman, 2013).



*Figure 2.15. Photograph of a brown hyaena. Photo credit: Wiesel (2006).*

### 2.9.7.3. Distribution range.

The brown hyaena is endemic to southern Africa except for a marginal extension into the arid parts of south western Angola. The range of the brown hyaena has shrunk significantly since the end of the eighteenth century when it was last recorded from Table Bay in the extreme south-west of the continent. At the end of the nineteenth century it was still regularly found as far south as Malmesbury and Beaufort West in the then Cape Province, South Africa. Its current distribution range includes southern African countries that include: South Africa, Angola, Namibia, Botswana, Zimbabwe, Zambia and Mozambique. It is sympatric to the spotted hyaena but allopatric to the striped hyaena (Kingdon and Hoffman, 2013; Hofer and Mills 1998a; Crawford-Cabral and Simoes, 1990; Smithers 1971; Smithers and Lobão Tello, 1976).



*Figure 2.16. Current distribution range of the brown hyaena in Africa according to Kingdon and Hoffman, (2013).*

#### **2.9.7.4. Social and reproductive behavior.**

Brown hyaenas live in clans ranging in size from a solitary female and her cubs to groups containing several females and their offspring of different ages. Adult males either remain with their natal clan, become nomadic, or immigrate into a new clan (Owens and Owens 1979b, Mills 1990). Although members of a clan forage singly, several may come together at a large food source and members of a clan defend a common, fixed territory. Agricultural development may in some instances be beneficial to the brown hyaena. The type of food in the territory determines clan size, while the manner in which the food resources are distributed determines territory size (Mills 1990; Skinner *et al.*, 1995; Kingdon and Hoffman, 2013; Skinner and Van Aarde, 1987). Territorial ownership and communication between clan members is relayed mainly through pastings as well as by defecating at latrines. Brown hyaenas distribute pastings throughout the territory, particularly in the core areas, and increase pasting frequency near territory boundaries (Mills, 1990).

Pastings are placed on grass stalks, bushes or rocks. Pastings are so well distributed over a brown hyaena territory that an individual is hardly ever more than half a kilometer away from an active pasting, which lasts for over 30 days (Mills *et al.*, 1980, Mills, 1990). Latrines are scattered throughout the territory but tend to be concentrated around the boundary. Boundary latrines are visited more frequently than those within the territory. Some latrines are used over a short period only, while other latrines are used over a period of years (Skinner and Van Aarde, 1981, Mills, 1982). Meetings between clan members involve mutual sniffing around the head and face, neck and body, and anal pouch. Territorial fights are usually ritualized neck-biting bouts between two animals of the same sex from different clans accompanied by loud yelling and growling by the submissive animal. Meetings between individuals of different sexes and from different groups are often amicable (Kingdon and Hoffman, 2013).

Both nomadic and immigrant males may mate with adult females, and all adult females in a clan may reproduce, although the matriarch appears to produce more cubs than the others (Mills 1990). Cubs are born and raised in dens. The den is usually a single hole in the ground, often a disused aardvark burrow, which the female modifies to her requirements, although in some areas caves are used (Skinner, 1976; Goss, 1986). Dens have a narrow entrance of about 30 cm high and 50cm wide, and typically have a single entrance (Mills, 1990). At most dens a single litter of cubs is raised, but two or even more females may share a den in territories where more than one female breeds (Owens and Owens 1979a, Mills 1990).

The breeding females are usually a mother and her grown-up daughters and although they give priority to their own they may even suckle each other's cubs. The denning period lasts several months, during which time the cubs use several different dens. Mothers will carry cubs to new dens, but from about six months, cubs may even initiate the move themselves (Mills, 1990). For the first three months of their lives the cubs are nursed by their mother, typically at sunset and sunrise, after which the milk diet is supplemented to an ever-increasing degree by meat brought to the den. Consequently, brown hyaena dens often become littered with bones and other remains. All members of the clan help to feed the cubs by carrying food in the form of meat, skin and bones to the den (Mills, 1990; Kingdon and Hoffman, 2013). After weaning, cubs begin to forage for themselves (Mills 1990).

Vocalizations include a loud growl when frightened, a yell or a short deep growl when confronted by lions or in encounters with spotted hyaenas, and submissive animals may scream when neck-biting with dominants, or squeal or whine on greeting them. Cubs and sub adults utter a soft growl, accompanied by panting, when muzzle wrestling. Cubs utter a harsh whine prior to suckling, and a soft whine when being groomed. Adult males utter a very soft growl when calling cubs in the den. The adults hoot and pilo-erect when approaching others on a kill. The brown hyaena has no long distance call analogous to the spotted hyaena's whoop, nor do they giggle (Mills 1990).

The brown hyaena is a polyoestrous, non-seasonal breeder with anoestrous occurring during lactation. In the wild, oestrus in the females lasts 4–6 nights. The gestation period is approximately 97 days and a typical litter size ranges between 1-5 cubs (Skinner, 1976). Mean inter-litter interval is about 24 months although if a litter dies the female will come into oestrus earlier (Mills, 1990). Cubs are born with eyes closed, and ear pinnae folded; eyes start to open on the one week and are fully open after 2 weeks, while ears become erect after one month (Schultz, 1966). The cubs are weaned at about 12-15 months of age. Cub and young adult mortality rates are low, but sub adult and aged individual mortality appears to be quite high (Kingdon and Hoffman, 2013).

#### **2.9.7.5. Feeding ecology, foraging behavior and competition.**

Brown hyaenas are primarily scavengers of a wide range of vertebrate remains, supplementing their diet with wild fruits, insects, birds' eggs, medium-sized and small mammals. Hunting is unspecialized and opportunistic. They exhibit a predilection for ostrich eggs that are easily carried and opened; unlike the larger spotted hyaena which seems to have greater difficulty in accomplishing a similar task. Carrion forms the primary component of the diet, particularly from ungulate carcasses (Skinner, 1976; Mills, 1978, 1982a, 1990; Mills and Mills, 1978; Owens and Owens, 1978; Skinner and Van Aarde, 1981; Siegfried, 1984; Stuart and Shaughnessy, 1984; Maddock, 1993b; Burgener and Gusset, 2003; Maude and Mills, 2005; Kuhn *et al.*, 2008; Kingdon and Hoffman, 2013). Along the Namib desert coast, brown hyaenas feed predominantly on Cape fur seal pups, and scavenge other marine organisms washed up on the shore (Goss, 1986; Skinner and Van Aarde, 1981; Siegfried, 1984; Stuart and Shaughnessy, 1984; Kuhn *et al.*, 2008; Skinner *et al.*, 1995; Wiesel, 2010).

The brown hyaenas are mainly nocturnal with some crepuscular and diurnal activity. Food items are often taken back to the den to provision the young, and bone assemblages have been shown to reflect faunal composition of the area at that time (Skinner and Van Aarde, 1981; Skinner *et al.*, 1998; Skinner, 2006; Kuhn *et al.*, 2008). Excess food is often stored and/or scatter-hoarded (Mills, 1990). Over much of its range, the brown hyaena lives in association with other carnivores and benefits from many of them by scavenging from their kills. Lion kills provide many scavenging opportunities for brown hyaenas, although they are dominated, or even killed by lions. (Owens and Owens, 1978; Apps, 1982). The brown hyaena is usually dominant over leopards, cheetahs and caracals and often appropriates the kills of these species (Owens and Owens 1978; Mills, 1990).

Competition for food between the brown hyaena and black-backed jackal can at times be severe and vultures too can deprive it of food. The spotted hyaena is dominant to the brown hyaena and in certain areas deprives it of a significant amount of food. This may have a detrimental effect on brown hyaena numbers and may even affect its distribution in areas where the spotted hyaena is common (Mills, 1990). Wounds inflicted during both inter- and intra-specific fights and starvation; or starvation due to severe wearing down of the teeth and an inability to consume bones, are the main cause of natural mortality in protected areas. Although rabies has been recorded from brown hyaena (Swanepoel *et al.*, 1993), no evidence for disease being an important form of mortality has been found (Kingdon and Hoffman, 2013).

#### **2.9.7.6. Relationship with man and the ensuing conservation challenges.**

The brown hyaena is Red Listed as a Near Threatened species by the International Union for the Conservation of Nature (IUCN, 2015). The impact of the brown hyaena on domestic animals is usually small (Mills, 1998), although sheep and goats in particular, but also calves, poultry, domestic dogs and cats have very infrequently been recorded as kills. In agricultural areas of Mpumalanga and Limpopo Province, Skinner (1976) reported two cases of stock killing over several months that ceased once the individual predator was removed, even though there were other brown hyaenas in the area; for the most part, carrion and medium-sized and small indigenous animals were commonly eaten.

There are a number of large conservation areas with viable populations of the brown hyaena, including: Namib-Naukluft, Skeleton Coast, Sperrgebiet and Etosha National Parks (Namibia), Kgalagadi Transfrontier Park (South Africa, Botswana), Pilanesberg National Park (South Africa) and the Central Kalahari Game Reserve (Botswana). However, outside these protected areas, the brown hyaena may run into conflict with humans, and they are often shot, poisoned, trapped and hunted with dogs in predator eradication or control programmes, or inadvertently killed in non-selective control programmes (Kingdon and Hoffman, 2013). They are also occasionally victims of road kills in South Africa, though this is unlikely to represent a major threat (Mills, 1998).

Although used in traditional medicine and rituals, the brown hyaena is not nearly as sought after in this regard as the spotted hyaena (Hofer and Mills, 1998b). A recent study from Botswana suggested that a significant proportion of the global brown hyaena population is found in non-protected areas, and that these animals can also tolerate land-use changes under some circumstances (Kent and Hill, 2013). Boast and Houser (2012) found that brown hyaenas occurred evenly on game and cattle farms in Botswana, and in Namibia. Increased efforts to educate farmers and pastoralists about the fact that brown hyenas pose very little risk to livestock is likely to enhance conservation of these animals (Lindsey *et al.*, 2013; Kingdon and Hoffman, 2013).

## **CHAPTER 3. Materials and Methods.**

### **3.1.1. Résumé du matériaux et méthodes.**

Le comté de Samburu (zone d'étude principale) est un vaste paysage semi-aride dans l'ancienne province de la vallée du Rift au Kenya. Sa superficie est d'environ 21,126.5 km<sup>2</sup>, coimpris entre 1,33333 Nord et 37,11667 Est, avec des précipitations annuelles moyennes entre 600 et 800 mm. Les principaux milieux du paysage de Samburu comprennent les mosaïques de la savane, les prairies d'acacias, les garrigues d'acacias et les forêts des zones sèches. Soysambu Conservancy (site d'étude complémentaire) est une réserve privée de 190 km<sup>2</sup> entourant le lac Elementeita (000 46'S, 0360 23'E), située dans le comté de Nakuru, dans la Rift Valley. Il s'agit d'une zone subhumide à semi-aride sec avec une pluviométrie annuelle moyenne de 920 mm. Le milieu est constitué de grandes parcelles d'espèces d'Acacia et de forêts mixtes entrecoupées de savanes.

Les méthodes de l'étude comprennent: documentation des modes de consommation de carcasses par trois carnivores modernes (lion, léopard et hyène tachetée), à l'aide de notes détaillées sur le type d'habitat, la saison, les espèces prédatrices (connue et/ou confirmée), le nombre de prédateurs (si connu et/ou confirmé), l'espèce-proie et la taille de la carcasse (âge, sexe), sont état et emplacement lors de la collecte, présence de restes alimentaires (viande). Les carcasses collectées sur les sites d'étude ont ensuite été traitées à la section d'Ostéologie du Musée National de Nairobi, en utilisant des méthodes classiques consistant à faire bouillir les échantillons dans de grandes casseroles couvertes pendant plusieurs heures, jusqu'à ce que toute chair restante sur les os soit devenue douce et tendre et facilement détachable. Après séchage, les os ont été nettoyés et conservés à la section d'Ostéologie pour des analyses néotaphonomiques (par exemple, modèles de désarticulation osseuse, fréquences des parties squelettiques et modifications de la surface des carcasses de proies). Un catalogue a été établi pour tous les spécimens étudiés et la somme totale des éléments osseux, ainsi que l'étude et localisation des marques dentaires de carnivores, et les types de fractures. Des analyses ont été effectuées pour déterminer les schémas de consommation osseuse suivant chaque espèce de carnivores des terrains d'études (Samburu, Soysambu).

Des échantillons de fèces des carnivores concernés ont été recueillis lors de recherches opportunistes le long des routes et/ou des pistes, à proximité des sites de tuerie/charognage. Pour les fèces les plus fraîches nous en avons conservé une petite quantité à l'aide d'équipements stérilisés, stockés dans des flacons contenant de l'éthanol absolu en vue de

futures analyses ADN. L'ensemble des échantillons ont été séchés à l'air, catalogués puis stockés dans des sacs en papier des analyses au laboratoire de la section d'Ostéologie.

Un de nos objectifs est d'évaluer les effets des variables climatiques et de l'habitat sur la prédation du bétail par les grands carnivores. Nous avons mis en place un réseau de collaborateurs qui ont fourni les données suivantes pour notre recherche doctorale :

- une décennie de données (Janvier 2009 - Décembre 2018) pour le comté de Samburu, pour les variables climatiques suivantes : précipitations mensuelles, températures quotidiennes (maximum et minimum), indice de végétation par différence normalisée (NDVI), indice de précipitation standard (SPI) avec l'aimable autorisation du Centre de prévision et d'applications du climat de l'IGAD (ICPAC);
- données annuelles du recensement de la population animale (herbivores domestiques et sauvages) pour Samburu (2010, 2013 et 2015), avec l'aimable autorisation du Département des enquêtes sur les ressources et de la télédétection (DRSRS);
- près de dix années de données sur la prédation de carnivores et d'animaux (Janvier 2010 à Décembre 2018) pour Samburu, avec l'aimable autorisation du Northern Rangelands Trust (NRT).

Nous avons alors traité et testé statistiquement ces informations pour déterminer les effets du climat sur l'ensemble des populations animales de Samburu (herbivores domestiques et sauvages), et les effets du climat et de l'habitat sur les modèles de prédation du bétail à Samburu ; selon différents contextes : fréquences des prédateurs (jour contre nuit), par espèce de carnivore (lion, léopard, guépard, hyène et chien sauvage africain), par type de bétail (ovicaprinés, bœuf, âne, chameau), par catégorie de taille de bétail (petits animaux vs gros stock), par mois de (janvier à décembre), par années (entre 2010 et 2018) et par zone d'étude (Meibae, Westgate, Ltungai et Namunyak Community Wildlife Conservancies).

Enfin, des enquêtes ethnographiques ont été menées pour comprendre la relation entre les pasteurs Samburu et les grands carnivores (lions, léopards, guépards, hyènes tachetées, hyènes rayées et chiens sauvages africains). Des questionnaires selon un schéma d'enquête semi-structurée ont été utilisés pour échantillonner les familles de pasteurs du comté de Samburu dans des différentes zones étudiées, en utilisant une approche aléatoire simple. Nous avons relevé les variables démographiques telles que le sexe (homme/femme), l'âge (personnes âgées/d'âge moyen/jeunes), le niveau de scolarité et le statut socio-économique (classes

supérieures / moyennes / basses) en fonction de la fréquence et de la variété des types de stocks (ovicaprinés, bovins, âne, chameau) pour chaque répondant ; puis une notation a permis de classer les opinions générales des répondants sur les carnivores comme positives ou négatives, et le niveau de tolérance général à zéro, faible ou élevé en ce qui concerne la présence de carnivores dans leur voisinage (coexistence). Pour compléter ces enquêtes ethnographiques, nous avons organisé un atelier d'une journée sur la conservation des carnivores à Samburu en Mars 2018. Cet atelier a porté sur des discussions et échanges entre les parties prenantes et les représentants de la communauté pastorale de Samburu. Des chercheurs et des membres de la communauté ont ainsi présenté des exposés sur la gestion et la conservation de la faune sauvage dans la région.

### **3.1.2. Summary of materials and methods.**

Samburu County (main study area) is a vast semi-arid landscape in the former Rift Valley Province of Kenya with an administrative area lying between Latitude 1.33333 North and Longitude 37.11667 East, with a mean annual rainfall between 600 – 800 mm. It covers approximately 21,126.5 km<sup>2</sup>. The major ecosystems within the Samburu landscape include: savannah mosaics, acacia grasslands, acacia scrublands, and dryland forests. Soysambu Conservancy (complementary study site) is a privately-owned wildlife conservancy 190 km<sup>2</sup> in size surrounding Lake Elementeita (00° 46'S, 036° E23'E), and is situated within Nakuru County in the former Rift Valley Province of Kenya. It is classified as dry sub-humid to semi-arid with a mean annual rainfall of 920 mm. The habitat consists of large patches of acacia species and mixed woodland interspersed with savannahs.

Study methods included: Documentation of carcass consumption patterns by three modern carnivores (lion, leopard and spotted hyaena), using detailed notes on habitat type, season, predator species (if known and/or confirmed), number of predators (if known and/or confirmed) carcass size, state/nature upon recovery and location of carcass remains including surviving flesh in the form of bulk muscle (partial or complete) or as scraps on each element. The procured carcasses from the study field sites were later processed at the Osteology Section of the National Museums of Kenya using standard osteological methods of boiling specimen in large covered cooking pots using liquefied petroleum gas for several hours until all surviving flesh on the bones became soft and tender and easily removable. After drying, the bones were cleaned and accessioned at the Osteology section for further taphonomical analyses (*e.g.* bone

disarticulation patterns, skeletal part frequencies and surface modifications on prey carcasses). A catalogue was then derived for all study specimen and their sum total of surviving parts and toothmarks types, toothmark distributions and breakage types. Analyses were then carried out to determine bone consumption patterns by each study carnivore species for Samburu and Nakuru study sites.

Scat samples for the study species were collected during opportunistic searches along roads and/or tracks and near kill/scavenging sites. Whenever we encountered ‘fresh wet scat’ of any of the large carnivores, we collected a small quantity through sterilized equipment and stored in vials containing absolute ethanol for possible future DNA analyses. Scat samples for microscopic analyses were air dried and stored in paper bags for later cataloguing and analyses at the laboratory of the Osteology Section at the National Museums of Kenya.

Assessing the effects of climatic variables and habitat on livestock depredation by the large carnivores: Project collaborators provided the following datasets for this PhD study; a decade worth of data (January 2009 - December 2018), for the following climatic variables; monthly rainfall, daily temperatures (maximum and minimum), normalised difference vegetation index (NDVI) and standardized precipitation index (SPI) for Samburu County, courtesy of the IGAD Climate Prediction and Applications Centre (ICPAC); animal population census data (domestic *vs* wild herbivores) for Samburu County (2010, 2013 and 2015) courtesy of the Directorate of Resource Surveys and Remote Sensing (DRSRS); and, a near decade worth of carnivore-livestock depredation data (January 2010 - December 2018) for Samburu County courtesy of the Northern Rangelands Trust (NRT). Statistical tests were then conducted to determine effects of climate on overall animal populations in Samburu (domestic *vs* wild herbivores); and, effects of climate and habitat on livestock depredation patterns in Samburu County within the context of: depredation frequencies (day *vs* night), per carnivore species (lion, leopard, cheetah, hyaena and African wild dog), per livestock type (sheep, cattle, donkey, camel), per livestock size category (small stock *vs* large stock), per month (January to December), per year (2010 – 2018), and per location (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies).

Ethnographic surveys were conducted to understand the dynamic relationship between the Samburu pastoralists and the large carnivores (lion, leopard, cheetah, spotted hyaena, striped hyaena and African wild dog). Questionnaires with a semi-structured survey design were used to sample pastoralist households in Samburu County within strata (conservancy blocks) using a simple randomized approach of sampling every third household. Demographic variables such as gender (male/female), age (elderly/middle-aged/youth), educational background, socio-economic status (upper/middle/lower classes) based on the frequency and variety of stock types (shoats/cattle/donkey/camel) for each respondent, were scored against a set criteria of factors to eventually classify each respondent's overall view towards carnivores as positive or negative, and overall tolerance level as zero or low or high towards carnivore presence in their neighbourhood (co-existence). In addition to the ethnographic surveys, a one-day carnivore conservation workshop in Samburu was conducted in March 2018. The said workshop was about deliberations between the stakeholders and representatives of the Samburu pastoralist community. Presentations were made on the management and conservation of wildlife in the area by researchers and community members.

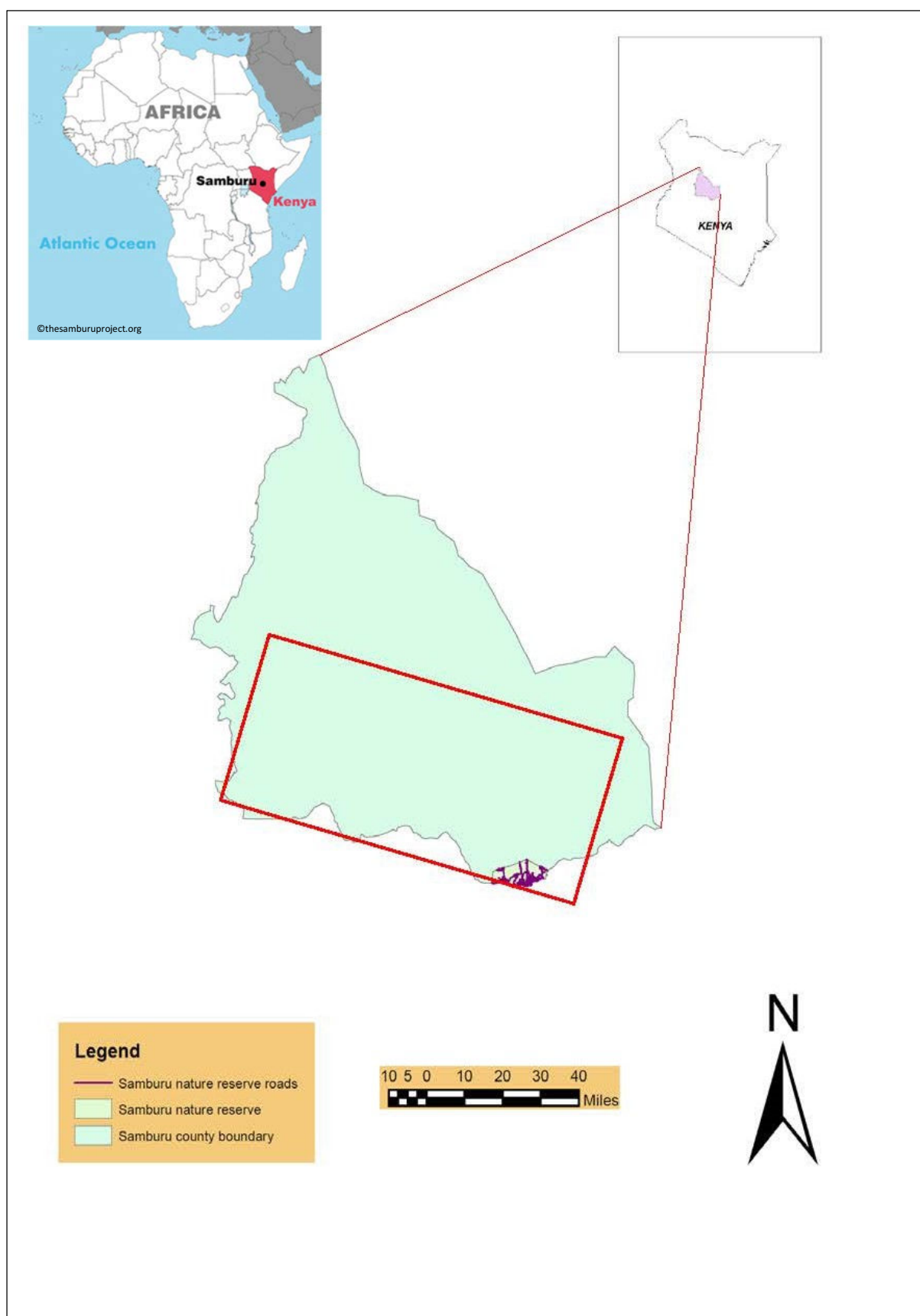
### **3.2.1. Samburu County, northern Kenya.**

Samburu County (our main study area) is a vast semi-arid landscape in the former Rift Valley Province of Kenya with an administrative area lying between Latitude 1.33333 North and Longitude 37.11667 East (*see* Figure 3.1). It covers approximately 21,126.5 Km<sup>2</sup>. This semi-arid landscape is characterized by seasonal variations in surface water and vegetation resources, with several implications for humans and their livestock, wild carnivores and wild herbivores (De Leeuw *et al.*, 2001). Rainfall in the county is sporadic and unreliable with a bimodal distribution (De Leeuw *et al.*, 2001; Barkham and Rainy, 1976). About 90% of the mean annual rainfall (600 – 800 mm) occurs during April - May and November - December (Barkham and Rainy, 1976; Samburu County Government and WFP, 2015). Consequently, surface water is a heterogeneously distributed, limiting resource which becomes scarcer as the dry season approaches. Subsequently, the regular need to access drinking water constrains the movement of herbivores, and hence their distribution in the dry season. Large migrant animals congregate in the Samburu National Reserve during the long dry season because of permanent availability of green riverine vegetation along Ewaso Ng'iro River. Therefore, water dependence influences the movement of pastoralists and their livestock, wild herbivores and consequently large carnivores (Western, 1975; De Leeuw *et al.*, 2001; Smit *et al.*, 2007).

In general, Samburu pastoralists rear sheep, goats, cattle, camels and donkeys. The inhabitants dwell in communal homesteads where different families and clans share grazing resources with wildlife. They are semi-nomadic; grazing their herds around temporary livestock enclosures during times of drought and also maintain semi-permanent home bases in their home territory to which they retreat when resources are in plenty (Raizman *et al.*, 2013).

The context of pastoralism has been changing with increases in human and livestock populations, expansion of agriculture, political insecurity, market dependence, and wealth differentiation (Western *et al.*, 1994, 2015). As a result, pastoral groups are increasingly marginalized and impoverished (Western *et al.*, 1994; Galaty, 1981). The Samburu community groups have had to adapt their way of life and resource management practices to a new and changing environment (Hogg, 1985; Dyson-Hudson, 1972; Western *et al.*, 1994).

To this end, the relationships between the Samburu and wildlife are dynamic and influenced over time by various factors, such as droughts, decreasing grazing lands, political instability, modernization, and human encroachment on traditional wildlife lands (Hogg, 1985; Raizman *et al.*, 2013).



*Figure 3.1. Map showing location of Kenya in Africa; and Samburu County in Kenya, with approximate project study area highlighted by the red rectangle within the Samburu County map.*

### 3.2.2. Soysambu Conservancy, Nakuru, central Kenya.

Soysambu Conservancy is a privately-owned wildlife conservancy (*see* Figure 3.2), 190 km<sup>2</sup> in size surrounding Lake Elementeita (00° 46'S, 036° E23'E; 1670m asl). It is classified as dry sub-humid to semi-arid with a mean annual rainfall of 920mm/yr. The habitat consists of large patches of acacia species and mixed woodland interspersed with open savannah grassland (Muller, 2018).

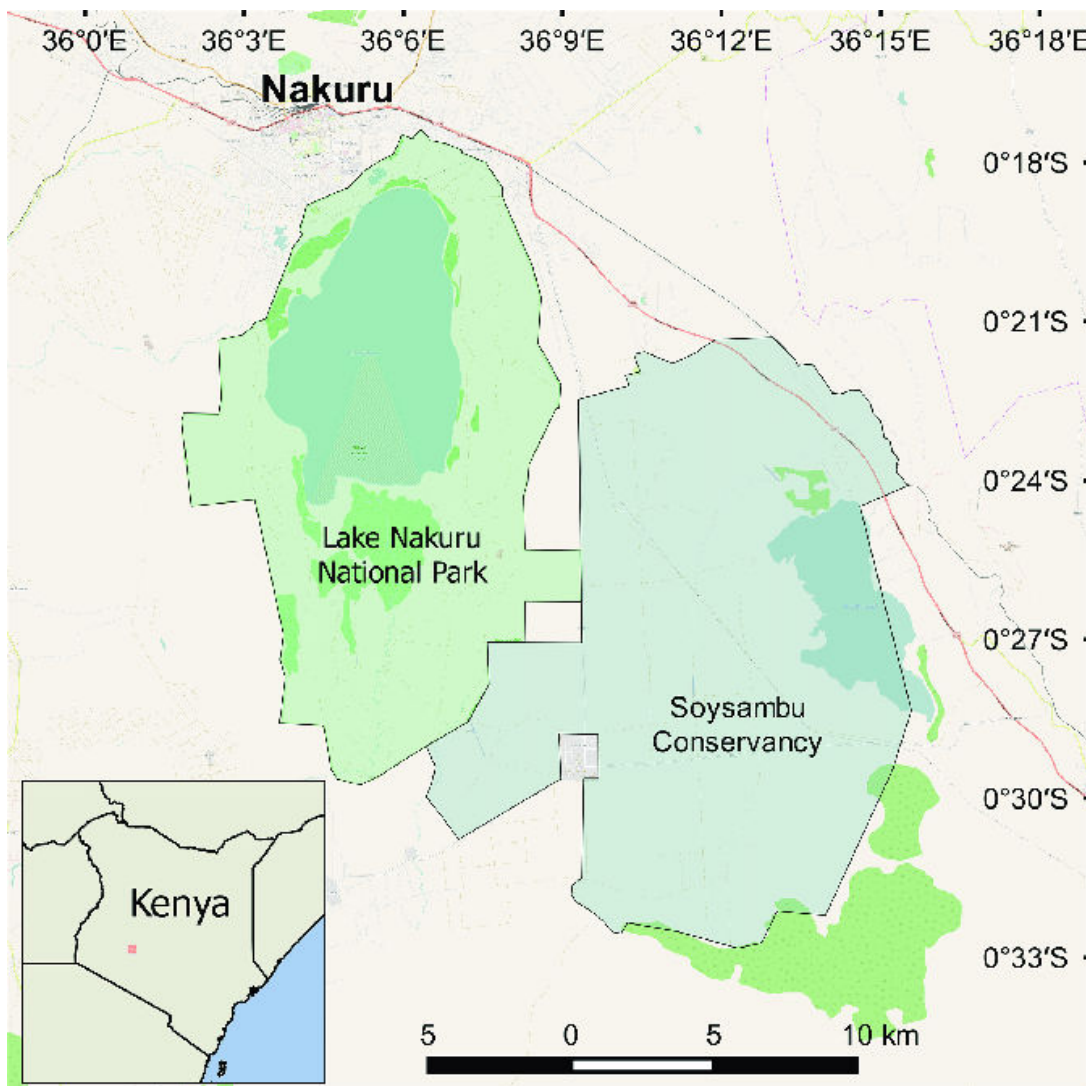


Figure 3.2. Map of Soysambu Conservancy in Nakuru County according to Muller (2018).

### **3.3. Methods.**

#### **3.3.1. Documenting carcass consumption patterns by lion, leopard and spotted hyaena at kill sites in Kenya (Samburu and Nakuru).**

Using methods modified from (Tunnell, 1990; Tappen, 2001; Gidna *et al.*, 2014), detailed notes on; habitat type, season, predator species (if known and/or confirmed), number of predators (if known and/or confirmed); carcass size, state/nature upon recovery and location of carcass remains including surviving flesh in the form of bulk muscle (partial or complete) or as scraps on each element. Aging of the individuals was made by comparing dental eruption and wear patterns with known age collections at the National Museums of Kenya.

Detailed information regarding flesh survival on each anatomical element and conspicuous damage to the bones at the kill/scavenging site and portable skeletal parts (e.g. limb bones, vertebra, skull and lower jaw) were collected depending on the size of prey. For example, in the case of an elephant calf or large domestic animal like the camel, only limb bones would be collected; but in the case of medium-sized antelopes such as the grants gazelle, the gerenuk; or small to medium sized domestic animals such as goats and sheep, the handful of surviving skeletal parts were collected wholly. Abandoned leopard kills procured from tree perches were almost always collected wholly.

Kill sites were classified based on forensic evidence of a kill (e.g. presence of stomach contents); while also using several accompanying indicators such as: camera trap evidence (whenever possible), predator tracks, hair and scat, indications of a struggle visible in broken and trampled vegetation, the positioning of the carcass remains, the condition of any remaining hide bearing claw, and bite marks typical of large carnivore predation (Davidson *et al.*, 2013; Ghoddousi *et al.*, 2016).

Direct observations were also used as a method (see Kruuk, 1972a), although this required being in the right place at the right time. Since the project did not have the resources to utilise radio telemetry methods in tracking specific large carnivore species whenever they made kills; we relied on our bush-craft tracking techniques. In addition, crucial information was periodically relayed to our team by tour guides in the reserve whenever they witnessed successful hunts by any of the large carnivores.

Carcass consumption patterns by lion, leopard and spotted hyaena, were documented using detailed notes on habitat type, season, predator species (if known and/or confirmed), number of predators (if known and/or confirmed) and prey carcass size. The procured carcasses from the study field sites were later cleaned at the Osteology Section of the National Museums of Kenya using standard osteological of boiling specimen in covered large cooking pots using liquefied petroleum gas for several hours until all surviving flesh on the bones become soft and tender and easily removable. After drying, the bones were accessioned and stored at the Osteology section for further neotaphonomic analyses (e.g. bone disarticulation patterns, skeletal part frequencies and surface modifications on prey carcasses).

Bone alterations were recorded according to the portion eaten, gnawed or modified, following descriptions provided by Binford (1981): scores (defined as deep furrows or shallow indentations shaped as longitudinal scratches on bone surfaces), punctures (deep holes produced by the crushing of the bone), pits (small, shallow depressions, often appearing in multiple sets) and furrowing (defined as the removal of cancellous tissue from bone).

During the documentation of carcass modification patterns, the following variables were recorded: (1) Presence of tooth mark damage: bone alterations were recorded according to the portion eaten, gnawed or modified; (2) Tooth mark sizes: marks were measured with the aid of a digital calliper. The length (maximum axis) and breadth were measured. Due to the unavailability of proper microscopic equipment to measure pits and scores, only punctures were measured for this study; (3) Tooth mark distribution: marks were tallied according to bone section; epiphysis (both, proximally and distally) and midshaft; (4) Surviving bone parts (in case carcass was procured wholly: bones were recorded by anatomical parts (*e.g.* humerus, femur, distal or proximal) and a bilateral symmetry (left or right); and, (5) Bone breakage: breakage types (symmetrical, stepwise to complete).

A catalogue was then derived for all study specimen and their sum total of surviving parts and types of toothmarks, toothmark distributions and types of breakages and analyses carried out to determine the nature of bone consumption by each carnivore species.

### **3.3.2. Collecting carnivore scats for morphometric assessment.**

Quantifying wild carnivore diets is crucial to understanding predator ecology and the influence that predators have on their prey populations (Radloff *et al.*, 2004; Owen, 2008). Sampling protocols modified from (Wilson *et al.*, 1996; Boitani and Powell, 2012; Berg, 2003; Ogara *et al.*, 2010; Davidson *et al.*, 2013; Ghoddousi *et al.*, 2016; Kruuk 1972a) were used to sample large carnivore scat and distribution of their kill sites/scavenging locations. Even though several non-independent scat samples could be collected at one site, only one sample (for each identified carnivore species) was analysed to avoid any pseudo-replication (Marucco *et al.*, 2008). We also visited hyaena latrines as proposed by Kruuk (1972a) to sample dry hyaena scat, and whenever possible ‘fresh wet’ hyaena scat. Scat samples for the study species were collected during opportunistic searches along roads and/or tracks and near kill/scavenging sites. Whenever we encountered ‘fresh wet scat’ of any of the large carnivores, we collected a small quantity through sterilised equipment and stored in vials containing absolute ethanol for possible future DNA analyses. Scat samples for microscopic analyses were air dried and stored in paper bags for later analysis. Scat measurements taken after each scat sample was dried included: dry scat weight, maximum and minimum scat fragment width and scat fragment height. Variation in scat morphometry for lion, leopard and spotted hyaena scat was then investigated.

### **3.3.3. Mapping and determining cattle depredation conflict rates.**

The study area in Samburu was stratified on the basis of Community Wildlife Conservancies (Meibae, Ltungai, Westgate and Namunyak). As many depredation incidences as possible were investigated to determine actual carnivore species responsible; and, to monitor rates of depredation by lions, leopards, cheetahs, wild dogs, spotted and striped hyaenas per study location following methods modified from (Ogada *et al.*, 2003; Woodroffe *et al.*, 2007; Dickman, 2008). Since livestock depredation conflict had never been comprehensively assessed and results used to inform mitigation of human-carnivore conflict for Samburu County (*but see* Spira, 2014); we were interested in assessing the livestock depredation conflict trends since 2010, when our project collaborator - NRT, began collecting data on human-carnivore conflict through trained community scouts and rangers in various community conservancies in Samburu. This long term data monitoring data on human-carnivore conflict blended well with my PhD study objectives.

Livestock keepers' perceptions and tolerance of large carnivores have been quantified through livestock losses and owners' responses to depredation events (Marker *et al.*, 2003a,b), including propensity to kill large carnivores in retaliation (Hazzah *et al.*, 2009). The number of livestock someone would tolerate losing to predators, limit above which that individual would attempt to retaliate, has also been used as a proxy for tolerance (Romañach *et al.*, 2007). We were interested in finding out the specifics of local habitat attributes of areas that consistently recorded higher depredation incidences in comparison to the mean depredation rate; this would allow us to identify cattle depredation hotspots and consequently, be in a position to advice Conservancy managers on which informed decisions would work best based on the nature and circumstances of depredation events. The actual rates of depredation were then compared with the perceived impacts of depredation, through semi-structured questionnaires in selected households within various community conservancies.

Romañach *et al.*, (2007), Woodroffe *et al.*, (2005) and Dickman, (2008); recommended the need, to check the validity of such long-term monitoring data on human-carnivore conflict through subsequent interviews. It is also worthy of note that, unvalidated, self-reported data, are subject to various sources of bias that should be considered in any analysis and interpretation (Spira, 2014; Dickman, 2008; Kissui, 2008a,b). The nature of self-reporting implies that not all conflicts are systematically reported (Gavin *et al.*, 2009), especially when livestock are only injured and not killed (Cotterill, 2013). Therefore, “observed conflicts” often represent only a fraction of total conflict, and are biased towards fatal incidents (Kissui, 2008a,b; Spira, 2014). However, a parallel can be made between self-reported data and the presence-only data commonly used in species distribution models: both lack “absence” data, which in the case of livestock depredation would represent records from sites that did not experience depredation, and are therefore biased representations of reality (Pearce and Boyce, 2006). In the absence of a compensation scheme or other form of support, livestock keepers might have little incentive to report depredation incidents, thus increasing underestimation of the extent of depredation (Kissui, 2008a,b). Conversely, people may exaggerate losses in hope for any sort of support, while compensation might give people an incentive to over-emphasise conflict events (Nyhus *et al.*, 2005; Dickman, 2008, 2010). Cautiousness in the interpretation of data analysis is therefore recommended (Pearce and Boyce, 2006).

#### **3.3.4. Ethnographic study on community practices and perceptions in relation to human-carnivore conflict.**

Ethnographic information was gathered to understand the dynamic relationship between the Samburu pastoralists and the large carnivores (lion, leopard, cheetah, spotted hyaena, striped hyaena and African wild dogs). Ethnographic methods are based on the principle that cultural mechanisms are resources that can be used to facilitate changes in human perceptions towards the environment. This builds on the idea that customs and patterns maintain a dynamic process of creative invention and reinvention, lending itself to a strategy of reviving cultural forms and traditions to effect and serve change (Kleymeyer, 1994; Kuriyan, 2002).

Questionnaires with a semi-structured survey design (*see* Appendix IX) using methods modified from (Romañach *et al.*, 2007; Maddox, 2002; Dickman, 2008; Mwebi 2007; Suryawanshi *et al.*, 2013); were used to survey pastoralist households within selected conservancies in Samburu County. We followed (Romañach *et al.*, 2007) method to sample households within strata (conservancies) using a simple randomized approach of sampling every third household. The surveys tested attitudes towards wildlife in general, as well as attitudes over time towards the large carnivore species. The survey was initially pre-tested on local community members of varying ages, sexes and backgrounds (by conducting mock interviews) to ensure clarity before use.

Demographic variables such as gender (male vs female), age (elderly vs middle-aged vs youth), educational background, socio-economic status (upper vs middle vs lower classes) based on the frequency and variety of stock types (shoats, cattle, donkey and camel), including the most common stock type and reasons for stock preferences were incorporated in the semi-structured questionnaire survey. In addition to the questionnaires, a one-day carnivore conservation workshop was conducted at the tail end of the study at the Kalama Community Wildlife Conservancy in Samburu; with presentations on the management and conservation of wildlife in the area by researchers and community members. The aim of the workshop was to deliberate and discuss which practices would work best for a participatory community approach to improved human-large carnivore co-existence in Samburu.

## **CHAPTER 4. Carnivore carcass consumption and the hunting-scavenging debate.**

### **4.1.1. Résumé du Chapitre 4.**

Les recherches antérieures sur la consommation de proies par les grands carnivores indiquent que chaque espèce d'Ursidés, de Canidés, de Hyénidés et de grands Félidés infligent des dommages distincts sur les carcasses (ossements) des proies consommées sur les sites de tuerie et/ou retrouvées dans les tanières et repaires. Dans ce travail, toutes nos données ont été analysées à l'aide du logiciel de statistiques R-software (version 3.6.0). Notre analyse a étudié les perforations dentaires (mesures) visibles sur les ossements des proies de lions, léopards et d'hyènes tachetés par rapport aux classes de taille des proies, trouvées sur les sites de mort (*kill-site*) provenant de deux régions du Kenya (Samburu et Nakuru). Une comparaison est effectuée avec les perforations laissées par les hyénidés: hyènes tachetées et rayées de Djibouti et, hyène brune de Namibie (données d'après Fourvel, 2012). Les dimensions des perforations dentaires entre zones épiphysaire ou diaphysaire des os longs des proies, suivant les espèces de carnivores, n'ont pu être menées que sur les sites de tuerie, car ces informations sont manquantes sur les sites en repaires. Enfin, nous avons aussi comparé les proportions des éléments squelettiques des proies des carnivores (NISP et MNI) sur nos sites de tuerie par rapport à celles trouvées sur un site d'hyène provenant de Samburu (d'après Mwebi, 2013).

D'après les résultats de l'analyse comparative sur les marques de perforation dentaire ('puncture') de félidés et hyénidés africains sur les os de leurs proies (sites d'abattage et de tanière), il a été possible de distinguer statistiquement les marques dentaires de perforation ('punctures') sur les os de proie entre l'hyène brune et les autres carnivores (hyène rayée, hyène tachetée, lion et léopard). Cependant, il n'a pas été possible de distinguer statistiquement entre les marques dentaires de lion, du léopard et de l'hyène tachetée, alors qu'il est possible de distinguer les marques entre hyène rayée de celles de hyène tachetée, lion et léopard. Ces résultats reflètent et contredisent des recherches antérieures similaires (voir Domínguez-Rodrigo et Piqueras, 2003; Pobiner, 2007; Gidna *et al.*, 2013, 2014; Domínguez-Rodrigo *et al.*, 2012). La taille de la proie affecte les marques dentaires des grands félins et des hyènes sur les éléments osseux de la proie, une force de morsure accrue étant requise sur les os des proies plus grandes. Cela reflète les résultats de recherches antérieures similaires (voir Binford, 1981; Blumenschine, 1986a; Brain, 1981; Mills and Mills, 1978; Haynes, 1980a, b; Kuhn *et al.*, 2009; Gifford-Gonzalez, 2018).

Cependant, l'effet induit par des différences de densité osseuse n'a pas été pris en compte dans notre analyse. Nous n'avons pas pu distinguer statistiquement les perforations (maximum et minimum) des grands félidés et des hyénidés par rapport à leur localisation sur les zones diaphysaire ou épiphysaire des os longs.

Notre comparaison des valeurs NISP et MNI suivant les classes de taille de proie (I-II et III-IV) et par rapport aux sites d'abattage de carnivores et aux sites de repaire indique que des valeurs NISP élevées sur les sites de destruction ne conduisent pas nécessairement à des valeurs MNI plus élevées. Il y a plus de proies dans les sites de repaires d'hyènes que sur les sites de tuerie des lions, des léopards, des guépards ... Cela montre que les environnements écologiques influencent la nature de la consommation d'os avec plus d'os consommés dans les sites en repaires par rapport au site de tuerie.

Nous avons enfin exprimé plusieurs commentaires et critiques sur le débat chasse-charognage. Les lions sont concernés par la majorité des tueries, suivies par le léopard (bien que ces proies soient plus cachées). Il est discutable de savoir si les groupes d'homininés ont été passifs ou plus actifs (plus agressifs) dans la recherche de lieux de tueries faites par les homologues phylogénétiques du léopard dans les arbres au cours du Pléistocène. Notre étude ethnographique a ensuite validé ce point de vue sur la relation entre les pasteurs modernes et les grands carnivores africains. L'étude ethnographique fournit des informations importantes sur la nature des relations entre une communauté de pasteurs africains modernes en Afrique de l'Est et les grands félidés, hyénidés et canidés, qui peuvent être utilisées comme analogues. Il s'agit d'une relation qui mélange la peur et le respect des grands carnivores, en tant que compétiteurs dignes des ressources disponibles. Les membres de la communauté pastorale de Samburu profitent de la chasse du lion, telle que les carcasses d'éléphants, de buffles, d'élans ou de girafes. Les membres de la communauté ont également souligné les difficultés rencontrées lors de la tentative de récupération des tueries de léopards cachés dans les arbres. Cette étude montre à la fois le caractère charognard des humains chaque fois que l'occasion se présente mais aussi combiné avec l'instinct de chasseur chaque fois que le besoin s'en fait sentir. Par conséquent, l'apport de cette étude au débat chasse-charognage dans les études de paléanthropologie est que si ces deux stratégies favorisent une communauté pastorale Africaine moderne, c'est que ce trait doit reposer sur des fondements évolutifs issus des sociétés humaines anciennes.

#### 4.1.2. Summary of Chapter 4.

Past taphonomic research on prey carcass consumption by large carnivores indicate that each species of ursids, canids, hyaenids and large felids makes distinct damage patterns on prey bones during consumption at kill sites and/or den sites. All kill site and den site datasets were analysed using the R-software statistical package (version 3.6.0). This study assessed tooth puncture marks impacted on prey bones of lion, leopard and spotted hyaenas relative to prey class size classes found at kill sites across two Kenyan landscapes (Samburu and Nakuru); in comparison to those impacted on prey bones of hyaenids relative to prey size classes found in a spotted hyaena den and a striped hyaena den (Djibouti); and a brown hyaena den in Namibia. Datasets on den sites were complementary data availed to this study courtesy of Jean-Baptiste Fourvel's PhD study in 2012. Assessments of tooth puncture mark sizes at the epiphyseal vs diaphyseal regions of prey long bones relative to carnivore species, were uniquely assessed at kill sites because such information was missing at the den sites. We also compared the carnivore prey skeletal element proportions (NISP & MNI) at our carnivore kill sites relative to those found at a spotted hyaena den site in Samburu courtesy of Ogeto Mwebi's PhD study in 2013.

From the comparative analysis output on large African felid and hyaenid tooth puncture marks on their prey bones at kill sites and den sites; it was possible to statistically differentiate brown hyaena tooth puncture marks from striped hyaena, spotted hyaena, lion and leopard tooth puncture marks on prey bones. However, it was not possible to statistically differentiate between lion, leopard and spotted hyaena tooth puncture marks on prey bones. It was also possible to statistically differentiate striped hyaena tooth puncture marks from spotted hyaena, lion and leopard tooth puncture marks on prey bones. These findings mirror and contradict past similar research (*see* Domínguez-Rodrigo and Piqueras, 2003; Pobiner, 2007; Gidna *et al*, 2013, 2014; Domínguez-Rodrigo *et al.*, 2012). Prey size affects large felid and hyaenid tooth puncture marks on prey bone elements, with greater bite forces required on bones of larger prey. This mirrors the findings from past similar research (*see* Binford, 1981; Blumenschine, 1986a; Brain, 1981; Mills and Mills, 1978; Haynes, 1980a, b; Kuhn *et al.*, 2009; Gifford-Gonzalez, 2018). However, the perceived effect of differences in prey bone density was not accounted for in our analysis. We could not statistically differentiate tooth puncture marks (maximum and minimum) of large felid and hyaenids relative to placement on diaphyseal and epiphyseal regions of long bones of their prey.

In the comparative assessment of NISP and MNI values for *prey size classes I-II & III-IV* relative to carnivore kill sites and den sites; indicate that high NISP values at kill sites do not necessarily lead to higher MNI values. There were more prey animals at the spotted hyaena den site than the lion, leopard, cheetah and shared lion and spotted hyaena kill sites. This shows that the ecological environments influence the nature of bone consumption with more bones consumed at the den site in comparison to the kill site.

Finally, we provide a complementary critique to the hunting and scavenging debate. Lions made the majority of kills in our modern carnivore kill sites study followed by the leopard, but the leopard kills were more often than not cached up high in trees away from any other potential scavenging mammalian predators. It is debatable whether the hominin groups were passive or aggressive in scavenging such kills made by the phylogenetic counterparts of the leopard from up trees during the Pleistocene. These views were validated further by our ethnographic study component on the relationship between modern day pastoralists and large African carnivores. The ethnographic study offers some deep insights on the nature of relationship between a modern African pastoralist community in East Africa, and modern African large felids, hyaenids and canids; which can be used as a modern analog to infer past human societies in the Pleistocene. It is a relationship that borders on fear and great respect for the large carnivores as worthwhile competitors for available resources. Members of the Samburu pastoralist community occasionally benefit by passively scavenging from lion kills such as elephant, buffalo, eland or giraffe carcasses. The said community members also highlighted the difficulty involved attempting to scavenge from leopard kills cached up high in trees away from human reach. It shows the scavenging trait of humans whenever opportunity arises, and the hunter instinct whenever the need arises. Therefore, the contribution of this study to the hunting-scavenging debate in the domain of anthropology is that, if both hunting and scavenging favours a modern African pastoralist community, then the trait must have evolutionary underpinnings from past human societies.

## 4.2. Carnivore carcass consumption.

It has been widely recorded that each species of ursids, canids, hyaenids and large felids makes distinct damage patterns on prey bones during consumption at kill/scavenging sites or at den sites (Haynes, 1983; Brain, 1981; Bunn, 1983; Dart, 1954; Hill, 1979, 1989; Mills and Mills, 1977, 1978; Skinner *et al.*, 1980; Sutcliffe, 1970; Mwebi, 2013; Fourvel, 2012; Kruuk, 1972; Gidna *et al.*, 2013, 2014, 2015; Yravedra *et al.*, 2014; Fosse *et al.*, 2009; Domínguez-Rodrigo and Pickering, 2010; Stiner *et al.*, 2012; Domínguez-Rodrigo 1997, 1999; Domínguez-Rodrigo and Barba, 2005; Pobiner, 2007). This study assessed tooth puncture marks impacted on bones of lion, leopard and spotted hyaena prey of different weight classes found at kill sites across two Kenyan landscapes (Samburu and Nakuru); in comparison to those impacted on bones of hyaena prey of different weight classes found in a spotted hyaena den and a striped hyaena den (Djibouti); and a brown hyaena den in Namibia (*see* Appendices I, II & III). Information on the nature of damage(s) and/or modification(s) on prey bones collected at each kill site (*see* Appendix IV); and, a comparative sample showing nature of damage(s) and/or modification(s) on prey bones at leopard and lion kill sites (*see* Appendix V), has been availed to better understand large carnivore kill site taphonomy. Datasets on den sites were complementary data availed to this study courtesy of Jean-Baptiste Fourvel's PhD study in 2012 (<https://tel.archives-ouvertes.fr/tel-00830276>). Five prey class size categories were selected for this study following Brain (1981), (*see* Figure 4.1).

Prey size description	Prey Size Class	Weight (Kg)
small	I	< 20
medium small	II	20 - 100
medium large	III	100 - 300
large	IV	300 - 1000
extra large	V	>1000

Table 4.1. The prey size class categories following Brain, 1981.

Large carnivores tend to consume their prey in a generally similar order, depending on the carnivore-prey size ratio and the dentitions of the carnivores in question (Binford, 1981). Felids, hyaenids and canids differ in the degree of damage they can inflict on bone (Binford 1981; Binford and Bertram 1977; Brain 1981; Marean *et al.*, 1992; Haynes, 1983). Such consumption sequences have been documented by Binford (1981), Blumenschine (1986a), Brain (1981), and others. They describe carcass and bone consumption as a process that begins

with the regions offering the highest nutrients yield for the energy spent, plus lowest risks of injury to teeth and mouth; these preferred regions at the beginning of the consumption process includes the viscera and muscles, finally to segments with less muscle mass, or those with musculoskeletal attachments that present more challenges.

When it comes to handling of skeletal elements, a bone-consumer begins with the most nutritionally rewarding and least physically challenging skeletal elements or element portions, leaving the less rewarding and more challenging reserved for later (Blumenschine, 1986a; Brain, 1981; Haynes, 1980a, b, Gifford-Gonzalez, 2018). We adopted the format outlaid by Binford (1981), Binford and Bertram (1977), Marean and Spencer (1991), Marean *et al.*, (1992) and Haynes (1980a, b) to assess bone consumption by large carnivores at kill sites and den sites by compartmentalizing prey bone material into six skeletal regions listed below (*see* Table 4.2).

Nº	<b>Skeletal region</b>
I	cranial
II	vertebrae
III	ribs
IV	scapula and coxal bone
V	long bones
VI	phalanges and sesamoids

*Table 4.2. Prey skeletal consumption by the terrestrial mammalian large carnivores demarcated into six regions adopting the format outlaid by Binford (1981), Binford and Bertram (1977), Marean and Spencer (1991), Marean et al., (1992) and Haynes (1980a, b).*

Data from 29 kill sites (Samburu National Reserve and Soysambu Conservancy in Kenya) were catalogued and assessed to determine surviving prey bone elements (NISP) from lion, leopard and lion-and-spotted hyaena kill sites. Lion, leopard and spotted hyaena scat were assessed to determine interspecies variations in morphometry in terms of global scat dry weight, scat fragment width (maximum and minimum) and scat fragment heights. Even though the actual number of large carnivore kill sites were 29; we excluded a cheetah kill site and a late addition of leopard kill site from the analyses relative to tooth punctures impacted by large carnivores on prey bones and on the assessment for number of identified specimen (NISP). There were no tooth puncture marks on the prey skeletal remains from the cheetah kill (a juvenile gerenuk); and concerning the late addition of a leopard kill (a female impala adult), there was a time constraint in processing it and taking measurements of the tooth punctures inflicted by the

leopard on the prey bones. However, the said impala carcass was included in a basic comparative analysis of prey size class representation between kill sites and den sites (*see* Table 4.13 and Figure 4.7).

All kill site and den site datasets were analysed with the R-software statistical package (version 3.6.0) through the R-studio interphase. In the first step of analysis, the kill and den site data were graphed using QQ plots in the *ggplot2* package in R-software. The datasets were then individually subjected to Shapiro-Wilk's normality tests to confirm if they followed a normal distribution. QQ plots and the Shapiro-Wilk's normality test are used to check whether a given data follows normal distribution (R Core Team, 2019).

The P value from the Shapiro-Wilk's normality test for each data set was significant at ( $< 0.05$ ), implying that the maximum and minimum puncture width datasets from kill sites and den sites came from non-normal distributions. The non-parametric equivalent of a one-way ANOVA - the Kruskal-Wallis rank sum test, was therefore used to analyse relationships between carnivore species and prey weight classes on the maximum and minimum puncture width sizes. Significant outputs from the Kruskal-Wallis rank sum tests were further subjected to Wilcoxon rank sum tests to calculate pairwise comparisons between groups.

Tooth marks recorded and measured in this study were limited to punctures only. Punctures were defined as circular to oval depressions in which the entire thickness of compact bone has been breached (Binford, 1981; Maguire *et al.*, 1980). Our method of collection of carnivore tooth mark data sets at our large carnivore kill sites was similar to the method used by Fourvel's PhD study in 2012; but dissimilar to the method used by Mwebi's PhD study in 2013. To this end, we assessed the effect of carnivore species (lion, leopard, spotted hyaena, brown hyaena and striped hyaena), prey size class (*I-II & III-IV*) and prey skeletal region (cranial, vertebrae, ribs, scapula & coxal bone, long bones and phalanges and sesamoids) on maximum and minimum tooth puncture widths on prey bones at kill sites and den sites within the context of our study and Fourvel's PhD study in 2012. The effect of placement (diaphyseal vs epiphyseal) on tooth mark size on long bones could not be assessed for den sites because of such details were missing.

A compliment to the hunting vs scavenging debate is then made at the end of this chapter (*see* Chapter 4.7), incorporating result outputs from carnivore carcass consumption (*see* Chapter 4) alongside highlights from an ethnographic study component (*see* Chapter 6) with a view of making an inference to the past human societies in the Pleistocene.

#### 4.2.1. Effect of carnivore species on tooth puncture widths between kill site and dens and between species.

All kill site data are primary data collected in the duration of this PhD. All hyaenid den site data are complimentary courtesy of Fourvel (2012). The data sets include: spotted hyaena and striped hyaena dens in Djibouti and brown hyaena den in Namibia. Summary statistics were generated from the R-software indicating the sample size (n), mean, standard deviation (SD), median and interquartile range (IQR) for maximum tooth puncture widths (*see* Table 4.3) and minimum tooth puncture widths (*see* Table 4.4). There were no minimum puncture width measurements from the brown hyaena den, hence the brown hyaena was excluded from the analysis on carnivore interspecies variation relative to minimum puncture widths.

<b>Carnivore</b>	<b>count</b>	<b>mean</b>	<b>SD</b>	<b>median</b>	<b>IQR</b>
spotted hyaena	71	5.67	2.66	5.00	3.00
brown hyaena	34	8.36	3.76	7.50	4.00
striped hyaena	80	4.10	2.27	4.00	2.35
lion	74	5.58	3.17	4.50	3.28
lion-and-spotted hyaena	34	7.76	3.11	6.75	4.65
leopard	49	5.42	2.95	4.7	3.3

*Table 4.3. Summary statistics on maximum tooth puncture widths impacted on prey bone elements by large carnivores at kill sites in Kenya and den sites in Namibia and Djibouti. R-software statistical package (version 3.6.0).*

<b>Carnivore</b>	<b>count</b>	<b>mean</b>	<b>SD</b>	<b>median</b>	<b>IQR</b>
spotted hyaena	71	4.28	2.27	4	2
striped hyaena	80	3.20	1.61	3	2
lion	74	4.31	2.40	3.6	2.27
lion-and-spotted hyaena	34	5.86	2.25	5.4	2.43
leopard	49	4.07	2.32	3.5	2.10

*Table 4.4. Summary statistics on carnivore species kill sites and den sites data for minimum puncture widths on prey bone elements. R-software statistical package (version 3.6.0).*

We assessed maximum tooth puncture widths (*see* Table 4.5 and Figure 4.1a) and minimum tooth puncture widths (*see* Table 4.6 and Figure 4.1b) impacted on prey bones by large carnivores at kill sites and dens sites in Kenya, Djibouti and Namibia relative to carnivore species (lion, leopard, spotted hyaena, striped hyaena & brown hyaena). The carnivore types at kill sites included, lion-only kill sites, leopard only kill sites and lion-and-spotted hyaena kill sites (where there was confirmed evidence of spotted hyaenas scavenging at a lion kill).

Kruskal-Wallis rank sum test					
Kruskal-Wallis chi-squared		df		P-value	
70.812		5		6.944e-14	
Wilcoxon rank sum test					
	spotted hyaena	brown hyaena	striped hyaena	lion	lion and spotted hyaena
brown hyaena	0.00011	-	-	-	-
striped hyaena	0.00011	1.1e-09	-	-	-
lion	0.47878	2.8e-05	0.00096	-	-
lion-and-spotted hyaena	0.00127	0.47878	1.0e-08	0.00012	-
leopard	0.47878	7.6e-05	0.00682	0.86257	0.00032

*Table 4.5. Test results on the inter carnivore species variation of maximum tooth puncture widths impacted on prey bones at kill sites (lion, leopard, lion-and-spotted hyaena) in relation to those impacted on prey bones at den sites (spotted, striped and brown hyaena). R-software statistical package (version 3.6.0).*

Kruskal-Wallis rank sum test				
Kruskal-Wallis chi-squared		df	P-value	
44.752		4	4.477e-09	
Wilcoxon rank sum test				
	spotted hyaena	striped hyaena	lion	lion and spotted hyaena
striped hyaena	0.00153	-	-	-
lion	0.74028	0.00293	-	-
lion-and-spotted hyaena	0.00017	2.2e-09	0.00012	-
leopard	0.44191	0.03457	0.51438	5.6e-05

*Table 4.6. Test results on the effect of carnivore species at kill sites (lion, leopard, lion-and-spotted hyaena) in relation to carnivore species at den sites (spotted, striped and brown hyaena) on minimum puncture widths on prey bone elements. R-software statistical package (version 3.6.0).*

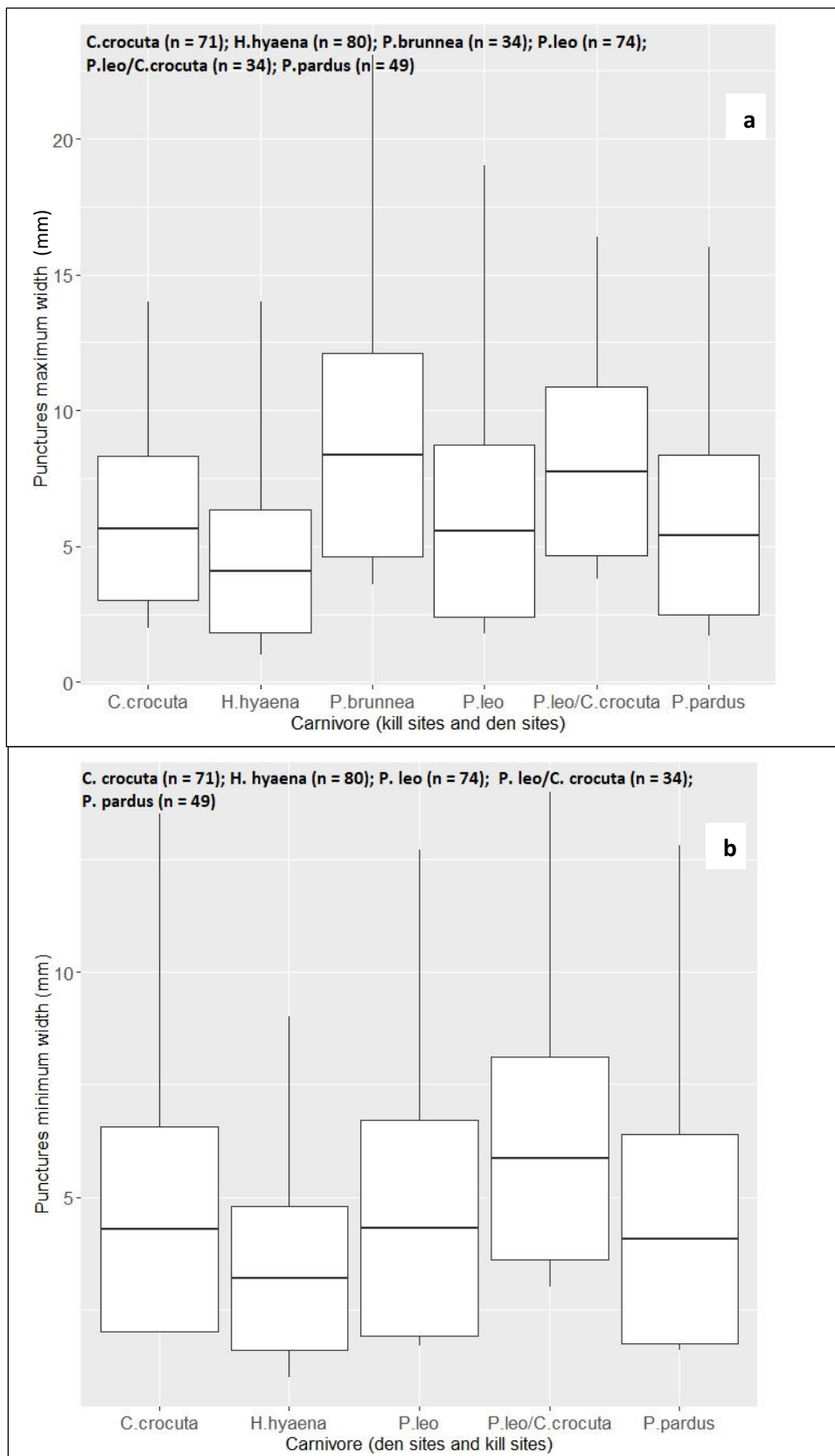


Figure 4.1. Carnivore tooth puncture marks (maximum and minimum widths) at kill sites and den sites.

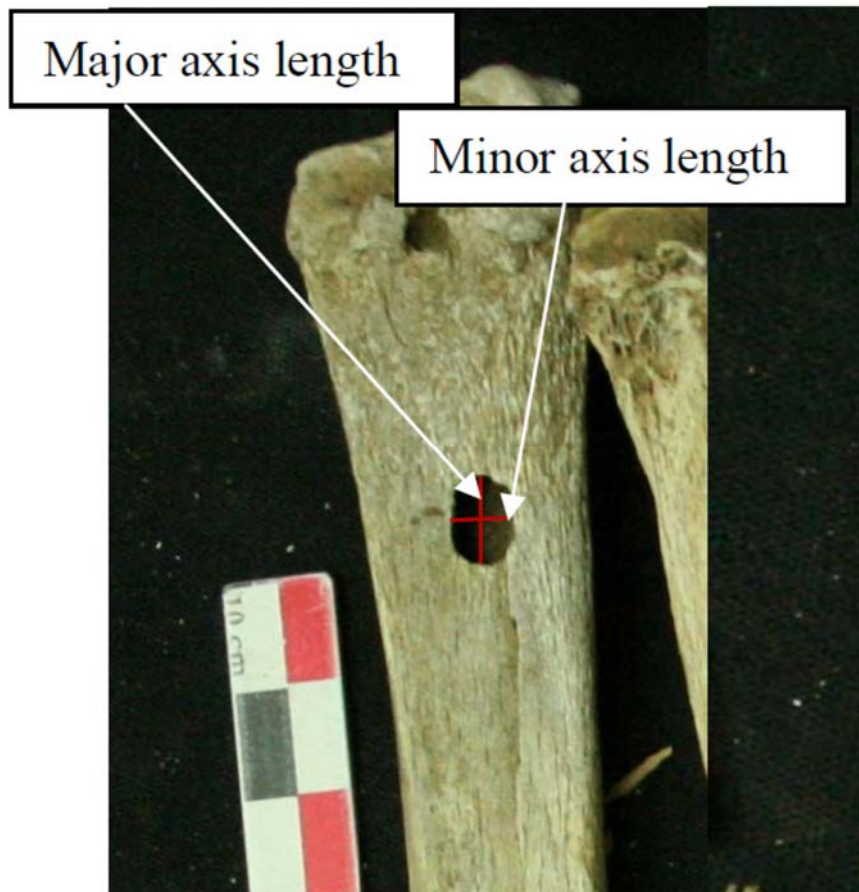
We conducted separate Kruskal-Wallis rank sum tests for maximum and minimum tooth puncture widths, followed by separate Wilcoxon rank sum tests. The Kruskal-Wallis rank sum tests (for maximum and minimum tooth puncture widths respectively) showed that carnivore species (lion, leopard, lion-and-spotted hyaena, spotted hyaena and striped hyaena) had distinct tooth puncture marks (maximum and minimum widths) ( $P < 0.05$ ); however when pairwise comparisons of the tooth puncture marks were conducted through separate Wilcoxon rank sum tests (for maximum and minimum tooth puncture widths respectively), there were no significant differences ( $P > 0.05$ ) between lion-only vs spotted hyaena-only; leopard-only vs spotted hyaena-only; and, lion-only vs leopard-only tooth puncture marks (maximum and minimum widths) on prey bones. In addition, no significant differences ( $P > 0.05$ ) were observed between lion-and-spotted hyaena vs brown hyaena-only tooth puncture marks (maximum widths) on prey bones (data on minimum tooth puncture widths for the brown hyaena were missing hence excluded from our comparative analyses).

Differences were significant ( $P < 0.05$ ) between spotted hyaena-only vs striped hyaena-only; lion-only vs striped hyaena-only; leopard-only vs striped hyaena-only; lion-and-spotted hyaena vs leopard-only; lion-and-spotted hyaena vs spotted hyaena-only; lion-and-spotted hyaena vs lion-only; lion-and-spotted hyaena vs striped hyaena-only tooth puncture marks (maximum and minimum widths) on prey bones; differences were also significant ( $P < 0.05$ ) between brown hyaena-only vs spotted hyaena-only; brown hyaena-only vs striped hyaena-only; brown hyaena-only vs lion-only; brown hyaena-only vs leopard-only tooth puncture marks (maximum widths) on prey bones (*see* Table 4.5 & Figure 4.1a for maximum puncture widths at kill sites and den sites; and, Table 4.6 & Figure 4.1b for minimum puncture widths at kill sites and den sites).

From our combined analysis of large felid and hyaenid tooth puncture marks on their prey bones at kill site and den sites, it was not possible for us to statistically differentiate between lion, leopard and spotted hyaena tooth puncture marks (maximum and minimum widths) on prey bones. This mirrors findings by Domínguez-Rodrigo and Piqueras, (2003); (*but see* Pobiner, 2007 and Gidna *et al*, 2014). Our findings both contradict and support findings by Domínguez-Rodrigo *et al.*, (2012) that postulated that the three major groups of carnivores (felids, hyaenids and canids) can be successfully differentiated; we were not able to statistically differentiate lion, leopard and spotted hyaena tooth puncture marks.

However, we were able to statistically differentiate brown hyaena tooth puncture marks from striped hyaena, spotted hyaena, lion and leopard tooth puncture marks on prey bones. We were also able to statistically differentiate striped hyaena tooth puncture marks from spotted hyaena, lion and leopard tooth puncture marks on prey bones (*see* Figures 4.1a,b).

In the analysis involving shared lion and spotted hyaena kill sites, it was not possible to accurately account for the number of lions that partly consumed their prey carcass(es) before spotted hyaena(s) visited and either took over the carcass from the lion(s) or, waited for the lion(s) to abandon the kill(s) before moving in to consume what was left over by the lion(s). Tooth puncture marks (maximum and minimum widths) on prey bones from the shared lion and spotted hyaena kill sites were statistically different from leopard, spotted hyaena, lion and striped hyaena tooth puncture marks. However, the said tooth marks from shared lion and spotted hyaena could not be statistically be differentiated from brown hyaena tooth puncture marks (maximum width only, since data on minimum widths for brown hyaena were missing).



*Figure 4.2. Photograph showing typical maximum and minimum tooth puncture mark measurements. Adopted from Mwebi (2013).*

#### 4.2.2. Carnivore tooth puncture marks relative to prey size class at kill sites and den sites.

We assessed maximum tooth puncture widths (*see* Table 4.7 and Figure 4.3a) and minimum tooth puncture widths (*see* Table 4.8 and Figure 4.3b) impacted on prey bones by large carnivores at kill sites and dens sites in Kenya, Djibouti and Namibia relative to prey size class.

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared	df	P-value
70.515	1	2.2e-16

*Table 4.7. Test results on the effect of prey class size on large carnivore maximum tooth puncture widths at kill sites and den sites. R-software statistical package (version 3.6.0).*

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared	df	P-value
61.423	1	4.603e-15

*Table 4.8. Test results on the effect of prey class size on large carnivore minimum tooth puncture widths at kill sites and den sites. R-software statistical package (version 3.6.0).*

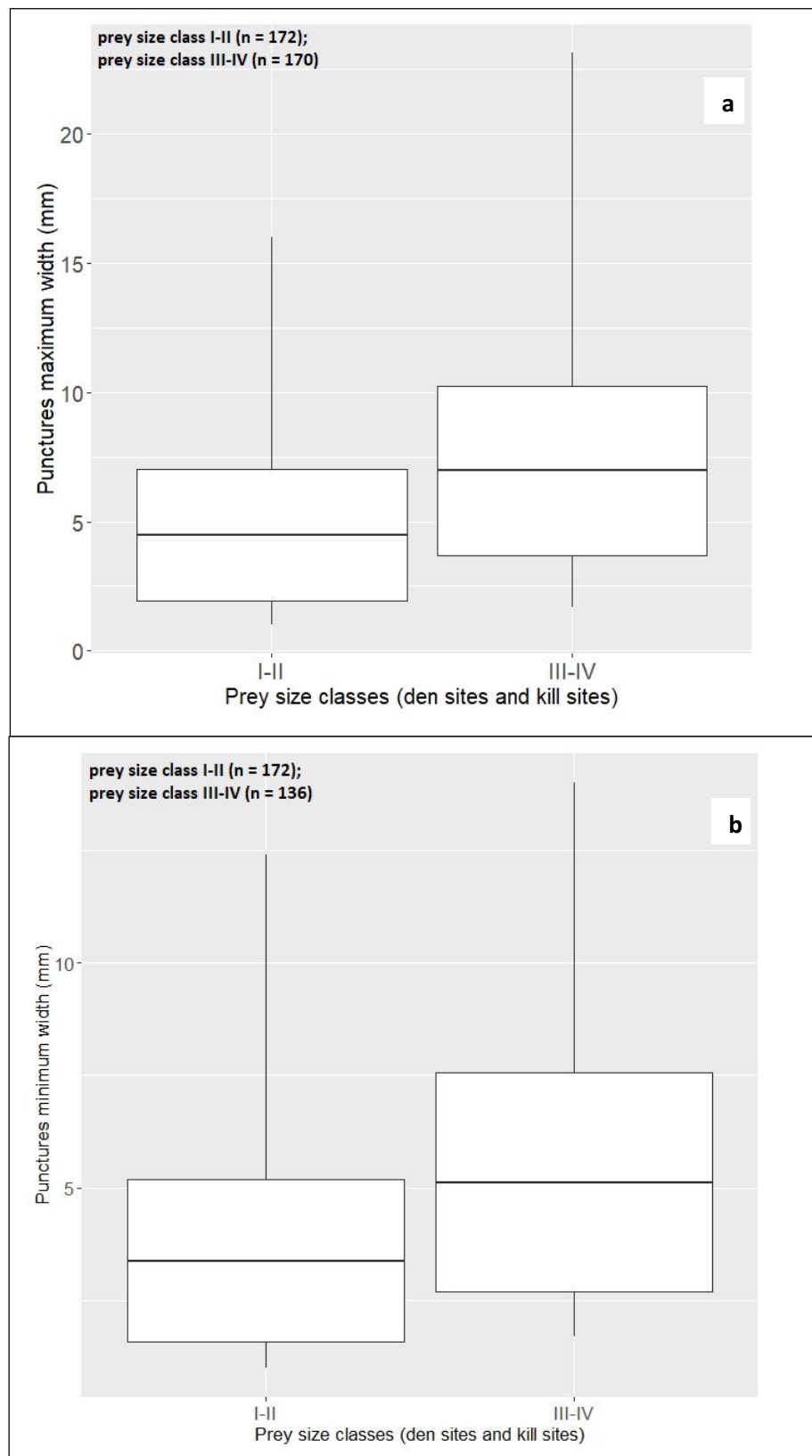


Figure 4.3. Carnivore tooth puncture marks relative to prey size class at kill sites and den sites. R-software statistical package (version 3.6.0).

When separate Kruskal-Wallis rank sum tests (for maximum and minimum tooth puncture widths relative to prey size class at kill sites and den sites respectively) were computed to assess the effect of prey size class on lion, leopard, lion-and-spotted hyaena, spotted hyaena, brown and striped hyaena tooth puncture marks (maximum and minimum widths) on prey bone elements; significant differences ( $P < 0.05$ ) between the *prey size classes I-II vs III-IV* were observed (see Tables 4.7 & 4.8 and Figure 4.3a,b).

Predator-prey size relationships have been recognized as central in structuring trophic linkages within food webs in both marine and terrestrial ecosystems (Cohen *et al.*, 1993; Woodward *et al.*, 2005). Large mammalian carnivores commonly kill prey equal to or larger than their own body mass (Carbone *et al.*, 1999). The expanding upper size limit to the prey species utilized has led to suggestions that the dietary range of larger carnivores is likely to be broader than that of smaller carnivores (Rosenzweig, 1966; Gittleman, 1985; Owen-Smith and Mills, 2008).

It is important to note that our analysis only differentiates that prey size class significantly affects large felid and hyaenid tooth puncture marks (maximum and minimum widths) on prey bone elements; but the perceived effect of differences in prey bone density is not accounted for in our analysis due to lack of the requisite resources, equipment and expertise required for accurate measurements of prey bone densities.

#### 4.2.3. Carnivore tooth puncture marks relative to prey skeletal region at kill sites and den sites.

When separate Kruskal-Wallis rank sum tests (for maximum and minimum tooth puncture widths relative to prey skeletal region at den sites respectively) were computed to assess the effect of prey skeletal region (cranial, vertebrae, ribs, scapula & coxal bone, long bones and phalanges & sesamoids), on lion, leopard, lion-and-spotted hyaena tooth puncture marks (maximum and minimum widths) on prey bone elements; differences were significant ( $P < 0.05$ ) between the prey skeletal region relative to tooth puncture marks (maximum and minimum widths) impacted on the prey bones by large carnivores at den sites. Further, when the Wilcoxon rank sum test was conducted to calculate pairwise comparisons between groups for maximum puncture widths at den sites; differences were significant ( $P < 0.05$ ) between the following prey skeletal region combinations: long bones vs phalanges & sesamoids; long bones vs vertebrae; and, long bones vs scapula & coxal regions of the prey skeletons (*see* Table 4.9 and Figure 4.5a). When the Wilcoxon rank sum test was conducted to calculate pairwise comparisons between groups for minimum puncture widths at den sites; differences were significant ( $P < 0.05$ ) between the vertebrae and long bones (*see* Table 4.10 and Figure 4.5b).

Kruskal-Wallis rank sum test					
Kruskal-Wallis chi-squared		df		P-value	
32.197		5		5.431e-06	
Pairwise comparisons using Wilcoxon rank sum test					
	cranial	long bones	phalanges & sesamoids	ribs	scapula & coxal
long bones	0.7006	-	-	-	-
phalanges & sesamoids	0.0101	0.0049	-	-	-
ribs	0.4976	0.6744	0.3377	-	-
scapula & coxal	0.2355	0.1580	0.0564	0.9461	-
vertebrae	0.0027	2.6e-05	0.6744	0.4638	0.0310

*Table 4.9. Test results on the effect of prey skeletal region on large carnivore maximum tooth puncture widths at kill sites and den sites. R-software statistical package (version 3.6.0).*

Kruskal-Wallis rank sum test					
Kruskal-Wallis chi-squared		df		P-value	
21.122		5		0.0007681	
Pairwise comparisons using Wilcoxon rank sum test					
	cranial	long bones	phalanges & sesamoids	ribs	scapula & coxal
long bones	0.412	-	-	-	-
phalanges & sesamoids	<b>0.022*</b>	<b>0.017*</b>	-	-	-
ribs	0.649	0.877	0.402	-	-
scapula & coxal	0.411	0.836	<b>0.025*</b>	1.000	-
vertebrae	<b>0.017*</b>	<b>0.012*</b>	0.377	0.412	<b>0.025*</b>

*Table 4.10. Test results on the effect of prey skeletal region on large carnivore minimum tooth puncture widths at kill sites and den sites. R-software statistical package (version 3.6.0).*



*Figure 4.4. Photograph of a common eland carcass at a lion kill site at the Soysambu Conservancy, Nakuru County. Photo credit: Titus Adhola.*

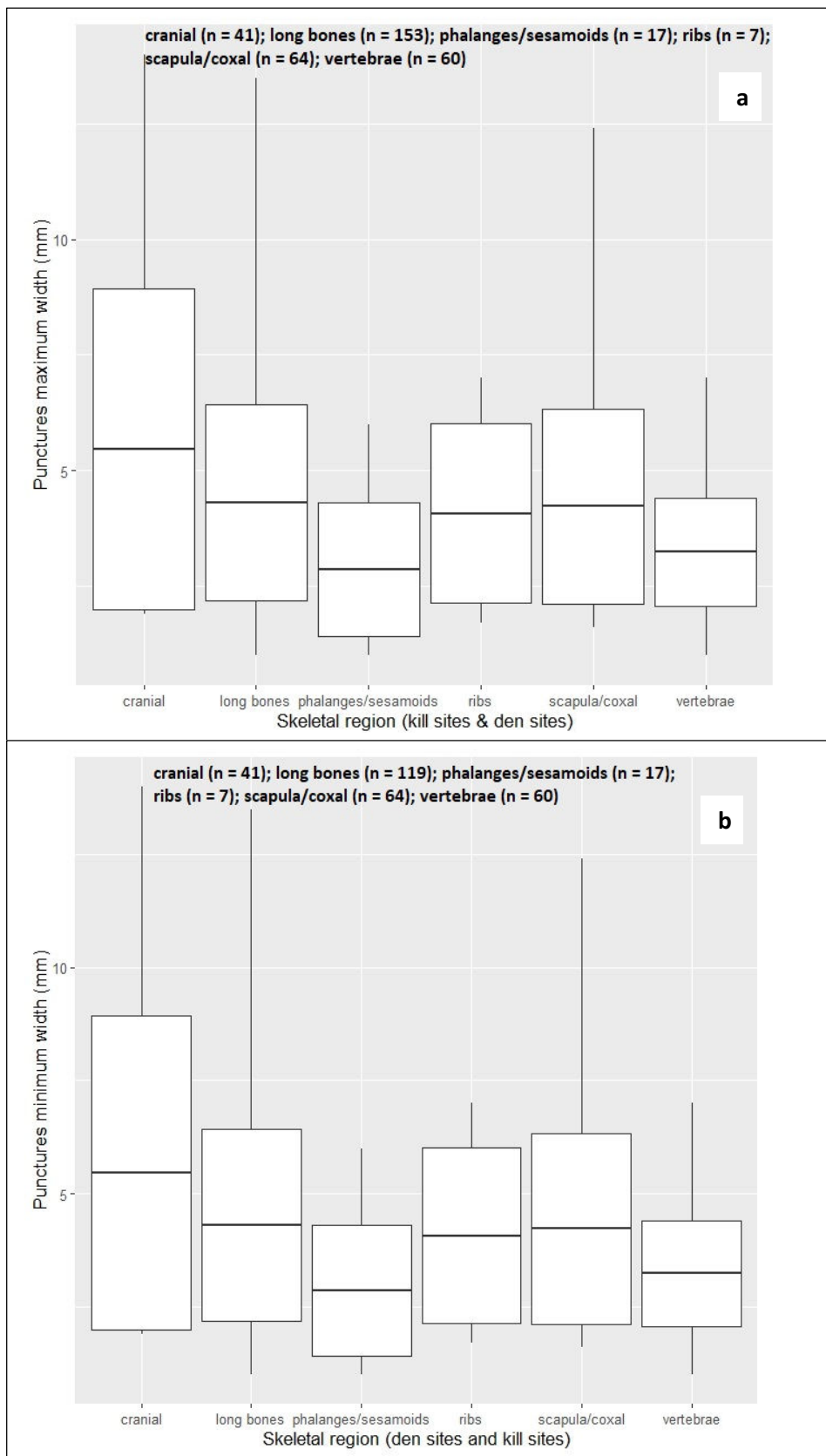


Figure 4.5. Carnivore tooth puncture marks relative to prey skeletal region at kill sites and den sites. R-software statistical package (version 3.6.0).

What comes out clearly from our study results is that sizes of large African felid and hyaenid tooth puncture marks on prey bones are influenced by prey skeletal region. It is expected that different skeletal regions offer varying degrees of challenge to a carnivore during consumption of prey bones owing to differences in prey bone densities with the hyaenids having a superior bone crunching capability than the large felids (*see* Binford, 1981; Blumenschine, 1986a,b; Brain, 1981; Haynes, 1980a,b; Binford and Bertram, 1977).

Mammalian carnivores often acquire prey animal bodies some distance from where they prefer to consume them. Prey that are small relative to the predator are transported whole to preferred locations. Larger prey animal bodies dismembered during the kill or initial consumption may be carried in segments from the acquisition site. Some species' repeated actions in transporting body segments build up substantial accumulations of bones in one locale (Gifford-Gonzalez, 2018; Binford and Bertram, 1977; Mills and Mills, 1978; Kuhn *et al.*, 2009).

According to their overall size in relation to the animal consumed and to their dentitions, mammalian carnivores differ in the degree of damage they can inflict on bone; nonetheless, they tend to feed on bodies of larger animals in a generally similar order, and likewise, those that obtain nutrients from within bones gnaw elements in a similar sequence (Binford, 1981; Blumenschine, 1986a; Brain, 1981; Haynes, 1980b). A general order of prey bone consumption by mammalian carnivores according to Binford (1981), Binford and Bertram (1977), Brain (1981) and Marean *et al.*, (1992) begins with the least dense and most porous bones, cartilaginous ends and then bones of ribs, vertebrae, scapulae, innominates, and other bones; this is then followed by consumption of slightly denser cancellous epiphyses of long bones; and finally consumption of denser compact bone elements enclosing edible soft tissues. Parts of the prey cranium and diaphysis of prey long bones offer the toughest challenge to any carnivore regardless of its family (hyaenid, canid or felid) (Gifford-Gonzalez, 2018; Binford and Bertram, 1977; Mills and Mills, 1978; Kuhn *et al.*, 2009; Haynes, 1980a, b).

#### 4.2.4. Carnivore tooth puncture marks relative to placement (diaphyseal vs epiphyseal) on prey long bones at kill sites in Kenya.

It was only possible to assess the effect of placement on tooth mark size on prey long bones at carnivore kill sites only. To this end we assessed the effect of placement on maximum and minimum tooth puncture widths on prey long bones at carnivore kill sites in Kenya. When separate Kruskal-Wallis rank sum tests (for maximum and minimum tooth puncture widths respectively) were computed to test for the effect of placement on maximum tooth puncture widths on prey long bones at carnivore kill sites; it was noted that differences in maximum and minimum tooth puncture widths were not significant ( $P > 0.05$ ) relative to placement (diaphyseal vs epiphyseal) on the prey long bones (*see* Table 4.11 & 4.12 and Figure 4.6a,b).

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared	df	P-value
0.027939	1	0.8673

Table 4.11. Carnivore maximum width tooth puncture marks relative to placement (diaphyseal vs epiphyseal) on prey long bones at kill sites. R-software statistical package (version 3.6.0).

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared	df	P-value
0.062888	1	0.802

Table 4.12. Carnivore minimum width tooth puncture marks relative to placement (diaphyseal vs epiphyseal) on prey long bones at kill sites. R-software statistical package (version 3.6.0).

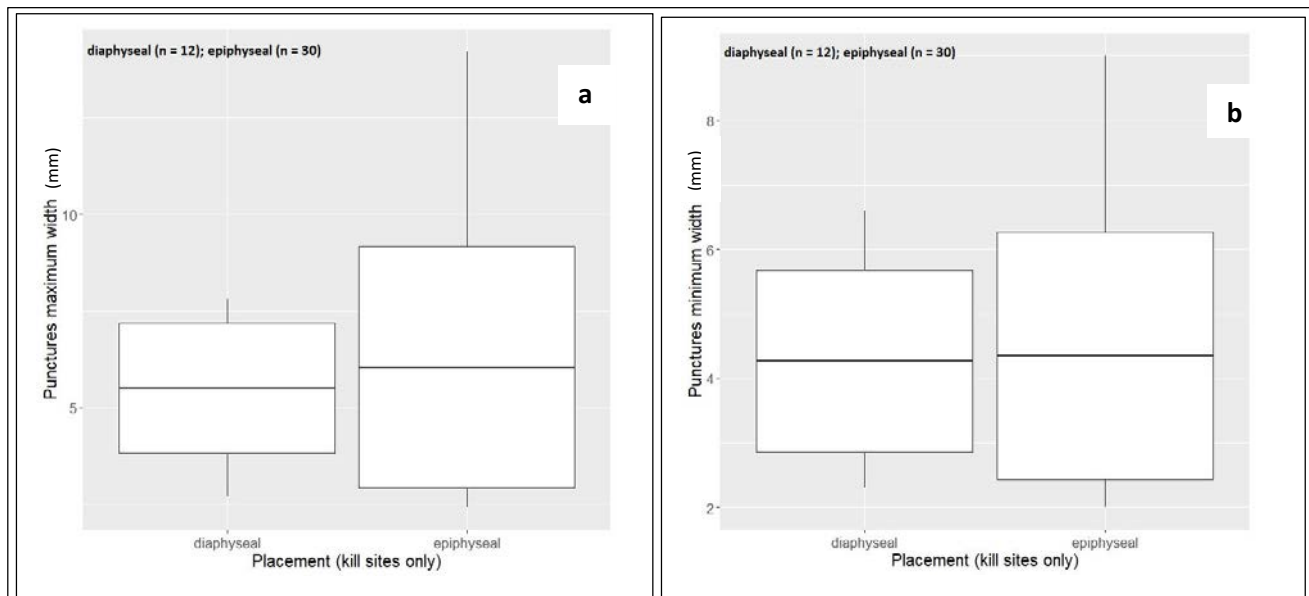


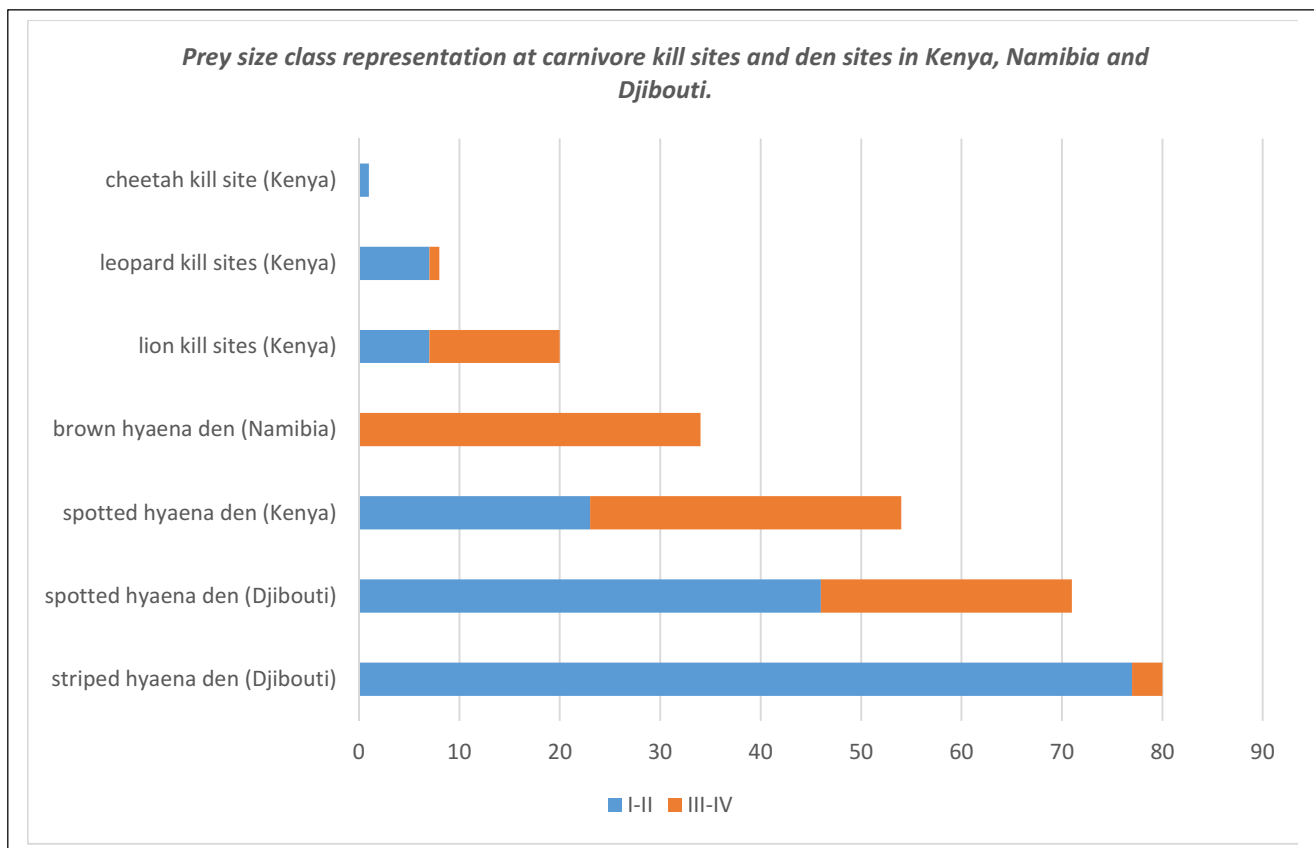
Figure 4.6. Carnivore tooth puncture marks impacted on the diaphyseal and epiphyseal regions of long bones of carnivore prey at kill sites. R-software statistical package (version 3.6.0).

#### 4.2.5. Carnivore prey size class representation at kill sites and den sites.

Our kill site data sets were assessed alongside hyaenid den site datasets courtesy of Fourvel (2012) and Mwebi (2013) to provide a general overview, and better understanding of the relative nature of prey size class representation at African carnivore kill sites and den sites within the context of Table 4.13 and Figure 4.7.

Prey size class	Kill sites			Den sites			
	Lion (Kenya)	Leopard (Kenya)	Cheetah (Kenya)	striped hyaena (Djibouti)	spotted hyaena (Djibouti)	Spotted hyaena (Kenya)	brown hyaena (Namibia)
I-II	7	7	1	77	46	23	0
III-IV	13	1	0	3	25	31	34
<b>Sample size (n)</b>	20	8	1	80	71	54	34

*Table 4.13. Prey size class representation at large carnivore kill sites and den sites in Kenya, Namibia and Djibouti.*



*Figure 4.7. Prey size class representation at large carnivore kill sites and den sites in Kenya, Namibia and Djibouti.*

Even though the kill site data and den site data were collected from separate regions at a regional African scale (Kenya, Djibouti and Namibia); the prey size class constitution at the spotted hyaena den sites in two separate regions (Kenya & Djibouti) mirrored similar (Kenya) and exact opposite (Djibouti) of the lion's kill site preferences. The lion seemed to have a prey preference skewed towards *bigger size classes III-IV*, but also preying upon smaller prey of the size class I-II. The inter-species relationship between the lion and spotted hyaena in terms of competition for prey has been discussed in detail in Chapter 6 of this PhD thesis.

The brown hyaena on the other hand had an exclusive preference for the *prey size classes III-IV* at its den sites. The leopard, cheetah and striped hyaena prey preferences were predominantly skewed towards *prey of size classes I-II* at kill sites (leopard and cheetah) and den sites (striped hyaena). It is however important to note that our sample size for cheetah kill sites was extremely small to be used for any meaningful comparisons.

At a very general scale, our study mirrors Owen-Smith and Mills, (2008) who studied five carnivore species; lion, leopard, spotted hyaena, cheetah and African wild dog in Kruger National Park, South Africa, observed that large carnivores selectively favoured prey species approximately half to twice their mass, within a total prey size range from an order of magnitude below to an order of magnitude above the body mass of the predator. They noted that the three smallest carnivores, i.e. leopard, cheetah and wild dog, showed high similarity in prey species favoured. They concluded that despite overlap in prey size range, each carnivore showed a distinct dietary preference.

#### 4.2.6. Assessment of prey skeletal part representation at kill sites and den sites.

Bone and tooth specimen were identified to skeletal part or element whenever possible. The number of identified specimens (NISP) was then calculated by summing up all the identified elements whether complete or not for each species identified (Mwebi, 2013; Chazan and Horwitz, 2007; Klein and Cruz-Urbe, 1984, Lyman, 1994, 2008). Unlike den sites where the prey killed by the carnivore may be unknown at the beginning of an assessment by a zooarchaeologist; the prey found killed at a kill site/scavenging site may be easily identifiable by the ecologist, hence the minimum number of individuals (MNI) may be straight forward without involving any formula to compute. To that end, the primary focus of study was to compare the NISP for prey skeletal parts found at carnivore kill sites relative to those found at carnivore den sites. This will help to better understand and/or account for any differences in the relative net results of NISP and MNI of prey skeletal elements at carnivore kill sites and den sites. The need to use the minimum number of elements (MNE) as a method of prey bone quantification never arose. NISP and MNE are both accepted methods of bone quantification in zooarchaeology (Lyman, 2008; Grayson and Frey, 2004; Gifford-Gonzalez, 2018).

It is important to note that the NISP numbers for prey bone elements for camel, elephant and grevy's zebra at our carnivore kill sites are not a true reflection of their prey bone elements that were discovered at the kill sites in the Samburu National Reserve; this was due to circumstances beyond our control, some challenges were human induced while others were logistics related especially in the case of fresh elephant and camel remains that would require some natural decomposition *in situ* before collection of skeletal remains. In addition, there was not enough space in the field car to ferry whole elephant and/or camel remains from the Samburu game reserve, to our laboratory in Nairobi at the Osteology section in National Museums of Kenya for processing. We computed a general output of 837 prey bones for NISP and 28 for MNI from all our carnivore kill sites in Samburu and Nakuru Counties (*see* Table 4.14). We then compared the carnivore prey skeletal element proportions (NISP & MNI) at our carnivore kill sites with those found at a spotted hyaena den in Samburu (*see* Table 4.15) from data availed to this study courtesy of Mwebi (2013). Since dissimilar methods had been used to account for proportions of bones in prey skeletal regions in the current study and that of Mwebi (2013), it was only practical to standardise comparison between prey representation (NISP & MNI) from kill site data and den site data through ungulate prey representation within the context of *prey size classes I-II & III-IV* (*see* Table 4.16 & 4.17 and Figures 4.8 to 4.12).

Family	Species	Common name	Size class	NISP	MNI
Bovidae	<i>Eudorcas thompsonii</i>	thompson's gazelle	I	64	1
Bovidae	<i>Ovis/Capra</i>	domestic sheep/goat (shoats)	I	9	2
Bovidae	<i>Aepyceros melampus</i>	impala	II	248	7
Bovidae	<i>Litocranius walleri</i>	gerenuk	II	41	2
Bovidae	<i>Bos taurus</i>	domestic cow	III	17	1
Bovidae	<i>Oryx beisa</i>	beisa oryx	III	7	1
Equidae	<i>Equus quagga</i>	common zebra	III	215	4
Equidae	<i>Equus grevyi</i>	grevys zebra	IV	4	1
Bovidae	<i>Tragelaphus strepsiceros</i>	greater kudu	III	3	1
Bovidae	<i>Tragelaphus oryx</i>	common eland	IV	103	1
Bovidae	<i>Syncerus caffer</i>	buffalo	IV	41	1
Camelidae	<i>Camelus dromedarius</i>	domestic camel	IV	19	3
Elephantidae	<i>Loxodonta africana</i>	elephant	V	5	1
Viveridae	<i>Civettictis civetta</i>	African civet		52	1
Canidae	<i>Canis mesomelas</i>	black-backed jackal		9	1
				<b>837</b>	<b>28</b>

Table 4.14. Cumulative NISP and MNI computed from lion, leopard, cheetah and lion-and-spotted hyaena kill sites (Samburu and Nakuru Counties).

Family	Species	Common name	Size class	NISP	MNI
Bovidae	<i>Aepyceros melampus</i>	impala	II	2	2
Bovidae	<i>Gazella granti</i>	grant's gazelle	II	13	2
Bovidae	<i>Litocranius walleri</i>	gerenuk	II	13	3
Suidae	<i>Phacochoerus aethiopicus</i>	desert warthog	II	12	3
Bovidae	<i>Rhynchotragus kirkii</i>	dik dik	I	6	1
Bovidae	<i>Oreotragus oreotragus</i>	klipspringer	II	1	1
Bovidae	<i>Capra/Ovis</i>	domestic sheep/goat	II	78	11
Bovidae	<i>Bos taurus</i>	domestic cow	III	135	13
Camelidae	<i>Camelus dromedarius</i>	domestic camel	IV	2	1
Bovidae	<i>Oryx beisa</i>	beisa oryx	III	2	1
Bovidae	<i>Tragelephus strepsiceros</i>	greater kudu	III	2	1
Equidae	<i>Equidae sp</i>	donkey/zebra	III	9	2
Equidae	<i>Equus asinus</i>	domestic Donkey	III	63	6
Equidae	<i>Equus quagga</i>	common zebra	III	2	2
Equidae	<i>Equus grevyi</i>	grevy's zebra	III	9	4
Giraffidae	<i>Giraffa camelopardalis</i>	reticulated giraffe	V	15	3
Bovidae	<i>Syncerus caffer</i>	buffalo	IV	4	1
Rhinocerotidae	<i>Diceros bicornis</i>	black rhinoceros	V	5	2
Bovidae	Bovid II	sheep/goat size	II	5	3
Ungulate	Bos size/Bovid III	cow size	III	9	3
Ungulate	Ungulate	ungulate		29	-
Hominidae	<i>Homo sapiens</i>	human being		3	2
Cercopithecidae	<i>Papio cynocephalus</i>	yellow baboon		1	1
Accipitridae	<i>Trigonoceps occipitalis</i>	white-headed vulture		7	2
Felidae	<i>Acinonyx jubatus</i>	cheetah		20	1
Hyaenidae	<i>Crocuta crocuta</i>	spotted hyaena		196	6
Hyaenidae	<i>Hyaena hyaena</i>	striped hyaena		5	1
Procaviidae	<i>Procavia capensis</i>	rock hyrax	I	205	5
Testudinidae	<i>Testudo pardalis</i>	leopard tortoise		2	1
<b>Totals</b>				<b>826</b>	<b>84</b>
<b>Totals excluding those identified as Bovid II &amp; III and ungulate</b>				<b>812</b>	<b>78</b>

Table 4.15. Cumulative NISP and MNI computed from a spotted hyaena den site in Samburu (SaNGuODen1) County courtesy of Mwebi (2013).

Cheetah kill sites	Skeletal region represented						NISP	MNI
	cranial	vertebrae	ribs	scapula & coxal bone	long bones	phalanges and sesamoids		
Prey size class I-II	3	0	0	1	0	0	4	1
Leopard kill sites	Skeletal region represented						NISP	MNI
	cranial	vertebrae	ribs	scapula & coxal bone	long bones	phalanges and sesamoids		
Prey size class I-II	10	66	10	13	47	73	219	7
Prey size class III-IV	3	8	0	1	5	0	17	1
Lion kill sites	skeletal region represented						NISP	MNI
	cranial	vertebrae	ribs	scapula & coxal bone	long bones	phalanges and sesamoids		
Prey size class I-II	14	19	3	10	56	82	184	5
Prey size class III-IV	10	93	91	15	51	58	318	5
Lion-and-spotted hyaena kill sites	Skeletal region represented						NISP	MNI
	cranial	vertebrae	ribs	scapula & coxal bone	long bones	phalanges and sesamoids		
Prey size class I-II	3	9	0	3	1	0	16	1
Prey size class III-IV	9	3	25	3	11	0	51	3
Large carnivore (lion, leopard, cheetah & spotted hyaena) kill sites in Kenya	Skeletal region represented						NISP	MNI
	cranial	vertebrae	ribs	scapula & coxal bone	long bones	phalanges and sesamoids		
Prey size class I-II	30	94	13	27	104	155	423	14
Prey size class III-IV	22	104	116	19	67	58	386	9

Table 4.16. Prey skeletal region proportions found at kill sites in Kenya.

	NISP	MNI
prey size class I-II (kill sites)	423	14
prey size class I-II (den site)	125	23
Prey size class III-IV (kill sites)	386	9
Prey size class III-IV (den site)	228	31

Table 4.17. Prey NISP and MNI found at large carnivore (lion, leopard, cheetah & spotted hyaena) kill sites and a spotted hyaena den site in Kenya.

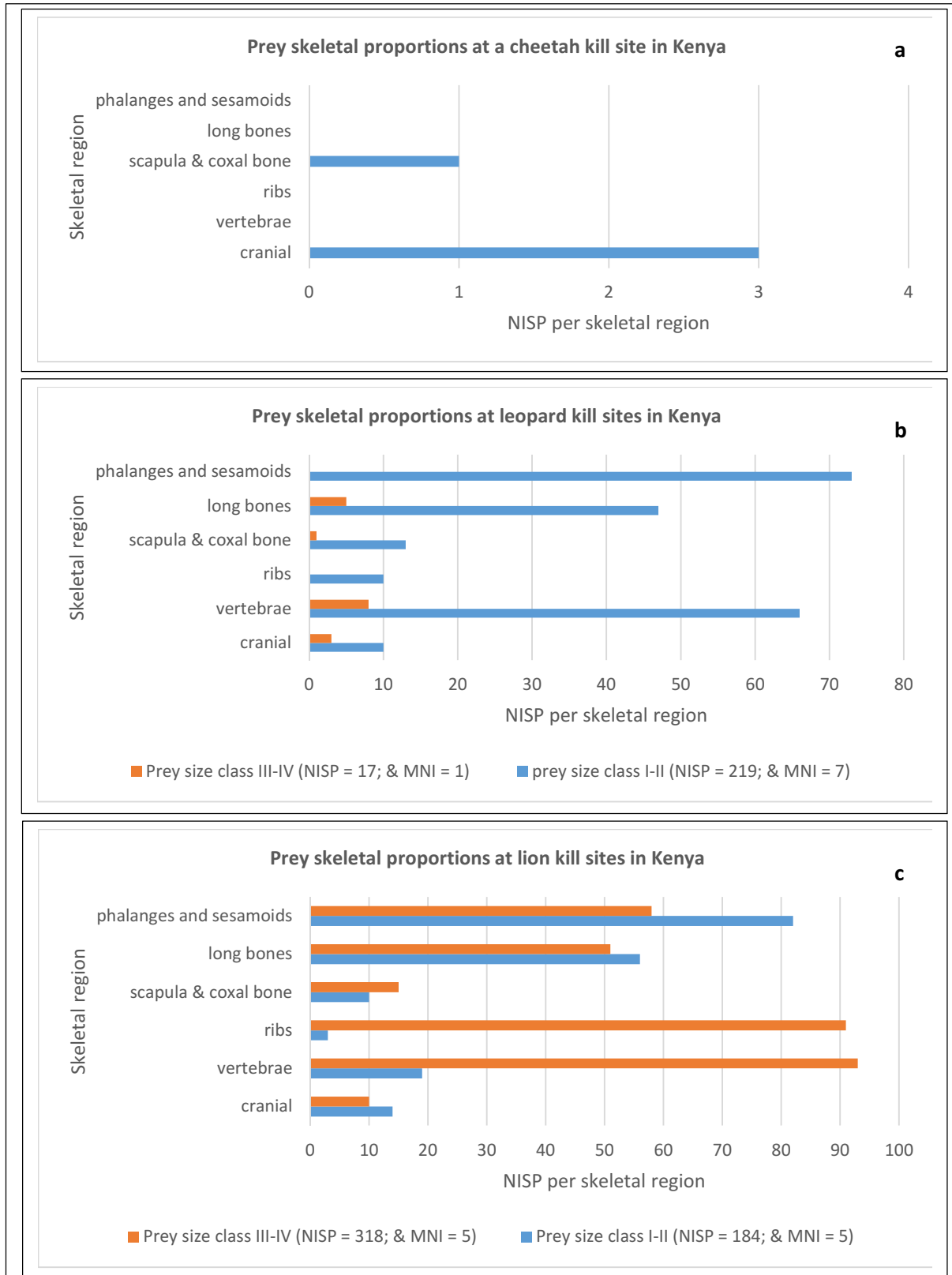


Figure 4.8. Prey skeletal proportions found at cheetah, leopard and lion kill sites in Kenya.

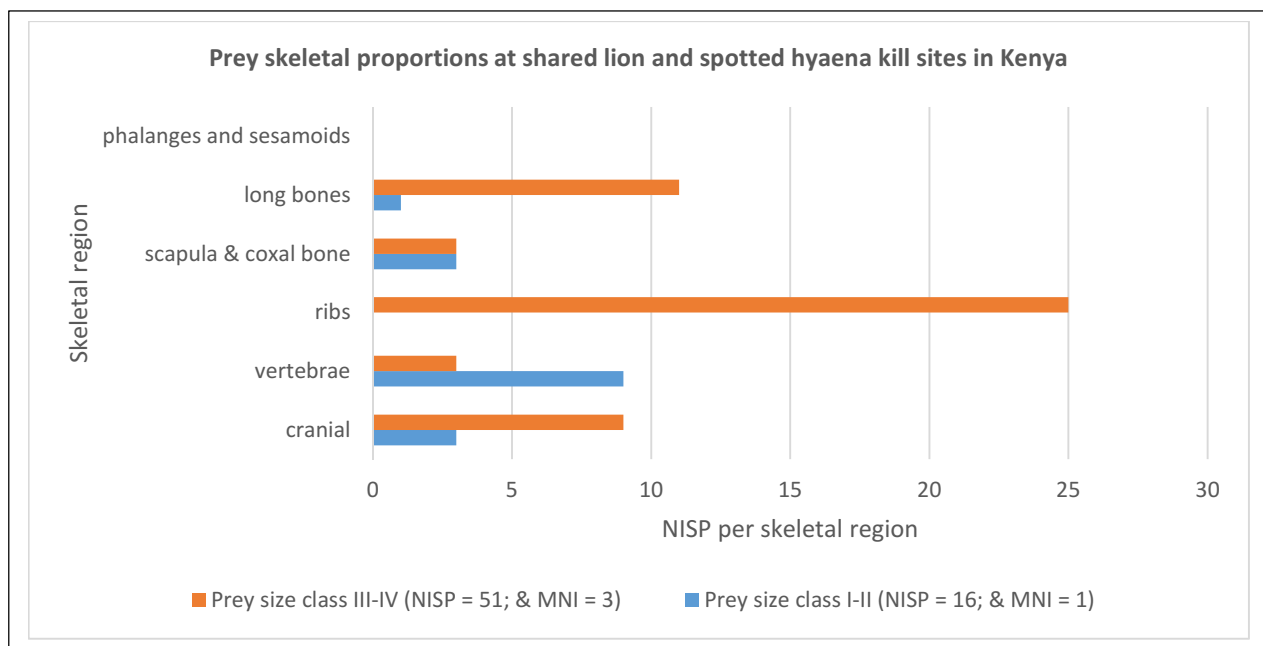


Figure 4.9. Prey skeletal proportions found at shared lion and spotted hyaena kill sites in Kenya.

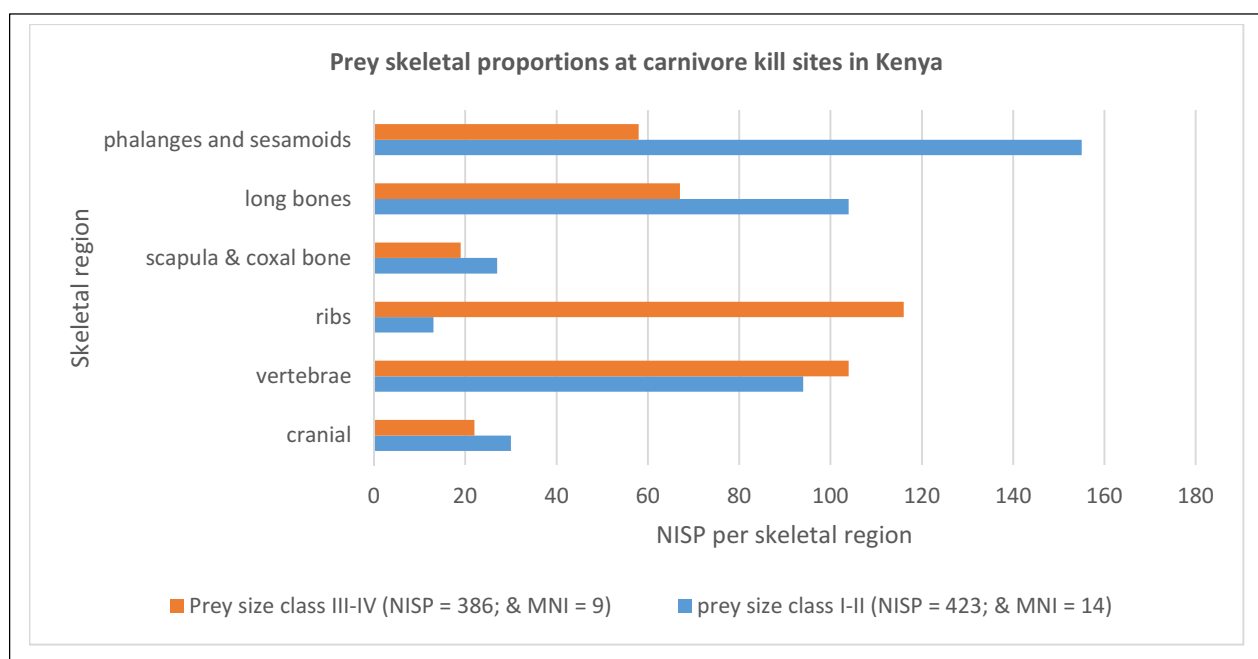


Figure 4.10. Prey skeletal proportions relative to skeletal region at carnivore kill sites in Kenya.

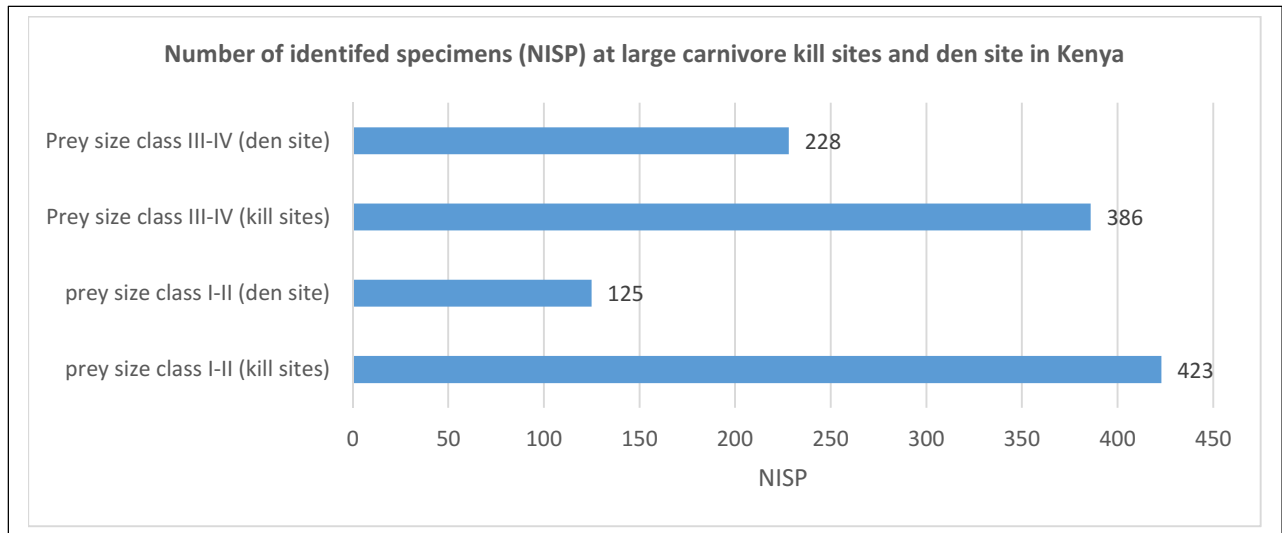


Figure 4.11. NISP at large carnivore kill sites and den site in Kenya within the context of ungulate prey size classes I-II & III-IV.

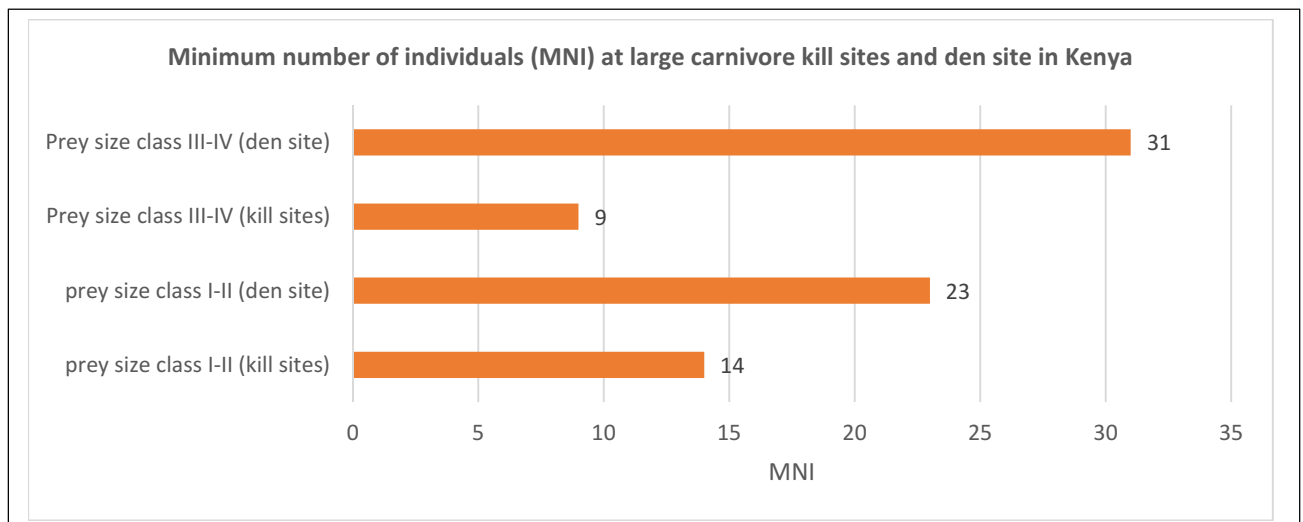


Figure 4.12. MNI at large carnivore kill sites and den site in Kenya within the context of ungulate prey size classes I-II & III-IV.

Mammalian carnivores often acquire animal bodies some distance from where they prefer to consume them. Prey that are small relative to the predator are transported whole to preferred locations. Larger animal bodies dismembered during the kill or initial consumption may be carried in segments from the acquisition site. Some species' repeated actions in transporting body segments build up substantial accumulations of bones in one locale (e.g. den site). An entire animal carcass can be thought of as a statistical event about which foragers make transport decisions (Schoville and Otárola-Castillo, 2014; Gifford-Gonzalez, 2018; Binford and Bertram, 1977; Blumenschine, 1986a).

Transport decisions can include, for example, whether to strip the meat off the appendicular elements of small animals, choosing which anatomical parts to transport to a den site (hyaenids, canids), or up a tree to cache kill away from other predators (leopard) and which to leave behind. Transported individual anatomical parts and their skeletal elements can therefore be viewed to be the end product of foraging decisions made by predators. (Binford, 1962, 1978, 1981; Binford and Bertram, 1977; Blumenschine, 1986a,b; Binford *et al.*, 1988 Schoville and Otárola-Castillo, 2014; Gifford-Gonzalez, 2018).

NISP by definition excludes non identifiable (NID) specimens. The statistic thus does not encompass all the specimens in an assemblage, and, depending upon the degree of fragmentation of the skeletal elements, NISP can represent a small fraction of the total assemblage of bone and tooth specimens. The Minimum Numbers of Individuals (MNI) is an estimate, based on NISP, of the lowest number of individual animals necessary to have provided the single most abundant element of each taxon in a sample. The fact that NISP and MNI varies from assemblage to assemblage probably stems in part from carcass processing strategies, and in part from the variable number of osteological elements in different taxa (Lyman, 2008, 2015; Grayson 1978,1979, 1981; Gifford-Gonzalez, 2018).

Unlike den sites where the prey killed by the carnivore may be unknown at the beginning of an assessment by a zooarchaeologist; the prey found killed at a kill site/scavenging site may be easily identifiable by the ecologist, hence the minimum number of individuals (MNI) may be straight forward without involving any formula to compute. To this end, we computed a general output of 837 prey bones for NISP and 28 for MNI from all our carnivore kill sites in Samburu and Nakuru Counties (*see* Table 4.14). We then compared the carnivore prey skeletal element proportions (NISP & MNI) at our carnivore kill sites (*see* Table 4.14) with those found at a den site in Samburu courtesy of Mwebi (2013) (*see* Table 4.15).

Since dissimilar methods had been used to account for proportions of bones in prey skeletal regions in the current study and that of Mwebi (2013), it was only practical to standardise comparison between prey skeletal representation (NISP & MNI) from kill site data and den site data through ungulate prey within the context of *prey size classes I-II & III-IV* (*see* Tables 4.16 & 4.17 and Figures 4.8 to 4.12). We did not carry out any statistical analyses on the NISP and MNI measurements from our carnivore kill sites and den sites due to lack of a sizeable sample size, we therefore presented our outputs in the form of stacked bar graphs to denote the differing values of NISP and MNI for ungulate prey within the context of *prey size classes I-II & III-IV*.

Impala carcasses yielded the highest NISP measurements in our kill sites in Samburu and Nakuru Counties while domestic ungulates were more abundant in the spotted hyaena den in Samburu. Research outputs from our human-carnivore conflict study in Samburu (2009 -2018) in Chapter 6 of this PhD thesis implicate the spotted hyaena as the most prolific predator of livestock among the large carnivores in Samburu (lion, leopard, cheetah, and African wild dog; the striped hyaena was excluded from our analysis due to insufficient data).

When we assessed the levels of prey skeletal proportions in terms of NISP and MNI per carnivore species. Even though only one kill site was recorded for the cheetah, it was interesting to look at the NISP values for the prey skeletal region of the juvenile gerenuk. It is possible to suggest that the absence of skeletal regions such as ribs, long bones, vertebrae and phalanges and sesamoids could be due to the kill site being scavenged by a much larger predator, probably a hyaenid that carried away the remaining carcass to a den; or maybe it was a leopard that took over the kill and carted the carcass along with bones up a tree in a different location. There are many possibilities that could have led to such a low NISP value for the single cheetah prey (see Figure 4.8a). Cheetahs can easily be harassed off kills by other large predators due to their smaller size in comparison to striped hyaena, spotted hyaena, lion, leopard or African wild dogs.

The prey skeletal proportions at leopard kill sites (*see* Figure 4.8b) show a prey preference skewed toward *size class I-II*. The prey skeletal regions, phalanges & sesamoids, long bones and vertebrae have high NISP values at leopard kills.

The lion kill sites (*see* Figure 4.8c) reveal a somewhat balanced prey preference, both *prey size classes I-II & III-IV* are evenly represented. The similarities in terms of high NISP values for prey skeletal regions phalanges & sesamoids and long bones exist for both *prey size classes I-II & III-IV*. However, there are higher NISP values for vertebrae and ribs for the *prey size class III-IV* relative to *prey size class I-II* at lion kill sites. This reflects on the differences in prey bone densities making it more challenging for the lion to consume certain prey bone parts of larger prey in comparison to smaller prey.

Even though the shared lion and spotted hyaena kill sites (*see* Figure 4.9) have a lower MNI than lion only kill sites, making it a little challenging to make an objective comparison due to differences in number of prey individuals (MNI), it is interesting to note the very low NISP

values for prey skeletal regions for prey in the *size class I-II* in comparison to prey in the bigger size class. The very low NISP values for the prey skeletal regions: phalanges & sesamoids and long bones at shared lion and spotted hyaena kill sites as opposed to lion only kill sites indicate that prey skeletal elements are more dispersed and/or fewer at shared kill sites due to being carted away by the predators to avoid further competition. The interspecies relationship between the lion and the spotted hyaena has been discussed in detail in Chapter 6 of this PhD thesis.

When all the NISP and MNI values for all carnivore kill sites were combined into one analysis (see Figure 4.10), high NISP values for the vertebrae, long bones and phalanges & sesamoids are observed for both *prey size classes I-II & III-IV*. It is important to note that the combined analysis is a mere control and provides a general overview but does not reflect individual carnivore bone consuming capabilities.

In the comparative assessment of NISP and MNI values for *prey size classes I-II & III-IV* relative to carnivore kill sites and den sites (see Figures 4.11 & 4.12) indicate that high NISP values at kill sites do not necessarily lead to higher MNI values. There were more prey animals at the spotted hyaena den site than the lion, leopard, cheetah and shared lion and spotted hyaena kill sites combined. This shows that the ecological environments influence the nature of bone consumption with more bones consumed at the den site in comparison to the kill site.



*Figure 4.13. Photograph of spotted hyaena sharing a buffalo carcass with black-backed jackal at the Soysambu Conservancy, Nakuru County. Photo credit: Rowena White.*

#### **4.2.7. A complementary contribution to the hunting and scavenging debate.**

Similar to actualistic studies, ecological studies on modern African carnivores are just as effective and useful in identifying potential carnivore taxa on modern prey bones. We postulate that, the information gained from our comparative ecological study of large African felid and hyaenid tooth puncture marks on prey bones, relative to carnivore species, prey sizes classes and prey skeleton regions at kill sites and den sites, offers valuable insights about predator and scavenger utilization of prey carcasses and provides a helpful reflection on prey vulnerability or availability in past communities. In carnivore-modified archaeofaunal assemblages it is important to evaluate the degree to which carnivores have overprinted hominin behavioural signals (Haynes, 1983; Faith *et al.*, 2007).

The composition of large carnivore kill sites and den sites and their ensuing taphonomic histories are of interest to paleoanthropologists, zooarchaeologists, and paleontologists because they may help elucidate questions about early hominin behaviour (Blumenschine and Cavallo, 1992; Domínguez-Rodrigo and Pickering 2003; Lansing *et al.*, 2009; Haynes, 1983; Leslie, 2016). In the same way modern carnivores' prey diversity reflects a healthy modern ecosystem; it is can also be postulated that archaeofaunas were also modified by extinct carnivores. The African larger carnivore guild during the Plio-Pleistocene included a much larger diversity of taxa than the modern guild (Turner, 1990; Lewis, 1997; Pobiner, 2007).

Carnivores have been implicated in the taphonomic histories of archaeological bone assemblages in a broad range of geographic and environmental contexts (Assefa, 2006; Bartram and Marean, 1999; Blumenschine, 1995; Brain, 1981; Chase *et al.*, 1994; Domínguez-Rodrigo *et al.*, 2002; Marean *et al.*, 2000; Marean and Kim, 1998; Monahan, 1996; Mondini, 2002; Potts, 1988). Inferring hominin behaviour from the patterns evident in the fossil record requires an understanding of the taphonomic processes that have mediated skeletal element representation (Brain, 1967, 1969). This is particularly relevant to carnivore mediated attrition, which has played a significant role in patterning the faunal remains from numerous assemblages of paleoanthropological interest (Faith *et al.*, 2007). A well-developed understanding of how carnivore-mediated taphonomic signals relate to variation in ecology, competition for nutrient resources and carnivore behavioral patterns can significantly enhance our ability to infer hominin behaviour, and general paleoecological conditions from archaeofaunal and paleontological assemblages altered by carnivores (Blumenschine and Marean, 1993; Gifford, 1981).

Different modes of meat acquisition by omnivorous hominins imply different frequencies of meat-eating and distinct foraging strategies. Two general modes of meat acquisition – hunting and scavenging, are available to a meat-eater. Scavenging, or foraging for and consuming animals found dead. Implies meat-eating to be an opportunistic behaviour conducted irregularly and with a minimum of social cooperation. Hunting live quarry on the other hand, denotes meat to be regularly sought and an integral component of hominin dietary strategies; hunting success would be greatly enhanced by social adjustments including a high level of group cooperation during prey pursuit, capture and consumption (Blumenschine, 1986b).

Hunters often do not transport all nutrients encapsulated in carcasses from kill areas to camp. Instead, chosen anatomical parts are removed and returned for consumption while others are discarded. This seemingly simple fact has significant implications for inferences regarding the evolution of human foraging behavior. Understanding trade-offs involved in prey acquisition and the subsequent transport decisions made by hunter-gatherers are fundamental goals of ethnoarchaeology and human behavioral ecology (Blumenschine, 1986a,b, 1991; Schoville and Otárola-Castillo, 2014). Pioneering research by White (1952, 1953, 1954, 1955), Perkins and Daly (1968), and Binford (1978,1981, 1984), helped to contextualize prey part patterning observed archaeologically within frameworks of hunter-gatherer butchery and transport practices.

Zooarchaeologists frequently use the relative abundance of skeletal elements in faunal assemblages in conjunction with foraging theory models to infer subsistence decisions made by prehistoric hunter gatherers (Potts *et al.*, 1983; Bunn, 1986; Monahan, 1996; Stiner,1994; Marean and Frey, 1997; Klein, 1999; Parkington, 1981; Russell, 2012; Schoville and Otárola-Castillo, 2014). Interpretations on Pleistocene hominin subsistence, with special emphasis on the hunting and scavenging debate, revolve around adequate understanding on how felids consume their prey and the resulting bone modification patterns (Gidna *et al.*, 2014). Leslie, (2016) in his study of a striped hyaena scavenging behaviour in Olorgesailie, Kenya on an abandoned lion kill (a common eland carcass) in 2009, led him to suggest that paleoanthropologists should begin to incorporate such behavior patterns (solitary social structure, omnivorous diet, and sneak and deferential behavior) into the possible scavenging behaviors of early hominins. One of the main implications of his study was that early hominins would have been able to scavenge mammal remains from the Pliocene phylogenetic counterparts of striped hyenas more easily than from those more closely related to spotted hyenas (Werdelin and Solounias, 1991).

Lions made the majority of kills in our modern carnivore kill sites study followed by the leopard, but the leopard kills were more often than not cached in high in trees away from any other potential scavenging mammalian predators. It is debatable whether the hominin groups were passive or aggressive in scavenging such kills made by the phylogenetic counterparts of the leopard from up trees during the Pleistocene. The lion kills in our study sites were mainly in open bush lands hence if any scavenging were to be made by hominins from the lion's phylogenetic counterparts in the Pleistocene, then they would have to do so after it was safe enough to scavenge from the abandoned kills either before or after the spotted hyaena's phylogenetic counterparts swooped in to scavenge the same abandoned kill. These postulations mirror Blumenschine's (1986b) study on the ecology of scavenging in the Ngorongoro and Serengeti ecosystems.

Blumenschine's study showed how scavenging opportunities enabled by strictly flesh-eating predators in specific habitats and times of the year could be determined by resource availability: after felids defleshed carcasses and prior to the intervention of bone crunching hyenas, a theoretical scavenging niche was open for hominins in riverine settings at the end of the dry season. This was expanded by Tunnell's (1990) study of carcass availability in Maasai Mara (Kenya) and Tappen's (2001) study in Virunga National Park (Democratic Republic of Congo).

During our ethnographic study on the socio-cultural factors influencing human-carnivore conflict in a Samburu pastoralist landscape, we held a local community carnivore conservation workshop and during the panel discussions, a local community elder who participated in the workshop gave the following account as quoted in verbatim: "We as the Samburu pastoralist community had our traditional resource management systems that worked well, before colonial and government systems came to be. Wild animals were associated with various clans among members of our community who viewed them as sacred, thereby being protectors of the said wild animals. In essence, we viewed the wild animals as our second cattle, and killing any of them was considered a taboo. If our livestock had several young, then we not only looked at the resource in terms of catering for our day to day use; but we also accepted as normal, uncertainties in life, *for example*; theft of the said livestock, or depredation by carnivores; we also reserved a few for the occasional visitor. Retaliations due to livestock depredations by carnivores were minimal to very rare. We associated the hyaena with the vice of greed, as one who keeps thirsting for more even if he already has more than enough, for this reason the hyaena is greatly disliked because it will persistently attack our cattle and occasionally humans."

“We always viewed the lion as more than just a majestic king of the jungle, but also a very selfless animal. After making any kill, domestic or wild, the lion feeds on it but also makes sure to leave remains for other animals including man. If the lions killed a buffalo or elephant, they would feed for one or two days, then leave the remains for a while, as they rest due to their heavy meal. Our people would then get a piece of that meat and carry it to their homesteads; hyaenas, jackals and birds of prey would also have a chance to scavenge on that carcass. Besides, a lion does not kill all the time, and whenever he does, he shares his kill with other animals. We associate the lion with selfless leadership.”

“The leopard on the other hand” he continued, “split our opinion right in the middle... when a leopard growls, snarls, attacks, and kills your goats and sheep; expect an increase in the numbers of goats and sheep in your pen! Even though it was a good omen to receive that occasional visit from the leopard in your pen, we also associate the leopard with greed. Unlike the lion who shares his kill, the leopard hides his kill very high up in the trees where it is virtually inaccessible to other animals, except for the birds of prey. The leopard finishes his meal all by himself unless it gets stolen by some bird of prey up in the tree”.

The above account offers some deep insights on the nature of relationship between a modern African pastoralist community in East Africa, and modern African large felids and hyaenids which can be used as a modern analog to infer on past human societies in the Pleistocene. It is a relationship that borders on fear and mutual respect for the large carnivores as worthwhile competitors for available resources. The elder mentioned that occasionally, community members passively scavenge from big lion kills such as an elephant, buffalo, eland or giraffe. He also noted the difficulty involved in case one would make an attempt to scavenge from a leopard kill cached up high in a tree and beyond human reach. It shows the scavenging trait of humans whenever opportunity arises and the hunter instinct whenever the need arises. Therefore, the contribution of this study to the hunting-scavenging debate in the domain of anthropology is that, if both hunting and scavenging favours a modern African pastoralist community then the trait must have evolutionary underpinnings from past human societies.

## **CHAPTER 5. Large carnivore scat morphometry.**

### **5.1.1. Résumé du Chapitre 5.**

En ce qui concerne la morphométrie des fèces de carnivores, il était possible de différencier statistiquement entre léopard et hyène tachetée selon leur poids sec global et la largeur minimale des fragments/segments dans l'ensemble de nos échantillons collectés à Samburu au Kenya et sur des données complémentaires sur les hyènes tachetées de Lunel-Viel en France. Cependant, il n'a pas été possible de différencier statistiquement selon la hauteur (ou longueur) des segments fécaux et également sur la largeur maximale (grande variabilité).

### **5.1.2. Chapter 5 summary.**

In terms of carnivore scat morphometry, it was possible to statistically differentiate lion scat from leopard and spotted hyaena scat based on global dry scat weight; and minimum scat fragment width based on carnivore scat samples from the Samburu National Reserve in Kenya, and a complimentary data set of spotted hyaena scat measurements from Lunel-Viel in France. However, it was not possible to statistically differentiate lion, leopard and spotted hyaena scat based scat fragment height and maximum scat fragment width.

## 5.2. Large carnivore scat assessment.

Key measurements (morphometry) from carnivore (lion, leopard and spotted hyaena) scats were analysed with the R-software statistical package (version 3.6.0). Key variables that include: global dry scat weight, scat fragment height and scat fragment width (maximum and minimum) were first graphed using QQ plots in the *ggplot2* package in R-software (version 3.6.0). Complementary unpublished scat measurements for *Crocota crocuta spelaea* were availed to this study courtesy of Dr. Jean-Philip Brugal (*see* Appendix VI). The key variables were then individually subjected to Shapiro-Wilk's normality tests to confirm if the variable being tested followed a normal distribution. QQ plots and the Shapiro-Wilk's normality test are used to check whether a given data follows normal distribution (R Core Team, 2019).

The P value from the Shapiro-Wilk's normality test for our carnivore global dry scat weights was significant at ( $P < 0.05$ ), implying that the scat dry weights of the lion, leopard and spotted hyaena scat came from non-normal distributions therefore a non-parametric test- *the Kruskal-Wallis rank sum test* was used to assess the effect of carnivore species on global dry scat weight. However, the P value from the Shapiro-Wilk's normality test for each of the follow variables: scat fragment height, scat fragment maximum width and scat fragment minimum width was not significant at ( $P > 0.05$ ), implying that each of the following variables: scat height, scat maximum width and scat minimum width of the lion, leopard and spotted hyaena scats came from normal distributions. Hence a parametric test a *one-way ANOVA* was used to assess the effect of carnivore species on each of the follow variables: scat height, scat maximum width and scat minimum width. The P value from the Shapiro-Wilk's normality test for the *Crocota crocuta spelaea* scat measurement on scat fragment lengths was significant at ( $P < 0.05$ ), implying that the scat fragment lengths of the *Crocota crocuta spelaea* scats came from non-normal distributions, therefore a non-parametric test- *the Kruskal-Wallis rank sum test* was used to assess the effect of carnivore species on scat fragment lengths for the complementary data. The P value from the Shapiro-Wilk's normality test for the scat fragment maximum width of the *Crocota crocuta spelaea* was not significant at ( $P > 0.05$ ), implying that the scat fragment maximum width of the *Crocota crocuta spelaea* scats came from normal distributions. Hence a parametric test- a *one-way ANOVA* was used to assess the effect of carnivore species on maximum scat fragment width.

### 5.2.1. Effect of carnivore species on global dry scat weight.

Measurements of the global dry weight (whole scat amount produced in a defaecation event) for each carnivore species were analysed through the Kruskal-Wallis rank sum test to assess the effect of carnivore species (lion, leopard and spotted hyaena) on global dry scat weight. Differences were observed to be significant ( $P < 0.05$ ) between global dry scat weights of carnivore species. A pairwise comparison test was then done using the Wilcoxon rank sum test and differences were not significant ( $P > 0.05$ ) between spotted hyaena scat dry weights and leopard global dry scat weights. However, differences were significant ( $P < 0.05$ ) between lion global dry scat weights vs the leopard global dry scat weights and lion global dry scat weights vs spotted hyaena global dry scat weights (see Table 5.1 and Figure 5.5a). The outcome implies that one is able to differentiate lion scat from leopard scat and spotted hyaena scats through use of global dry scat weight, however this would require further analyses from larger sample sizes to ascertain the accuracy of such an inference. Information on the global dry scat weight was missing from the complementary *Crocuta crocuta spelaea* data set hence could not be assessed relative to global dry scat weight.

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared	Df	P-Value
14.261	2	0.0008002
Pairwise comparisons using Wilcoxon rank sum test		
	spotted hyaena	lion
lion	0.0047	
leopard	0.0872	0.0047

Table 5.1. Test on the effect of carnivore species on dry scat weight. R-software statistical package (version 3.6.0).

### 5.2.2. Effect of carnivore species on maximum scat fragment width.

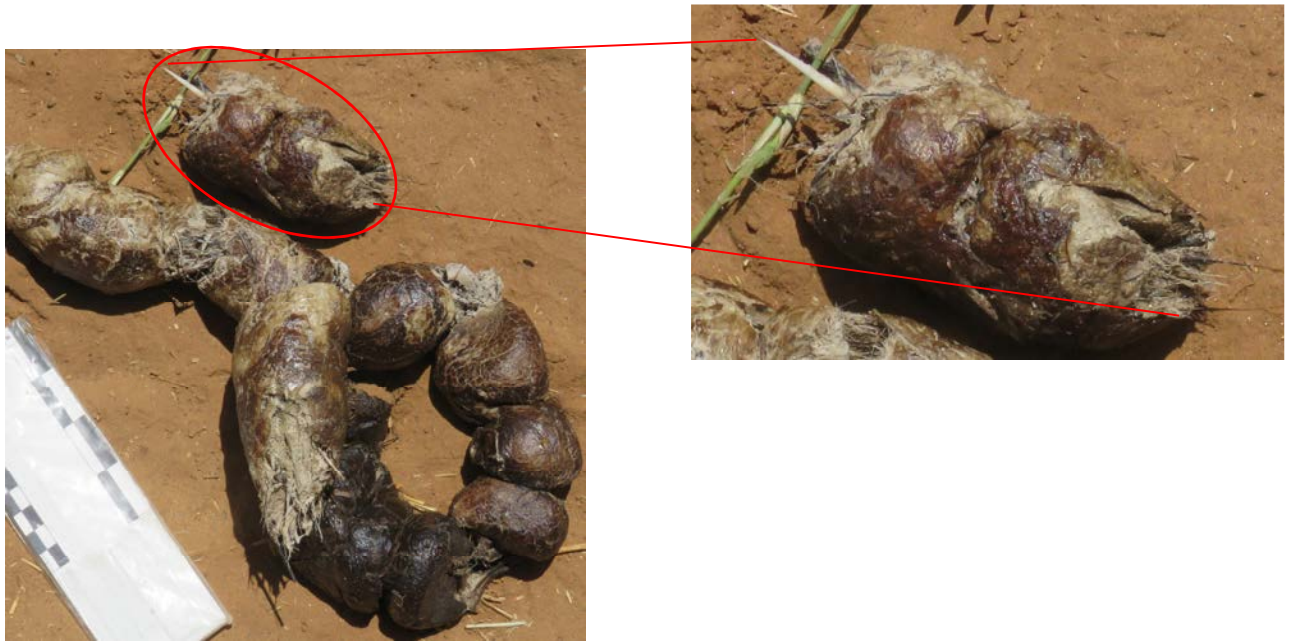
Measurements of the maximum scat fragment width for each carnivore species were analysed through the one-way ANOVA to assess the effect of carnivore species (lion, leopard and spotted hyaena) on maximum scat fragment width. Differences were observed to be significant ( $P < 0.05$ ) between maximum scat fragment widths of the three carnivore species. A Tukeys HSD pairwise test was then performed on the output and differences were observed not to be significant ( $P > 0.05$ ) between spotted hyaena maximum scat fragment widths vs leopard maximum scat fragment widths, and spotted hyaena maximum scat fragment widths vs lion maximum scat fragment widths. However, differences were significant ( $P < 0.05$ ) between lion maximum scat fragment widths vs the leopard maximum scat fragment widths (see Table 5.2 and Figure 5.5e). When the *Crocota crocuta spelaea* scat data were included and reanalysed using the one-way ANOVA to assess the effect of carnivore species (lion, leopard and spotted hyaena) on maximum scat fragment widths, no differences were observed ( $P > 0.05$ ) (see Table 5.3). The complementary spotted hyaena dataset has been coded in the graph as *C.crocota2* (see Figure 5.5f).

One-way Anova test					
	Df	Df Sum Sq	Df Sum Sq	F-value	Pr(>F)
Species	2	480.8	240.42	6.195	0.00768 **
Residuals	21	815.0			
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					
Multiple comparisons of Means: Tukey Contrasts					
	Estimate	Std. Error	t-value	Pr(> t )	
lion vs spotted hyaena	6.375	3.115	2.047	0.12583	
leopard vs spotted hyaena	-4.537	3.115	-1.457	0.33128	
lion vs leopard	-10.913	3.115	-3.503	0.00593 **	
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

Table 5.2. Test on the effect of carnivore species on maximum scat fragment widths. R-software statistical package (version 3.6.0).

One-Way Anova test					
	Df	Df Sum Sq	Df Sum Sq	F-value	Pr(>F)
Species	3	481	160.38	2.638	0.0525
Residuals	125	7598	60.79		
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

Table 5.3. Test on the effect of carnivore species on maximum scat fragment when the *Crocota crocuta spelaea* scat measurements were reanalysed with PhD project data. R-software statistical package (version 3.6.0).



*Figure 5.1. Photograph of a lion scat with porcupine quills highlighted in red. Photo credit: Titus Adhola.*



*Figure 5.2. Photograph of a leopard scat. Photo credit: Titus Adhola.*

### 5.2.3. Effect of carnivore species on minimum scat fragment width.

The one-way ANOVA analysis on the effect of carnivore species (lion, leopard, spotted hyaena) on minimum scat fragment width showed that differences were significant ( $P < 0.05$ ) between minimum scat fragment widths of carnivore species. However, unlike the effect of carnivore species on maximum fragment width; the Tukey's HSD pair wise comparisons showed that differences were significant ( $P < 0.05$ ) between the minimum scat fragment widths of the lion vs leopard minimum scat fragment widths; and, lion minimum scat fragment widths vs the spotted hyaena minimum scat fragment widths (*see* Table 5.4 and Figure 5.5b). In other words, according to our results output, it is possible to differentiate lion scat from leopard scat and spotted hyaena scat based on minimum scat fragment widths. However a cautionary approach should be taken and sample sizes adequately increased before such a morphometric inference is acceptable in standard practice.

One-Way Anova test					
	Df	Df Sum Sq	Df Sum Sq	F-value	Pr(>F)
Species	2	548.6	274.28	7.826	0.00289 **
Residuals	21				
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					
Multiple Comparisons of Means: Tukey Contrasts					
	Estimate	Std. Error	t-value	Pr(> t )	
lion vs spotted hyaena	9.525	2.960	3.218	0.01102 *	
leopard vs spotted hyaena	-1.137	2.960	-0.384	0.92210	
lion vs leopard	-10.663	2.960	-3.602	0.00464 **	
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

Table 5.4. Test on the effect of carnivore species on minimum scat fragment width. R-software statistical package (version 3.6.0).

#### 5.2.4. Effect of carnivore species on scat fragment height.

The one-way ANOVA test was used to assess the effect of carnivore species (lion, leopard and spotted hyaena) on scat fragment height and no differences were observed ( $P > 0.05$ ) between scat fragment heights of carnivore species (see Table 5.4).

One-Way Anova test					
	Df	Df Sum Sq	Df Sum Sq	F-value	Pr(>F)
Species	2	902.8	451.4	2.757	0.0903 .
Residuals	18	2947.0	163.7		
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

Table 5.5. Test on the effect of carnivore species on minimum scat fragment height. R-software statistical package (version 3.6.0).

The Kruskal-Wallis rank sum test was used to assess the effect of carnivore species (lion, leopard and spotted hyaena) on scat fragment height and no significant differences were observed ( $P > 0.05$ ) between scat fragment heights of carnivore species with the *Crocutea crocuta spelaea* scat measurements included in this analysis alongside my PhD project data (see Table 5.6). The *Crocutea crocuta spelaea* dataset was coded in the graph as *C.crocutea2* (see Figure 5.5d).

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared	Df	P-Value
7.1302	3	0.06786

Table 5.6. Test on the effect of carnivore species on scat fragment height when the *Crocutea crocuta spelaea* scat measurements were reanalysed with PhD project data. R-software statistical package (version 3.6.0).

We could not statistically differentiate between scat fragment heights of the three carnivore species (lion, leopard and spotted hyaena) from our own project data and even with the *Crocutea crocuta spelaea* scat data added, and reanalysed. According to our study results, it is not possible to differentiate between lion, leopard and spotted hyaena scat based on scat fragment height. We however recommended a further analysis based on adequate sample sizes of scat samples from each of the carnivore species to confirm if the outcome will statistically change or not.



*Figure 5.3. Photograph of a spotted hyaena scat with prey bone fragments. Photo credit: Titus Adhola.*



*Figure 5.4. Photograph of a typical Samburu landscape. Carnivore scats were collected either at carnivore kills or during random searches. Photo credit: Titus Adhola.*

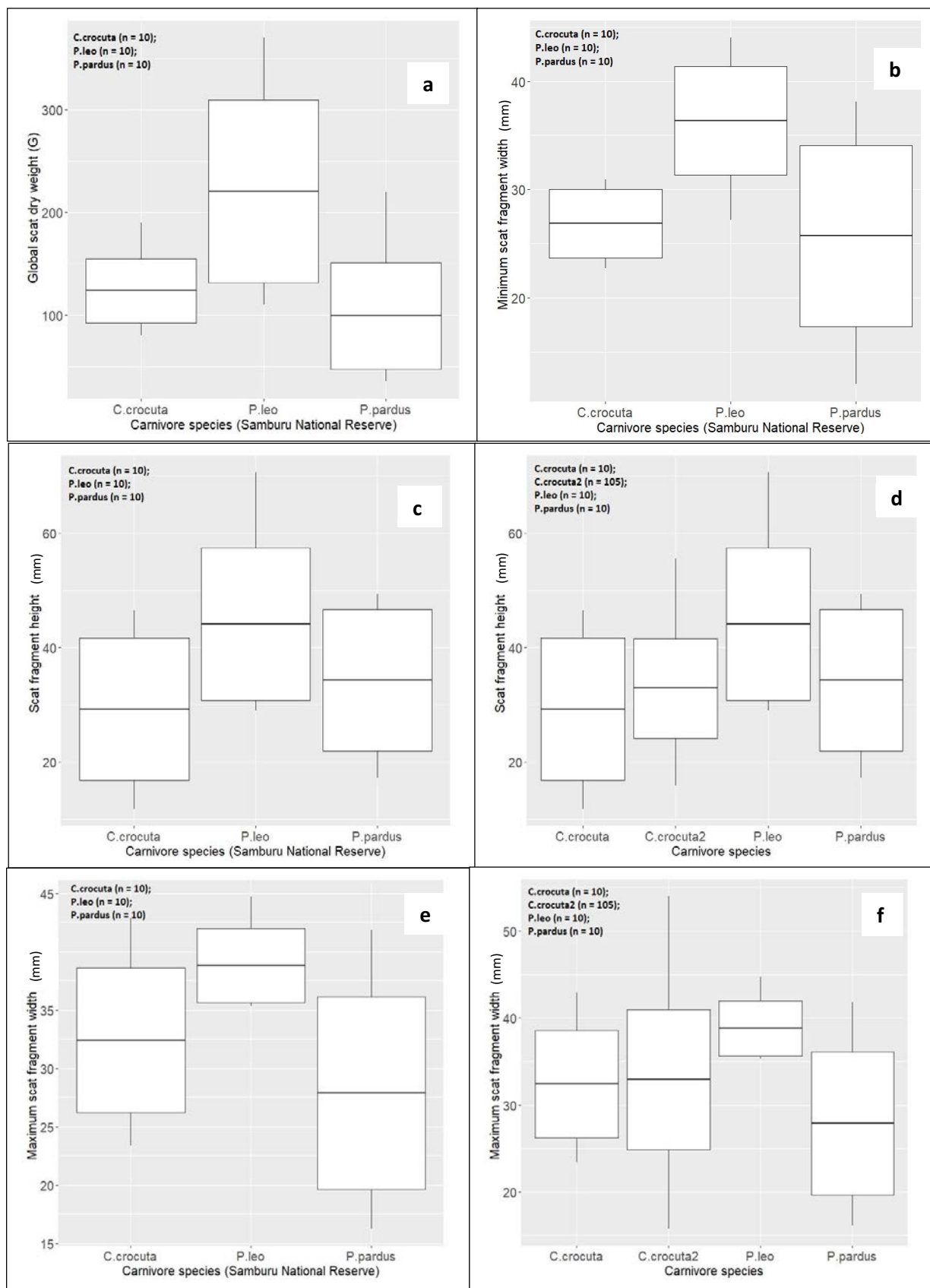


Figure 5.5. Carnivore scat measurements represented by mean box plots. R-software statistical package (version 3.6.0).

The study of carnivore scat is an effective way of assessing the individual and species prey preferences, local prey species assemblages, temporal availability of prey, prey vulnerability, potential competition with other carnivores and impact on prey populations. This in turn provides accurate knowledge which can be applied for conservation projects and support paleoecological research that use coprolites as the main source of study (Klare *et al.*, 2011; Macdonald and Loveridge, 2010). Research on terrestrial carnivore ecology frequently relies on scat identification and analysis, ultimately, species assignment is commonly based on scat morphology (Monterroso *et al.*, 2013). Scat fidelity is however compromised by weather elements such as heat, desiccation, humidity and rains. Fragmentation by beetles and/or termites also compromises scat fidelity (Chame, 2003; Stuart and Stuart, 1998).

The size and the amount of scat produced by each individual varies with age, the type of ingested food, and its absorption capacity (Chame, 2003). The challenge with the study of scat (scatology) is that the potential information retrieved from carnivore scats can only be useful upon correct species identification (*see* Appendix XI). In the recent past, advances in non-invasive molecular methods have allowed the extraction and amplification of fragmented and degraded DNA, and species-specific markers have been developed (Boitani and Powell, 2012; Broquet *et al.*, 2007; Beja-Pereira *et al.*, 2009; Livia *et al.*, 2006; Oliveira *et al.*, 2010). The application of genetic scatology has highlighted the fact that the evaluation of scat morphology alone is prone to misidentifications among sympatric carnivore species, even when evaluated by experienced field technicians (Davison *et al.*, 2002; Janecka *et al.*, 2008; Harrington *et al.*, 2010). Despite the potential pitfalls, scat morphology-based studies are still widely used to better understand carnivore ecology (Wilson and Delahay, 2001; Barea-Azcón *et al.*, 2006). We carried out measurements of key morphological variables of lion, leopard and spotted hyaena scats such as global scat dry weight, scat fragment height, scat fragment width (maximum and minimum); to determine diagnostic morphometric traits that would assist in distinguishing one species from the other based on scat samples. Our study results imply that it is statistically possible to differentiate lion scat from leopard and spotted hyaena scats based on global dry scat weight, and minimum scat fragment width. However, we were not able to statistically differentiate lion, leopard and spotted hyaena scats based scat fragment height and maximum scat fragment width. Nevertheless, we plotted scat fragment heights against maximum scat fragment widths from scats from *Panthera leo*, *Panthera pardus*, *Crocuta crocuta* & *Crocuta crocuta spelaea* to produce a scatter plot (*see* Appendix XII) for a visual impression of spread and/or clusters.

## **CHAPTER 6. Assessing key ecological and socio-cultural factors influencing human-carnivore conflict in Samburu County.**

### **6.1.1. Résumé du Chapitre 6.**

Notre étude concerne l'évaluation des principaux facteurs écologiques et socioculturels qui influencent le conflit homme-carnivore dans le comté de Samburu. La composante ethnographique de notre recherche a consisté en une enquête semi-structurée de 75 ménages/maisons, complétée par un atelier (workshop) que nous avons organisé auprès de la communauté locale sur le sujet de la conservation des carnivores (réalisé à la fin de notre travail doctoral). Des tests statistiques utilisant le logiciel R-software ont été menés pour déterminer les effets des variables climatiques clés et des types d'habitat sur les modèles de prédation du bétail par les grands carnivores en fonction du mois, de l'année et du lieu. Globalement, la distribution des prédateurs sur le bétail par différents espèces de carnivore montrent des pics et des creux correspondant aux saisons de mise bas, eux-mêmes influencés par la saisonnalité et les variations de longueur des cycles de reproduction de chaque type de bétail. L'indice de végétation (NDVI) n'influence significativement que les attaques du lion et du guépard sur le bétail. L'indice de précipitation standardisé (SPI) n'influence que de manière significative les attaques du lion sur le bétail. Les températures maximales n'influencent que de manière significative les attaques du léopard et du guépard sur le bétail. Le type de bétail et l'habitat local ont indépendamment des effets significatifs sur la nature et l'ampleur des pertes attribuées à la déprédation suivant chaque espèce de carnivore. Cependant, dans le cas d'attaques de lions ou d'hyènes, c'est l'interaction entre l'habitat local et le bétail qui détermine la nature et l'ampleur des pertes imputables à cette prédation. L'hyène tachetée enregistre le taux le plus élevé de prédation nocturne du bétail par rapport au léopard et au lion.

En termes de pertes économiques annuelles liées à la prédation du bétail dans le comté de Samburu, l'hyène tachetée est le carnivore responsable des pertes les plus importantes pour chaque type de bétail et du bétail en général; ensuite vient le léopard puis le lycaon. Il est intéressant de noter que le lion se classe après et que le guépard est dans le rang le plus bas comparé à toutes les autres grandes espèces carnivores du comté de Samburu. L'impact économique des pertes en US dollars due à la prédation des bovins par les grands carnivores est le plus élevé, suivi de par les pertes sur les caprinés. La perte par rapport aux dromadaires se classe en troisième rang parmi ces pertes classées, et finalement les pertes les plus faibles sont sur les ânes.

Les variables démographiques telles que le sexe (homme, femme), l'âge (personnes âgées, d'âge moyen, jeunes), le niveau d'éducation, la durée du séjour dans la localité, le statut socio-économique (classes supérieures, moyennes, basses) en relation avec la fréquence et la variété des types de bétail (caprinés, bovins, âne, dromadaire) de chaque interlocuteur ont été évalués permettant de classer la perception globale de chacun à l'égard des carnivores comme positive ou négative, ainsi que son niveau de tolérance global (nul, faible, égal) sur la présence de carnivores dans leur environnement (coexistence) égal ou nul ou faible à l'égard des carnivores présence dans leur voisinage (coexistence). Parmi les variables démographiques, seul le sexe a été identifié pour influencer de manière significative sur la capacité d'un individu à coexister avec des grands carnivores.

Les points saillants des commentaires de nos interlocuteurs au cours des entrevues concernent les caprinés qui représentent le bétail le plus apprécié en raison de leurs faibles coûts de maintenance et de leur taux de fécondité élevé; ce qui les rend idéaux pour la subsistance et la rentabilité, facilement réalisables grâce à des ventes rapides. Interrogés sur leurs réflexions pour des solutions locales au sujet du conflit hommes-carnivores, les points suivants ont été mis en évidence: le gouvernement devrait indemniser le bétail tué mais, indépendamment de l'indemnisation ou de l'absence d'indemnisation, il ne devrait pas y avoir de tuerie de prédateurs pour représailles. Les populations ont observé que les conflits avec la faune étaient inévitables. Par conséquent, il devrait exister de bonnes pratiques en matière d'élevage, complétées par des programmes communautaires d'éducation et de sensibilisation à la faune, et par la création de zones de conservation de la faune.

Les questions politiques clés qui ont émergé lors de notre atelier sur la conservation des carnivores locaux organisé à Samburu étaient que le manque perçu de partage équitable des bénéfices tirés des revenus de la faune sauvage au niveau national avec les communautés locales renforce par contrecoup les points de vues négatifs sur celle-ci en général et sur les carnivores en particulier, bien que la volonté de la communauté de fournir un espace à la faune sauvage existe. Les décideurs doivent prendre en considération ces problèmes dans l'intérêt des communautés et de la faune sauvage. Nos prochains ateliers à Samburu traiteront d'autres questions pertinentes, telles que l'association entre la déprédation du bétail et l'abattage illégal de grands carnivores.

### 6.1.2. Summary of Chapter 6.

Our study focussed on assessing the key ecological and socio-cultural factors that influence human-carnivore conflict in Samburu County. Statistical tests using the R-software were then conducted to determine the effects of key climate variables and habitat on livestock depredation patterns by large carnivores in Samburu County within the context of month, year and site/location. The ethnographic component of our research consisted of a semi-structured survey of 75 households complemented by a local community carnivore conservation workshop at the tail end of this PhD study.

In general, the pattern of livestock depredation by each large carnivore species exhibited peaks and troughs that conformed with the local calving seasons of livestock which were in turn influenced by seasonality and variations in lengths of breeding cycles of each livestock type. Normalised Difference Vegetation Index (NDVI) significantly influences only lion and cheetah attacks on livestock. Standardised Precipitation Index (SPI), only significantly influences lion attacks on livestock. Maximum temperatures only significantly influence leopard and cheetah day attacks on livestock. Both livestock type and local habitat independently had significant effects on the nature and magnitude of losses attributed to livestock depredation by each carnivore species however when it came to lion and spotted hyaena attacks on livestock, it was the interaction between local habitat and livestock that determined the nature and magnitude of losses attributed to livestock depredation. The spotted hyaena recorded the highest rate of nocturnal livestock depredation when compared to the leopard and lion.

In terms of annual economic losses incurred relative to large carnivore livestock depredation in Samburu County; the spotted hyaena was identified as the carnivore responsible for the highest economic losses due to livestock depredation for each livestock type and livestock in general. The subsequent lower in rank order after the spotted hyaena was the leopard followed by the African wild dog. It was interesting to note that the lion fell in the second lowest rank in all categories (livestock type and domestic herbivores in general). The cheetah fell in the lowest rank compared to the other large carnivore species in Samburu County. The economic impact of losses in USD due to cattle depredation by the large carnivores were the highest followed in lower rank by losses due to large carnivore depredation on shoats. Economic losses due to large carnivore depredation on camels were the second last in the ranked scale of losses. Least economic losses were incurred when large carnivores depredated upon donkeys.

Demographic variables such as gender (male/female), age (elderly/middle-aged/youth), educational background, length of stay in the locality, socio-economic status (upper/middle/lower classes) based on the frequency and variety of stock types (shoats/cattle/donkey/camel) for each respondent, were scored against a set criteria of factors to eventually classify each respondent's overall view towards carnivores as positive or negative, and overall tolerance level as zero or low or high towards carnivore presence in their neighbourhood (co-existence). Among the demographic variables listed above only gender was identified to significantly influence the capability of an individual to coexist with large carnivores in the landscape.

Key highlights from feedback from respondents during the open-ended interview discussions included: shoats being the most preferred stock to rear due to their low maintenance costs and high fecundity rates making them ideal for subsistence and profit easily attained through quick sales. When asked about their thoughts on local solutions to human-carnivore conflict, the following talking points featured prominently; government compensation should be given for livestock killed but regardless of compensation or lack of it, there should be no retaliatory killings of predators. The locals observed that conflicts with wildlife are inevitable therefore, there ought to be good livestock husbandry practices complemented by community wildlife education and awareness programmes and setting up of wildlife conservancy areas.

The two key policy issues that emerged during our locally organised community carnivore conservation workshop in Samburu were; that the perceived lack of equitable sharing of benefits from wildlife earnings nationally with local communities, inadvertently reinforces negative views towards wildlife in general and carnivores specifically; and that, community goodwill to provide space for wildlife persists. The two key issues need to be addressed appropriately by policy makers for the benefit of the communities and wildlife. Our future workshops in Samburu will address other pertinent issues such as association between livestock depredation, and illegal killings of large carnivores.

## **6.2. Key ecological variables (climate and habitat) influencing human-carnivore conflict in Samburu.**

The study focused on assessing the key ecological (climate and habitat) and socio-cultural factors influencing human-carnivore conflict in Samburu County. Ecological data (*see* Appendices VII, VIII & X) and socio-cultural data (*see* Appendix IX) were analysed using the R statistical package (version 3.6.0) to determine these relationships within the context of month, year and site/local habitat. Carnivores were assessed separately per species (lion, leopard, cheetah, spotted hyaena and African wild dog) (*see* Figures 6.8 to 6.10); as well as one unique ‘large carnivores’ group (*see* Figures 6.11 and 6.12); the subsequent analyses revealed differential and/or cumulative effects of large carnivores on livestock depredation per livestock type (sheep, cattle, donkey, camel) (*see* Figures 6.8 to 6.12), per month (January to December) (*see* Figures 6.13 to 6.17), per climatic variable (*see* Figures 6.23 to 6.27), and per local habitat/study sites during a period of nine years (2010 – 2018) (*see* Figures 6.18 to 6.22). The four study sites (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) span across the major ecosystems within the Samburu landscape that include: savannah mosaics, acacia grasslands, acacia scrublands, and dryland forests.

Key variables within the ecological dataset (climatic variables, depredation frequencies by each carnivore species during day only, night only, and day and night combined) were graphed using QQ plots in the *ggplot2* package in R. The datasets were then individually subjected to Shapiro-Wilk’s normality tests to confirm if the ecological dataset followed a normal distribution. QQ plots and the Shapiro-Wilk’s normality test are used to check whether a given data follows normal distribution (R Core Team, 2019).

The P value from the Shapiro-Wilk’s normality test for each variable in the ecological data set was significant at ( $< 0.05$ ), implying that ecological variables came from non-normal distributions. Variables within the ecological data set were then transformed into normal distributions by being subjected to *normal poisson glm model* and *zero inflated model* within the R-studio interface and the *Vuong test* (also known as *Vuong non-nested test*) subsequently used to confirm which model worked better for variables within the ecological dataset.

The *Vuong non-nested test* is based on a comparison of the predicted probabilities of two models that do not nest, subject to penalty on number of parameters. The test can be used for penalized or non-penalized Poisson (negative binomial) regression models, zero-inflated Poisson (ZIP) models (Vuong, 1989).

The Zero-inflated negative binomial (ZINB) model proved to be the better model after the *Vuong test* because our large carnivore livestock depredation counts dataset (*see* Appendix X) had excess zeroes and overdispersion. The summary of the ZINB models of variables within the ecological data set (climate and habitat variables) were then each subjected to a mixed-model ANOVA in R software to assess their differential effects on livestock depredation patterns across the Samburu landscape by carnivore species in particular and for the general super group of ‘large carnivores’ within selected parameters of during day only, night only and day and night combined (*see* Tables 6.3 to 6.16); Tukey’s *HSD posthoc* tests were conducted to differentiate any differences observed within significant variables. Key statistical outputs were then graphed separately through mean box plots (*see* Figures 6.8 to 6.12; and 6.18 to 6.27) and line graphs with mean error bars (*see* Figures 6.13 to 6.17) to depict a nine-year history (2010 to 2018) of livestock depredation by large carnivores in Samburu County.



*Figure 6.1. A Photographic record of a livestock depredation incident inside Samburu National Reserve where locals at times graze livestock during dry seasons. Photo credit: Titus Adhola*

### **6.2.1. Standardised Precipitation Index (SPI) and Normalized Difference Vegetation Index (NDVI).**

In the present study SPI and NDVI were obtained from Remote Sensed Satellite Imagery: PROBA-V and SPOT-VGT sensors courtesy of the ICPAC-GMES project which provided a decade worth of climatic variables (2009 -2018) analysed in this study to assess their said effects on livestock depredation by large carnivores in Samburu County (*see* Appendix VIII).

GMES, an initiative of the EU and ESA, is being developed to provide, on a sustained basis, reliable and timely services related to environmental and security issues in support of users and public policy makers' needs. This EU programme is now being taken beyond European borders: in the context of the 'GMES and Africa' initiative launched in 2007, African earth-observation capacities are being developed (<https://www.africa-eu-partnership.org>).

The SPOT-VGT program was launched in 1998 and consists of a series of optical remote sensing satellites with the primary mission of obtaining Earth imagery for land use, agriculture, forestry, geology, cartography, regional planning, water resources and GIS applications. The SPOT-VGT satellites are operated by the French Space Agency - CNES. The SPOT-VGT system provides global coverage between 87 degrees north latitude and 87 degrees south latitude. The SPOT-VGT mission was timely replaced by the PROBA-V mission, aiming to ensure, among other objectives, the seamless continuity of provision of VGT-like products, including NDVI. The PROBA-V satellite was launched in May 2013 by ESA as a preparation for the recently launched ESA Sentinel-3 land and ocean observation satellite mission (European Union, 2015). To optimally serve the vegetation and land surface community, PROBA-V's spectral channels are similar to those of the SPOT-VGT instrument, but deliver higher spatial detail. Using a constellation of 3 cameras, PROBA-V covers the entire Earth every two days and provides useful reflectance measurements for climate impact assessment, surface water resource management, agricultural monitoring, and food security purposes (<http://proba-v.vgt.vito.be/en/about/proba-v-satellite-mission>).

#### **6.2.1.1. Standardised Precipitation Index (SPI).**

SPI is the most commonly used indicator worldwide for detecting and characterizing meteorological droughts. Drought is an insidious natural hazard that results from lower levels of precipitations than what is considered normal. When this phenomenon extends over a season or a longer period of time, precipitation is insufficient to meet the demands of human activities and the environment. Drought must be considered a relative, rather than absolute, condition. There are also many different methodologies for monitoring drought. Droughts are regional in extent and each region has specific climatic characteristics (the amount, seasonality and form of precipitation). Temperature, wind and relative humidity are also important factors to include in characterizing drought. Droughts are commonly classified by type as meteorological, agricultural and hydrological, and differ from one another in intensity, duration and spatial coverage. Rainfall is to be believed as a normal, wet and dry condition of the climate. It has great impact on agricultural, hydrological, economic, environmental and social systems (Shah *et al.*, 2015; Dodamani *et al.*, 2015).

The SPI indicator measures precipitation anomalies at a given location, based on a comparison of observed total precipitation amounts for an accumulation period of interest (e.g. 1, 3, 12, 48 months or even longer), with the long-term historic rainfall record for that period (McKee *et al.*, 1993; Edwards and McKee, 1997). The historic record is fitted to a probability (gamma) distribution, which is then transformed into a normal distribution such that the mean SPI value for that location and period is zero. For any given region, increasingly severe rainfall deficits (i.e., meteorological droughts) are indicated as SPI decreases below  $-1.0$ , while increasingly severe excess rainfall are indicated as SPI increases above  $1.0$  (European Commission, 2019).

To this end, SPI is just as effective in analysing wet periods/cycles as it is in analysing dry periods/cycles (*see* Table 6.1). Owing to the fact that SPI values are in units of standard deviation from the long-term mean, the indicator can be used to compare precipitation anomalies for any geographic location and for any number of time-scales. The name of the indicator is usually modified to include the accumulation period. Thus, SPI-3 and SPI-12, for example, refer to accumulation periods of three and twelve months, respectively. Because SPI is based only on precipitation, it does not address the effects of high temperatures on drought conditions, such as by damaging cultivated and natural ecosystems, and increasing evapotranspiration and water stress. (European Commission, 2019; World Meteorological Organization, 2012).

SPI Range	Category
+ 2.0 to more	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 to less	Extremely dry

Table 6.1. SPI ranges and their indications of climate precipitation conditions (adopted from World Meteorological Organization, 2012).

Figure 6.2 depicts precipitation cycles (drought vs wetness) in Samburu County using SPI graphed monthly to represent overall annual trends for a period of one decade. The trends depict a consistent pattern of fluctuations between -2 (extremely dry) to + 2 (extremely wet) when considered within a context of SPI-12. The monthly SPI values were analysed within a mixed-model ANOVA in R software (version 3.6.0) to assess their differential effects on livestock depredation patterns across the Samburu landscape per large carnivore species (*see* Tables 6.4 & 6.5; and, Figure 6.25a) and for the general super group of ‘large carnivores’ (*see* Table 6.14 and Figure 6.25b).

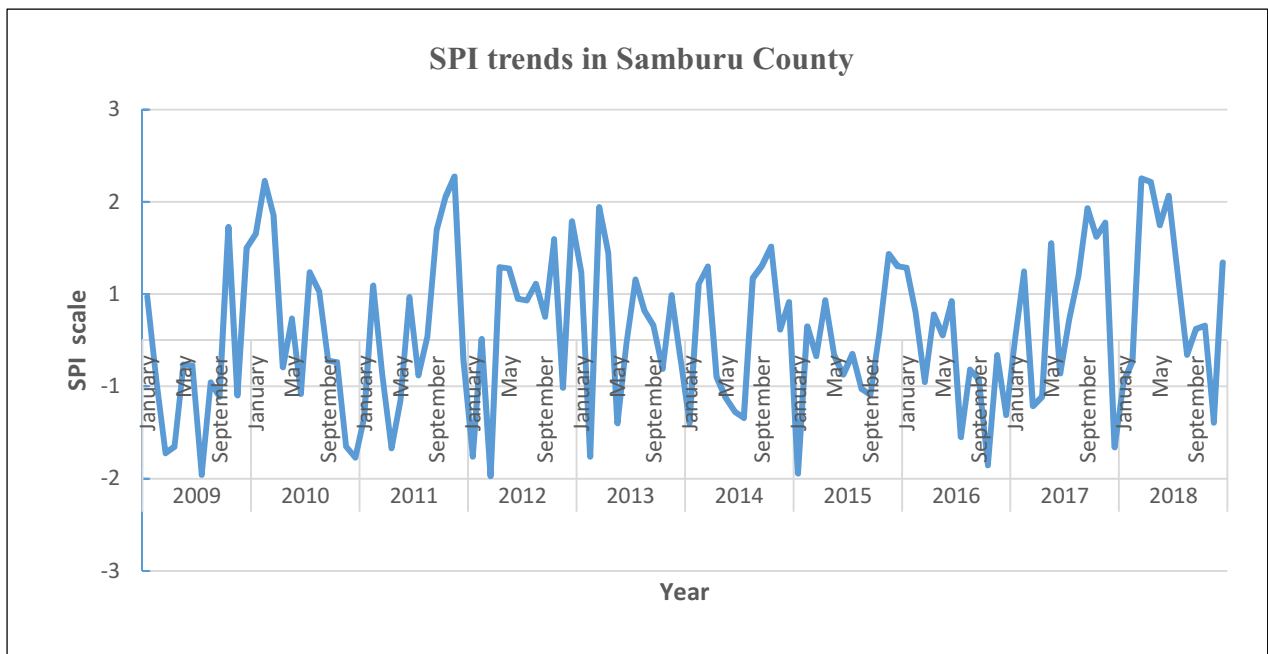


Figure 6.2. SPI trends in Samburu County in a decade.

### 6.2.1.2. Normalized Difference Vegetation Index (NDVI).

NDVI is a remote sensed numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum, and is adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not (Holme *et al.*, 1987; Roderick *et al.*, 1996; Rouse *et al.*, 1973). The basic assumption behind the development and use of this index is that some algebraic combination of remotely sensed spectral bands can reveal valuable information such as vegetation structure, state of vegetation cover, photosynthetic capacity, leaf density and distribution, water content in leaves, mineral deficiencies, and evidence of parasitic shocks or attacks (Jensen, 2007; Liang, 2005; Purkis and Klemas, 2011). NDVI is also a good indicator of drought (Orr, 2011; Yengoh *et al.*, 2015).

NDVI information can be derive by focusing on the satellite bands that are most sensitive to vegetation information (NIR and Red). The bigger the difference therefore between the near-infrared and the red reflectance, the more vegetation there has to be. The NDVI algorithm subtracts the red reflectance values from the near-infrared and divides it by the sum of near-infrared and red bands *i.e.* **NDVI = (NIR-RED) / (NIR+RED)** (Holme *et al.*, 1987; Roderick *et al.*, 1996; Rouse *et al.*, 1973). This formulation incorporates the fact that two identical patches of vegetation could have different values if one were, for example in bright sunshine, and another under a cloudy sky. The bright pixels would all have larger values, and therefore a larger absolute difference between the bands. This is avoided by dividing by the sum of the reflectances (Holme *et al.*, 1987; Roderick *et al.*, 1996).

The NDVI algorithm takes advantage of the fact that green vegetation reflects less visible light and more NIR, while sparse or less green vegetation reflects a greater portion of the visible and less near-IR. NDVI combines these reflectance characteristics in a ratio so it is an index related to photosynthetic capacity. The range of values obtained is between -1 and +1 (Holme *et al.*, 1987; Yengoh *et al.*, 2015).

Extreme negative values represent water, values around zero represent bare soil. Only positive values correspond to vegetated zones; moderate values represent shrub and grassland (0.2 to 0.4), while high values represent dense green vegetation (> 0.6) (Holme *et al.*, 1987; Orr, 2011; Yengoh *et al.*, 2015).

The monthly NDVI trends for Samburu County (Figure 6.3) depict vegetation characteristic of a semi-arid landscape dominated by shrubs and grasslands. The monthly values were modeled within a mixed-model ANOVA in R software (version 3.6.0) to assess their differential effects on livestock depredation patterns across the Samburu landscape per large carnivore species (see Tables 6.4 to 6.6, 6.10, 6.12; and Figures 6.23) and for the general super group of ‘large carnivores’ (see Table 6.16; and Figure 6.24).

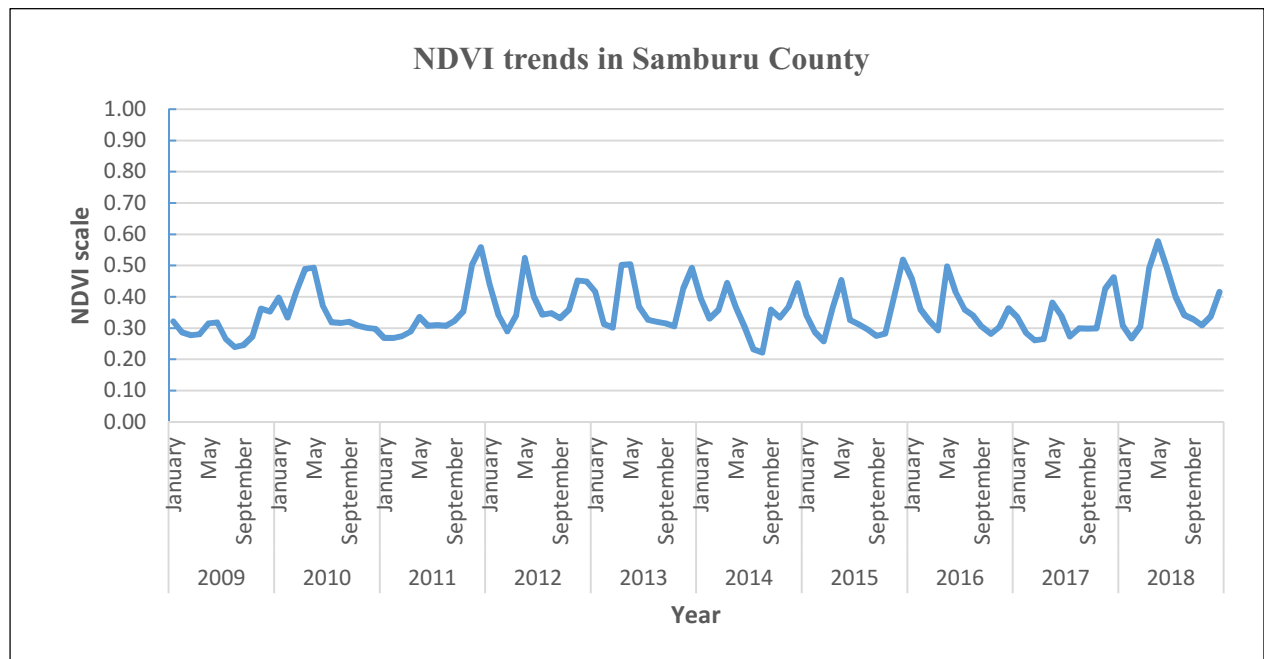


Figure 6.3. NDVI trends in Samburu County in a decade.

### 6.2.3. Rainfall.

Rainfall plays a very significant role in the climate system (Strangeways, 2007; Shah *et al.*, 2015; Dodamani *et al.*, 2015). Understanding the complete hydrological cycle – evaporation, water vapour, convection, condensation, clouds, soil moisture, groundwater and the origin of rivers helps to better understand the nature and extent of rainfall (Strangeways, 2007; Michaelides, 2008). It is a critical source of fresh water, sustaining life on earth, and an important process for energy exchanges between the atmosphere, ocean, and land, determining earth’s climate (Testik and Gebremichael, 2010; Adams, 2007). It is central to water supply, agriculture, natural ecosystems, hydroelectric power, industry, drought, flood, and disease hazards (Cecilia, 1987). Therefore, rainfall is at the heart of socio-economic and political challenges in today’s world (Testik and Gebremichael, 2010; Cecilia, 1987).

The estimation of rainfall over the globe is a big challenge, unlike many meteorological parameters, rainfall is discontinuous in space and time and exhibits large natural variability (Cecilia, 1987). Currently deployed observing systems, such as rain gauges and radar, are generally limited to the measurement of precipitation over land, and in these networks the density of gauges and the spacing of radars varies across political boundaries and sometimes within nations. Yet the greater part of the globe is covered not by land but by ocean (Cecilia, 1987; Fleisher, 2010). Because these vast expanses exist with little or no permanent human activity, oceanic rainfall is more frequently extrapolated from other data than actually measured, and seasonal or annual rather than daily rainfalls are usually computed (Cecilia, 1987; Testik and Gebremichael, 2010; Michaelides, 2008).

Satellites have been touted as a means to circumvent some of the difficulties attendant in gauge and radar measurement of rainfall (Cecilia, 1987). From the satellite platform, large regions can be viewed simultaneously and, under certain conditions, frequently; for instance, the tropics and middle latitudes can be viewed frequently from geosynchronous orbit, and the high latitudes can be viewed from a polar orbit (Cecilia, 1987; Straka, 2009). Further advantages of the satellite platform are that a number of meteorological satellites are now in orbit; with computer processing of digital data, timely estimates can be made at homogeneous densities for large regions, and in some regions the spatial resolution of the satellite sensor is finer than the resolution of present ground rainfall networks (Beven, 2001, 2012; Cecilia, 1987). One substantial drawback is that no satellite will ever carry sensors that directly measure rain, but a number of techniques (NDVI and SPI) have been developed to infer rainfall from visible or infrared data: (Holme *et al.*, 1987; Orr, 2011; Yengoh *et al.*, 2015; Shah *et al.*, 2015) or to relate it more physically to radiation emitted at microwave frequencies (Wagner *et al.*, 2004; Michaelides, 2008, Strangeways, 2007, Fleisher, 2010, Straka, 2009).

Figure 6.4 depicts annual rainfall patterns within a decade consistent for a semi-arid landscape with the deviation in May 2018 that recorded the relatively highest rainfall within a decade (2009 to 2018). The monthly values were modeled within a mixed-model ANOVA in R software (version 3.6.0) to assess their differential effects on livestock depredation patterns across the Samburu landscape per large carnivore species (*see* Tables 6.8 & 6.13; and Figures 6.13 to 6.15). and for the general super group of ‘large carnivores’ (*see* Figures 6.16 & 6.17).

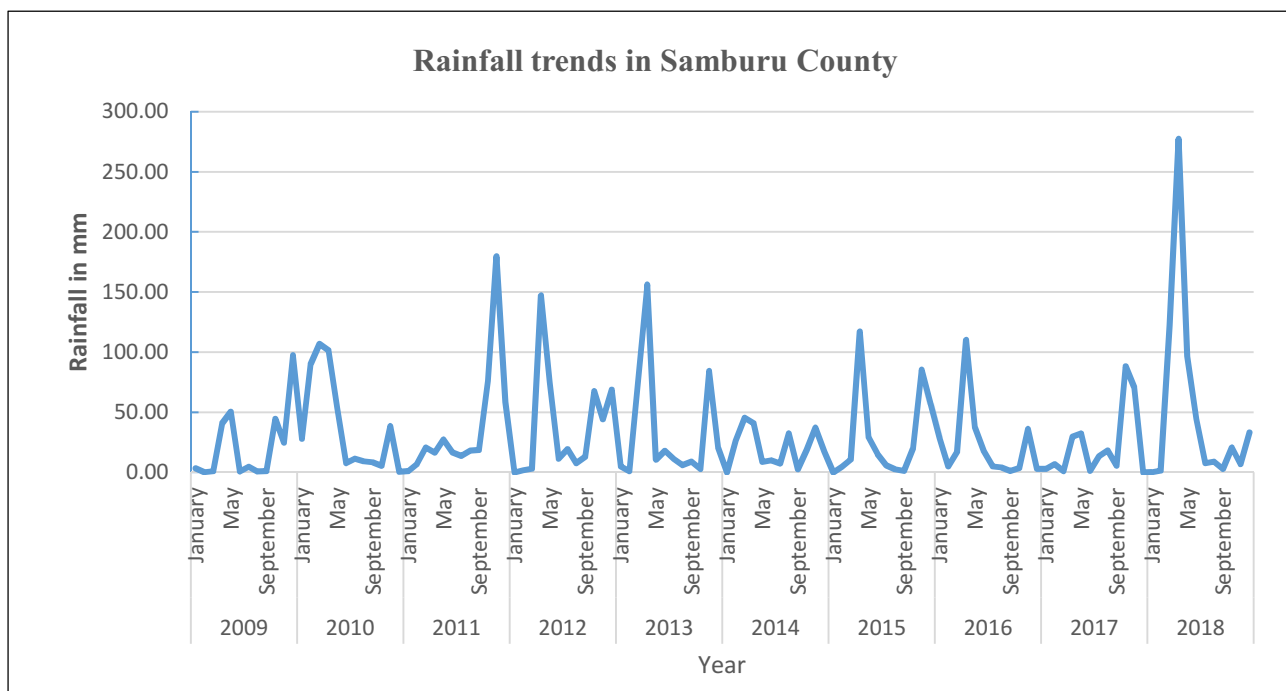


Figure 6.4. Rainfall trends in Samburu County in a decade.

#### 6.2.4. Maximum and minimum temperatures.

Analysis of the global mean surface air temperature has shown that its increase is due, at least in part, to differential changes in daily maximum and minimum temperatures, resulting in the narrowing of the diurnal temperature range (Easterling *et al.*, 1997). Several impacts of climate variable may depend more on changes in mean daily minimum (night-time) or maximum (daytime) temperatures than daily averages (Lobell *et al.*, 2006).

Several studies on climate at the global and regional scales have been derived from temperature and precipitation (Vinnikov *et al.*, 1990; Nicholson, 1994; Nicholls and Lavey 1992; Jones 1994, 1995; Parker *et al.*, 1993, 1994; Gregory *et al.*, 1991; Deser and Blackman 1993; Grossman *et al.*, 1991; Folland and Salinger, 1996; Antonov 1993; Bloomfield, 1992; Caesar *et al.*, 2006; Feng *et al.*, 2004; Gleason *et al.*, 2002). Studies using temperature records have shown that the mean global surface temperature has increased by about  $0.3^{\circ} - 0.6^{\circ} \text{C}$  over the last century (King'uyu *et al.*, 2000; Easterling *et al.*, 1997). There are however large geographical variations in the observed warming trends with some locations indicating some general cooling signals (Folland and Salinger, 1996). In the context of this study, we were interested in assessing the effects of maximum temperatures and minimum temperatures on livestock depredatory patterns by large carnivores in Samburu.

Figure 6.5 depicts within the context of month, maximum and minimum temperatures for Samburu County within a decade (2009 -2018). The maximum temperatures oscillate around 30<sup>0</sup>C with the exception of the period between January 2015 to January 2018; while minimum temperatures consistently oscillated around 20<sup>0</sup>C. The monthly values were modeled within a mixed-model ANOVA in R software (version 3.6.0) to assess their differential effects on livestock depredation patterns across the Samburu landscape per large carnivore species (*see* Tables 6.6, 6.7, 6.8 & 6.12; and Figures 6.26 & 6.27a) and for the general super group of ‘large carnivores’ (*see* Tables 6.14 & 6.16; and Figure 6.27b).

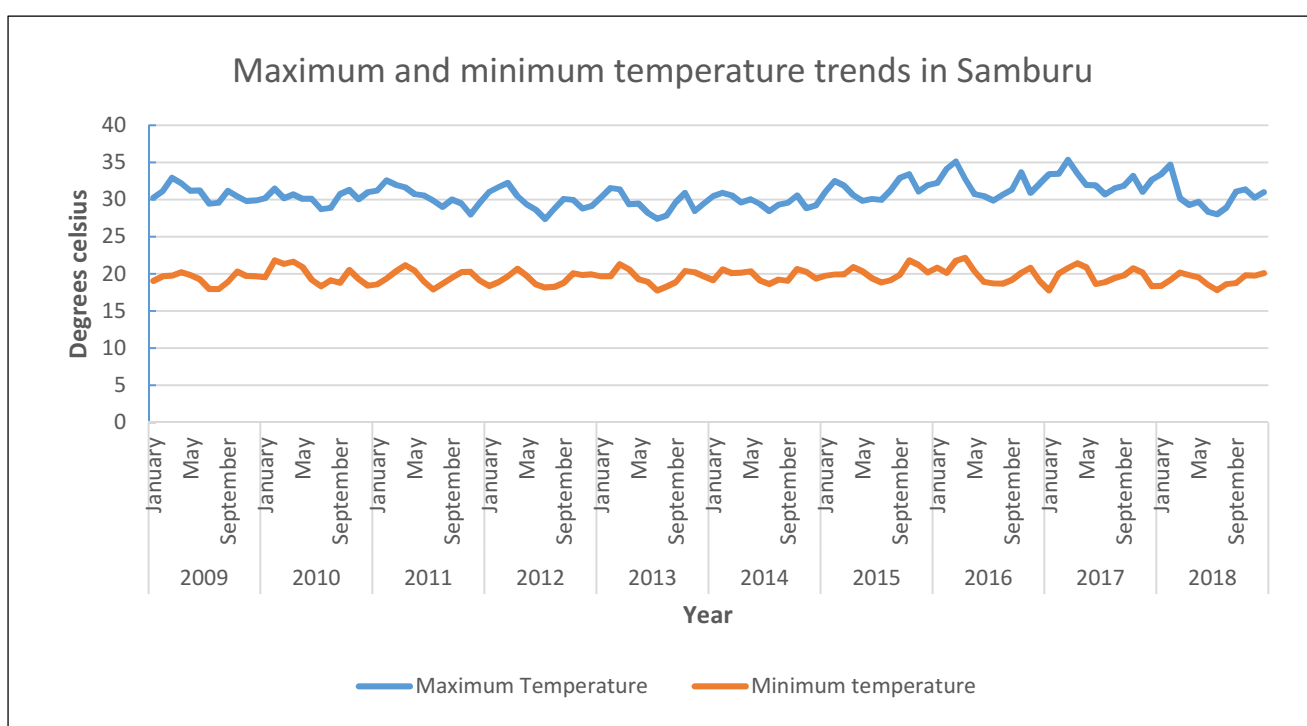


Figure 6.5. Maximum and minimum temperature trends in Samburu County in a decade.

### 6.2.5. Correlations between climatic variables.

Climatic variables from our ecological dataset were graphed using QQ plots in the *ggplot2* package in R-software (version 3.6.0). The datasets were then individually subjected to Shapiro-Wilk’s normality tests to confirm if the ecological dataset followed a normal distribution. QQ plots and the Shapiro-Wilk’s normality test are used to check whether a given data follows normal distribution (R Core Team, 2019). The P value from the Shapiro-Wilk’s normality test for each variable in the ecological data set was significant at ( $< 0.05$ ), implying that the climatic variables came from non-normal distributions. The Spearman’s (*rho*) rank correlation and Kendall’s (*tau*) rank correlation coefficients were the available non-parametric equivalents of Pearson's product-moment correlation test in R the software.

Even though both Spearman's (*rho*) rank correlation and Kendall's (*tau*) rank correlation coefficients are equally accepted measures of non-parametric rank correlations, we followed Logan (2010) based on our sample size, and chose Kendall's (*tau*) rank correlation coefficient to test for any correlations between the 4 climatic variables used in our climate data within the context of month for Samburu during the period January 2009 to December 2018 (Table 6.2). The correlation coefficient is comprised between -1 and +1; -1 indicates a strong negative correlation, this means that every time x increases, y decreases; 0 means that there is no association between the two variables (x and y); +1 indicates a strong positive correlation, this means that y increases with x (Logan, 2010; Wiley and Pace, 2015; Hollander and Wolfe, 1999).

Variables	Z-value	P-value	Tau (correlation coefficient)	Nature of correlation
Rainfall vs NDVI	4.4047	1.059e-05	0.2779235	weak, positive
Rainfall vs SPI	6.1568	7.424e-10	0.4320741	moderate, positive
NDVI vs SPI	3.0815	0.002059	0.2209096	weak, positive
NDVI vs maximum temperature	-4.6546	3.247e-06	-0.3164031	weak, negative
NDVI vs minimum temperature	0.93058	0.3521	0.06566357	none
SPI vs maximum temperature	-2.1753	0.02961	-0.1645428	weak, negative
SPI vs minimum temperature	2.1354	0.03273	0.1677036	weak, positive
Rainfall vs maximum temperature	-2.8625	0.004203	-0.190503	weak, negative
Rainfall vs minimum temperature	5.9853	2.159e-09	0.4134528	moderate, positive
maximum vs minimum temperatures	3.9909	6.581e-05	0.2971289	weak, positive

Table 6.2. Kendall's (*tau*) rank correlation coefficient output from R software (version 3.6.0) testing for associations within our climatic data for Samburu County (January 2009 to December 2018).

Levels of association (correlation) were tested for the climatic variables; Rainfall, NDVI, SPI, maximum and minimum temperatures using Kendall's (*tau*) rank correlation coefficient test (see Table 6.2). The patterns of the said climatic variables were also assessed for any consistency or deviations within a decade (see Figures 6.2 to 6.5). Even though correlations were observed between variables in our climate data (with the exception of NDVI vs minimum temperatures), no interactions were observed when data were analysed using mixed model ANOVAS when we tested various assumptions/hypotheses in our ecological (climate, habitat and livestock depredation conflict) dataset.

### 6.2.6. Livestock abundance relative to wild herbivores in Samburu.

Animal censuses (domestic vs wild herbivores) were conducted three times in 2010, 2013 and 2015 by DRSRS for Samburu County (*see* Appendix VII). Numbers of individual wildlife herbivore species collectively combined to form one super group called ‘wild herbivores’; were extremely low (1%), relative to those of domestic herbivores. The census data were analysed to give a global overview of the abundances (*see* Figure 6.6) and relative frequencies of livestock and wild herbivores. Shoats were the most abundant (82%) followed by cattle (14%) irrespective of the census year (*see* Figure 6.7).

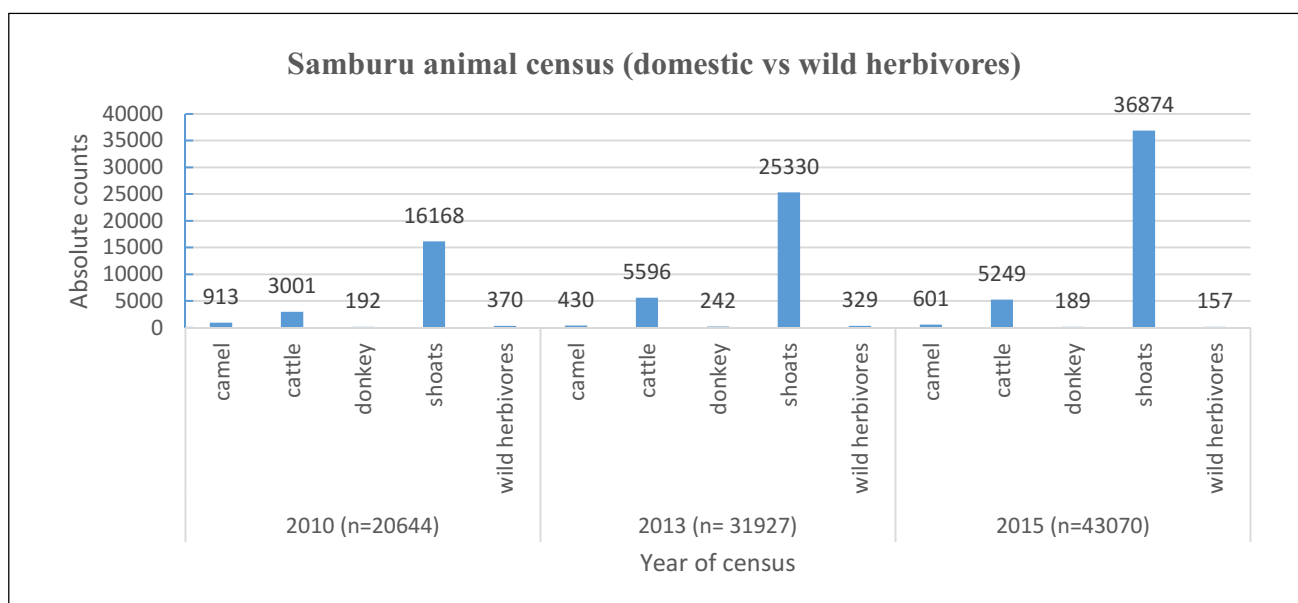


Figure 6.6. Samburu animal (domestic vs wild herbivores) census for Samburu County.

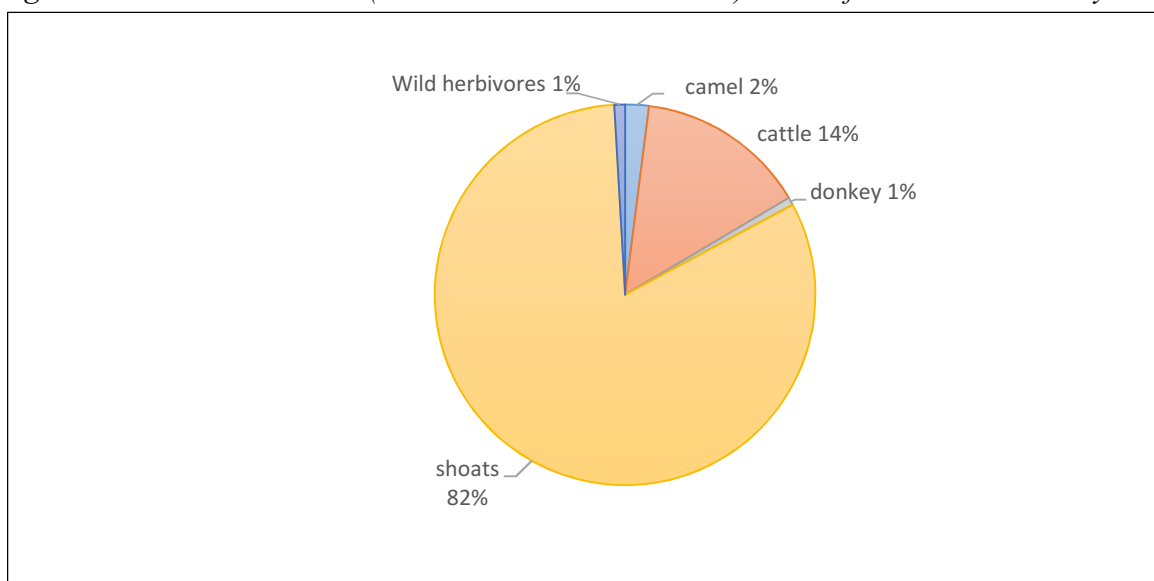


Figure 6.7. Samburu animal (domestic vs wild herbivores) **averaged census** for 2010, 2013 and 2015 (N = 31880).

### 6.2.7. Livestock losses in Samburu due to lion depredation.

Two climatic variables (NDVI and SPI) significantly influence livestock depredation losses due to lion attacks. Even though livestock type and site (local habitat) significantly influence livestock depredation by lion during the day and night, it is the interaction between them that determines the nature and extent of damage incurred due to livestock losses due to depredation by the lion (*see* Tables 6.3 to 6.5).

Independent variable	Df	F	P
Month	11	2.4549	0.0048355**
Rainfall	1	0.3331	0.5639137
NDVI	1	1.3589	0.2439041
SPI	1	2.6431	0.1041969
Maximum temperature	1	0.1907	0.6624158
Site	3	5.8089	0.0006022 ***
Livestock type	3	7.9407	2.95e-05 ***
Site:livestock type	9	2.2151	0.0188223 *
Residuals	1598		
Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

Table 6.3. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to lion attacks during the day.

Independent variable	Df	F	P
Month	11	3.5503	5.974e-05 ***
Rainfall	1	3.1268	0.077204 .
NDVI	1	11.6848	0.000646 ***
SPI	1	6.5339	0.010676 *
Minimum temperature	1	1.3279	0.249351
Site	3	8.5959	1.162e-05 ***
Livestock type	3	14.2530	3.621e-09 ***
Site:livestock type	9	4.5634	5.814e-06 ***
Residuals	1598		
Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

Table 6.4. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to lion attacks during the night.

Independent variable	Df	F	P
Month	11	3.0997	0.0003851 ***
Rainfall	1	0.7195	0.3964198
NDVI	1	4.7766	0.0289931 *
SPI	1	7.4280	0.0064918 **
Maximum temperature	1	0.8180	0.3659162
Minimum temperature	1	3.4725	0.0625819 .
Site	3	12.1311	7.502e-08 ***
Livestock type	3	12.9660	2.276e-08 ***
Site:livestock type	9	5.6591	9.682e-08 ***
Residuals	1598		
Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

Table 6.5. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to lion attacks during day and night.

### 6.2.8. Livestock losses in Samburu due to leopard depredation.

Rainfall, NDVI, maximum temperatures, minimum temperatures, site (local habitat) and livestock type all have significant effects on the nature and impact of livestock losses due to leopard depredation during day and night (see Tables 6.6 to 6.8). Unlike lion depredation on livestock, there is no interaction between site and livestock type for leopard depredation on livestock during day and night.

Independent variable	Df	F	P
Month	11	3.0444	0.0004819 ***
Rainfall	1	2.2536	0.1334996
NDVI	1	8.4603	0.0036800 **
SPI	1	3.3692	0.0666104 .
Maximum temperature	1	17.8682	2.501e-05 ***
Site	3	8.8745	4.365e-07 ***
Livestock type	3	31.5369	< 2.2e-16 ***
Site:livestock type	9	1.0517	0.3960933
Residuals	1599		
Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

Table 6.6. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to leopard attacks during day.

Independent variable	Df	F	P
Month	11	2.2140	0.01176 *
Rainfall	1	3.7628	0.05258 .
NDVI	1	1.6412	0.20035
SPI	1	0.6112	0.43445
Minimum temperature	1	3.9359	0.04744 *
Site	3	2.3214	0.07347 .
Livestock type	3	29.2833	< 2e-16 ***
Site:livestock type	9	0.2621	0.98436
Residuals	1599		
Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

Table 6.7. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to leopard attacks during night.

Independent variable	Df	F	P
Month	11	3.4322	9.796e-05 ***
Rainfall	1	7.2211	0.00728 **
NDVI	1	2.0887	0.14859
SPI	1	0.1353	0.71303
Maximum temperature	1	18.8426	1.509e-05 ***
Minimum temperature	1	0.3391	0.56042
Site	3	8.7499	9.335e-06 ***
Livestock type	3	94.3244	< 2.2e-16 ***
Site:livestock type	9	1.6590	0.09388 .
Residuals	1598		
Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

Table 6.8. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to leopard attacks during day and night.

### 6.2.9. Livestock losses in Samburu due to spotted hyaena depredation.

Livestock type and site (local habitat) significantly influence livestock depredation by spotted hyaena during the day and night (*see* Tables 6.9 & 6.10). However, an interaction exists between local habitat and livestock type when spotted hyaena day and night attacks were combined into one analysis (*see* Table 6.11).

Independent variable	Df	F	P
Month	11	2.4698	0.0045716 **
Rainfall	1	0.0890	0.7654410
NDVI	1	1.8403	0.1751110
SPI	1	3.0529	0.0807843 .
Maximum temperature	1	0.5243	0.4691382
Site	3	7.0762	0.0001006 ***
Livestock type	3	19.9732	1.039e-12 ***
Site:livestock type	9	1.1255	0.3409167
Residuals	1599		
Significant codes: 0 '****' 0.001 '***' 0.01 '**' 0.05 '.' 0.1 ' ' 1			

Table 6.9. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to spotted hyaena attacks during day.

Independent variable	Df	F	P
Month	11	1.9023	0.03499 *
Rainfall	1	0.6803	0.40960
NDVI	1	5.1605	0.02324 *
SPI	1	0.8187	0.36570
Minimum temperature	1	1.7419	0.18708
Site	3	20.3987	5.671e-13 ***
Livestock type	3	54.5172	< 2.2e-16 ***
Site:livestock type	9	0.7306	0.68111
Residuals	1599		
Significant codes: 0 '****' 0.001 '***' 0.01 '**' 0.05 '.' 0.1 ' ' 1			

Table 6.10. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to spotted hyaena attacks during night.

Independent variable	Df	F	P
Month	11	1.6433	0.08100 .
Rainfall	1	0.0030	0.95669
NDVI	1	1.4310	0.23177
SPI	1	0.3517	0.55323
Maximum temperature	1	3.7399	0.05330 .
Minimum temperature	1	2.3788	0.12319
Site	3	24.5557	1.559e-15 ***
Livestock type	3	73.0844	< 2.2e-16 ***
Site:livestock type	9	2.3172	0.01374 *
Residuals	1598		
Significant codes: 0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

*Table 6.11. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to spotted hyaena attacks during day and night.*

#### **6.2.10. Livestock losses in Samburu due to cheetah depredation.**

NDVI, maximum temperatures, site and livestock type significantly influence livestock losses due to depredation by the cheetah (*see* Table 6.12). Similar to the leopard livestock attacks, there was no significant interaction between livestock type and site for cheetah livestock depredation.

Independent variable	Df	F	P
Month	11	1.5929	0.0945663
Rainfall	1	1.0188	0.3129653
NDVI	1	3.9762	0.0463180 *
SPI	1	2.7558	0.0970953 .
Maximum temperature	1	8.6064	0.0033976 **
Site	3	6.0359	8.069e-05 ***
Livestock type	3	4.6827	0.0009274 ***
Site:livestock type	9	0.5120	0.8667716
Residuals	1600		
Significant codes: 0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

*Table 6.12. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to cheetah attacks during day.*

### 6.2.11. Livestock losses in Samburu due to African wild dog depredation.

Rainfall, site and livestock type significantly influence livestock losses due to depredation by the African wild dog (*see* Table 6.13). Similar to the leopard and cheetah livestock attacks, there was no significant interaction between livestock type and site for livestock depredation by the African wild dog.

Independent variable	Df	F	P
Month	11	2.3408	0.007400 **
Rainfall	1	5.9523	0.014806 *
NDVI	1	0.5691	0.450725
SPI	1	2.8954	0.089029
Maximum temperature	1	3.2899	0.069894 .
Site	3	5.1003	0.001628 **
Livestock type	3	11.6756	1.438e-07 ***
Site:livestock type	9	0.2424	0.988192
Residuals	1599		
Significant codes: 0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

Table 6.13. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to African wild dog attacks during day.

The effect of depredation by large carnivores (when considered as one super group consisting of the cumulative effect of each large carnivore species) on livestock in Samburu was also assessed. NDVI, SPI, maximum temperatures, site (local habitat) and livestock type had significant effects on large carnivore livestock depredation during day and night. The interaction between livestock type and local habitat determines the nature and extent of damage incurred due to livestock losses due to depredation by the large carnivores (*see* Tables 6.14 to 6.16). The numbers of livestock killed by each carnivore species were very variable in terms of depredations during day only and night only (*see* Figures 6.13 & 6.14) & day and night (*see* Figure 6.15). Livestock losses due to depredation by the super group 'large carnivores' also varied in terms of depredations during day only, during night only (*see* Figure 6.16) and during day and night (*see* Figure 6.17).

Independent variable	Df	F	P
Month	11	2.5549	0.0033087 **
Rainfall	1	0.5420	0.4617261
NDVI	1	1.7408	0.1872204
SPI	1	4.7355	0.0296926 *
Maximum temperature	1	11.9507	0.0005606 ***
Site	3	1.3565	0.2544682
Livestock type	3	135.6985	< 2.2e-16 ***
Site:livestock type	9	6.0565	2.136e-08 ***
Residuals	1600		
Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

Table 6.14. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to large carnivore attacks during day.

Independent variable	Df	F	P
Month	11	3.5344	6.387e-05 ***
Rainfall	1	0.0019	0.9653
NDVI	1	2.1878	0.1393
SPI	1	1.9579	0.1619
Minimum temperature	1	1.9046	0.1678
Site	3	10.7768	5.188e-07 ***
Livestock type	3	102.9775	< 2.2e-16 ***
Site:livestock type	9	6.3921	5.918e-09 ***
Residuals	1600		
Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			

Table 6.15. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to large carnivore attacks during night.

Independent variable	Df	F	P
Month	11	2.3887	0.006197 **
Rainfall	1	0.3725	0.541722
NDVI	1	5.5680	0.018411 *
SPI	1	0.5893	0.442811
Maximum temperature	1	15.4319	8.917e-05 ***
Minimum temperature	1	0.0016	0.968467
Site	3	8.8326	8.298e-06 ***
Livestock type	3	225.1391	< 2.2e-16 ***
Site:livestock type	9	11.5025	< 2.2e-16 ***
Residuals	1599		
Significant codes: 0 '****' 0.001 '***' 0.01 '**' 0.05 '.' 0.1 ' ' 1			

*Table 6.16. A mixed model anova output from R software (version 3.6.0) showing effects of climatic variables and habitat on livestock depredation losses due to large carnivore attacks during day and night.*

The numbers of livestock killed by each carnivore species were very variable in terms of depredations during day only and night only (*see* Figures 6.13 & 6.14) & day and night (*see* Figure 6.15). Livestock losses due to depredation by the super group ‘large carnivores’ also varied in terms of depredations during day only, during night only (*see* Figure 6.16) and during day and night (*see* Figure 6.17). In addition, the numbers of each livestock species killed by each carnivore species were observed to be variable in terms of depredations during day only and night only (*see* Figures 6.8 & 6.9) and day and night (*see* Figure 6.10). It was observed that an overwhelming majority of cheetah and African wild dog depredation of each livestock type (shoats and calves of cattle) occurred during the day for Samburu County. Livestock losses due to the super group ‘large carnivores’ also varied in terms of livestock type killed during day only and night only (*see* Figure 6.11) and day and night (*see* Figure 6.12).

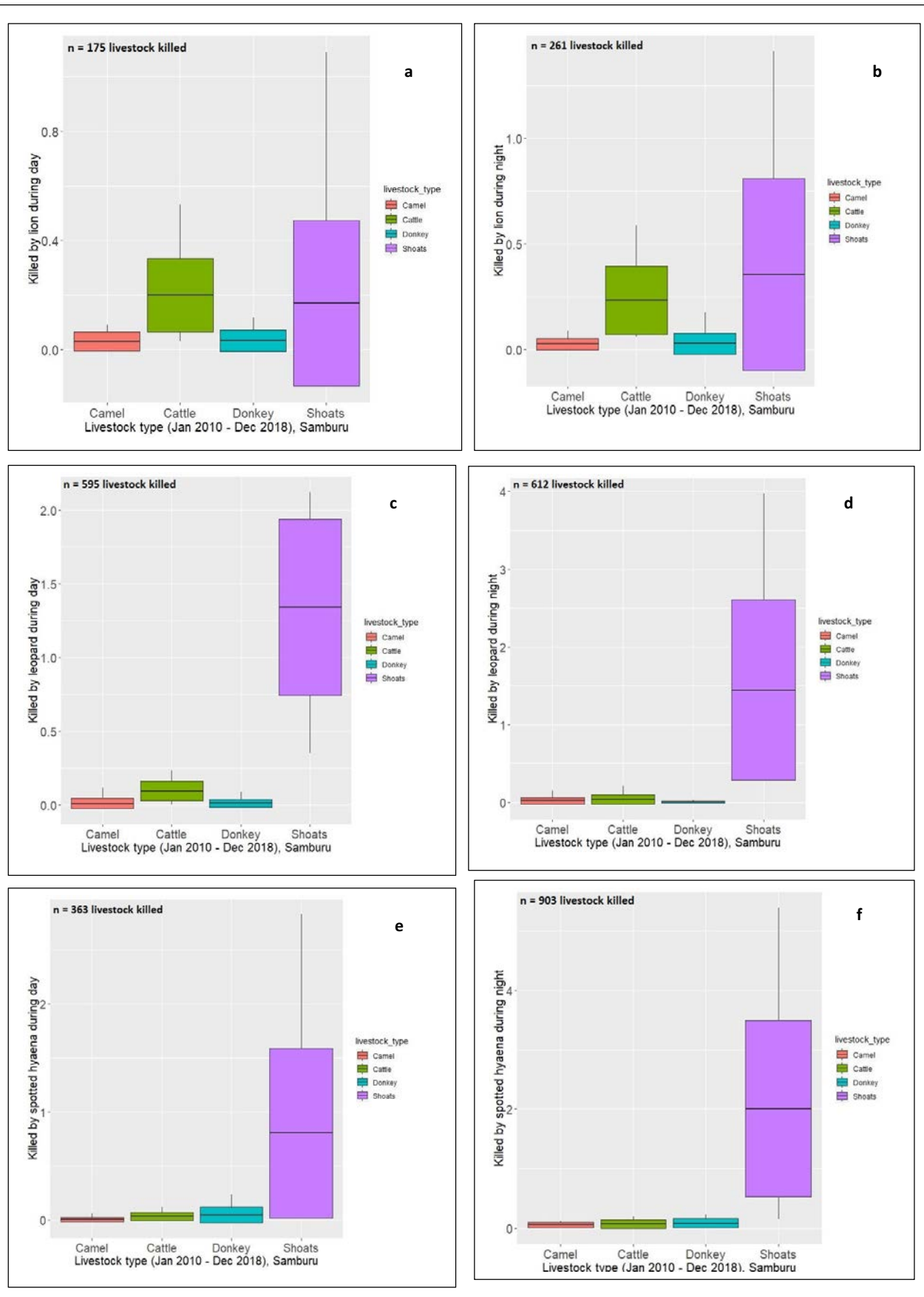


Figure 6.8. Livestock depredation by lion, leopard and spotted hyaena (day vs night) per livestock type in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

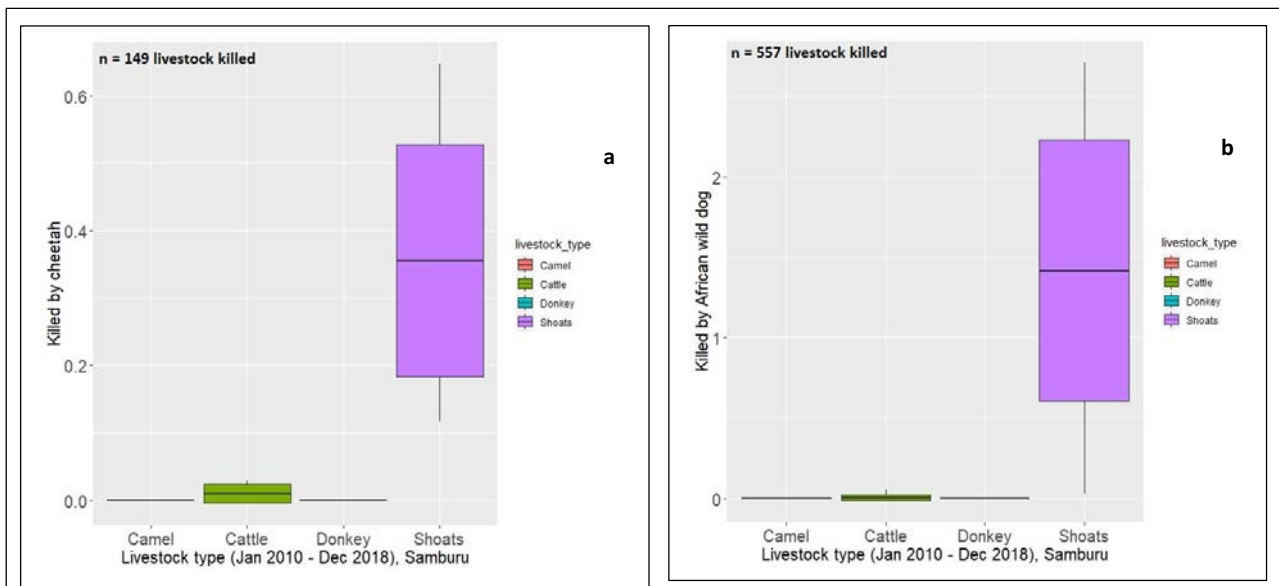


Figure 6.9. Livestock depredation by cheetah and African wild dog per livestock type in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

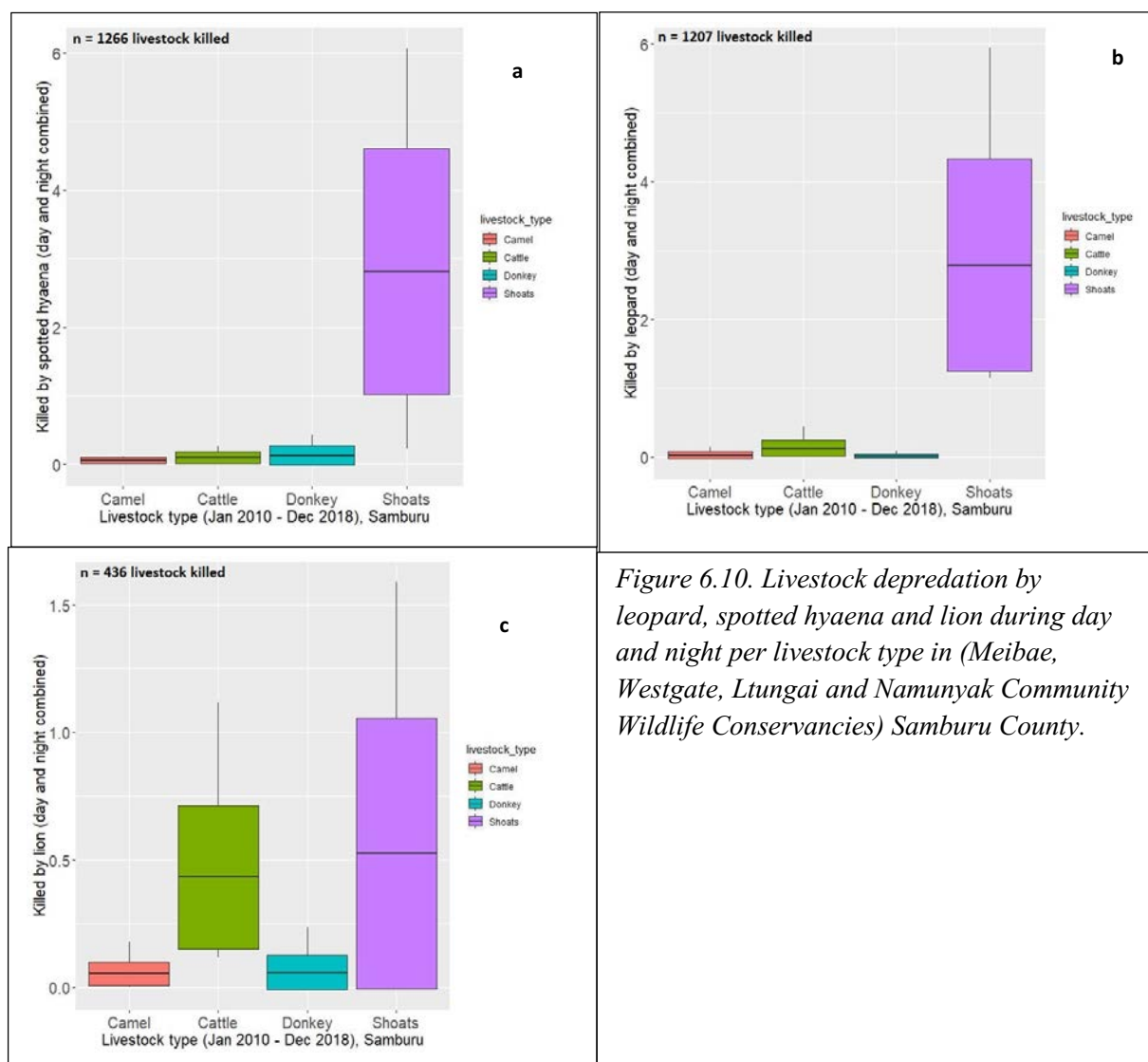


Figure 6.10. Livestock depredation by leopard, spotted hyaena and lion during day and night per livestock type in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

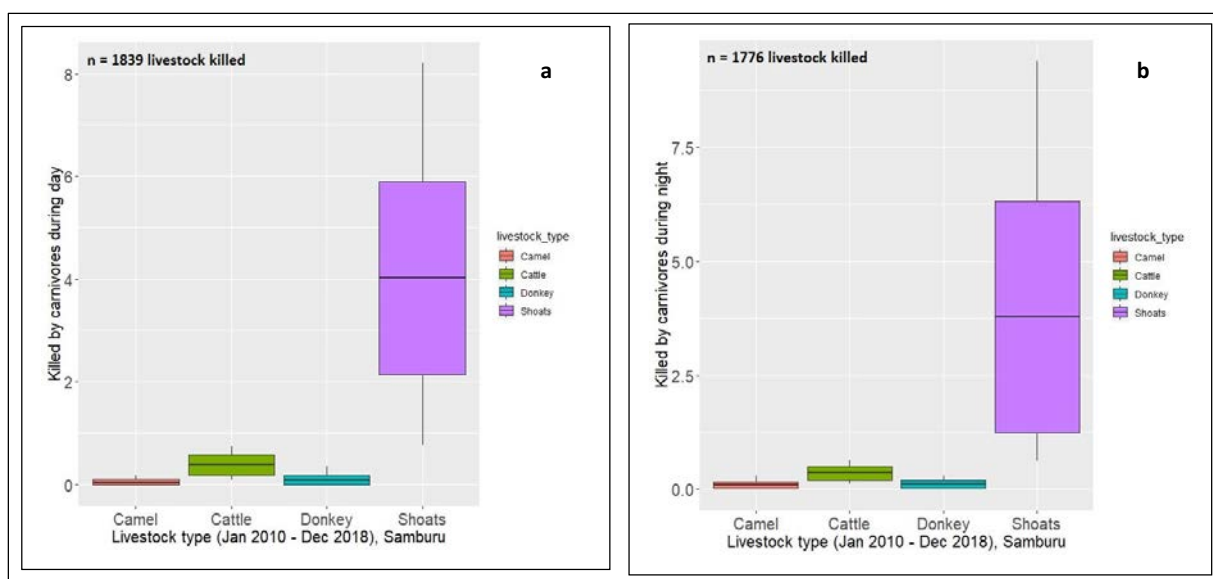


Figure 6.11. Livestock depredation by large carnivores (day vs night) per livestock type in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

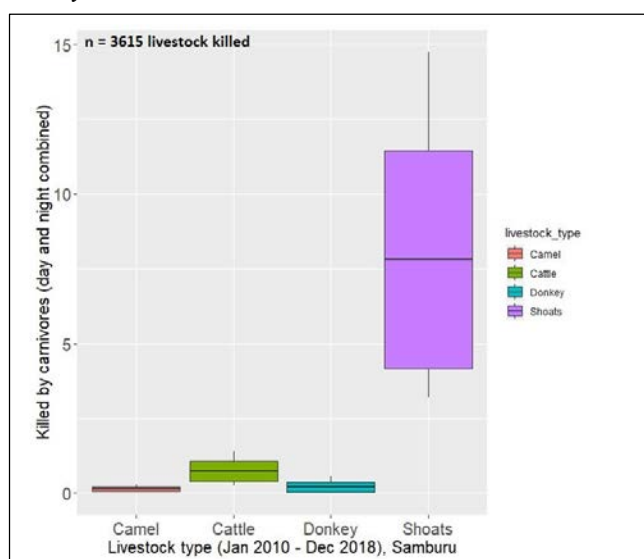


Figure 6.12. Livestock depredation by large carnivores per livestock type during day and night in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

The numbers of livestock killed by each carnivore species were observed to be variable in terms of depredations during day only and night only (see Figures 6.18 to 6.20) and day and night (see Figure 6.21) for each site (locality). Livestock losses due to depredation by the super group 'large carnivores' also varied relative to local habitat in terms of livestock killed during night only and day and night (see Figure 6.22).

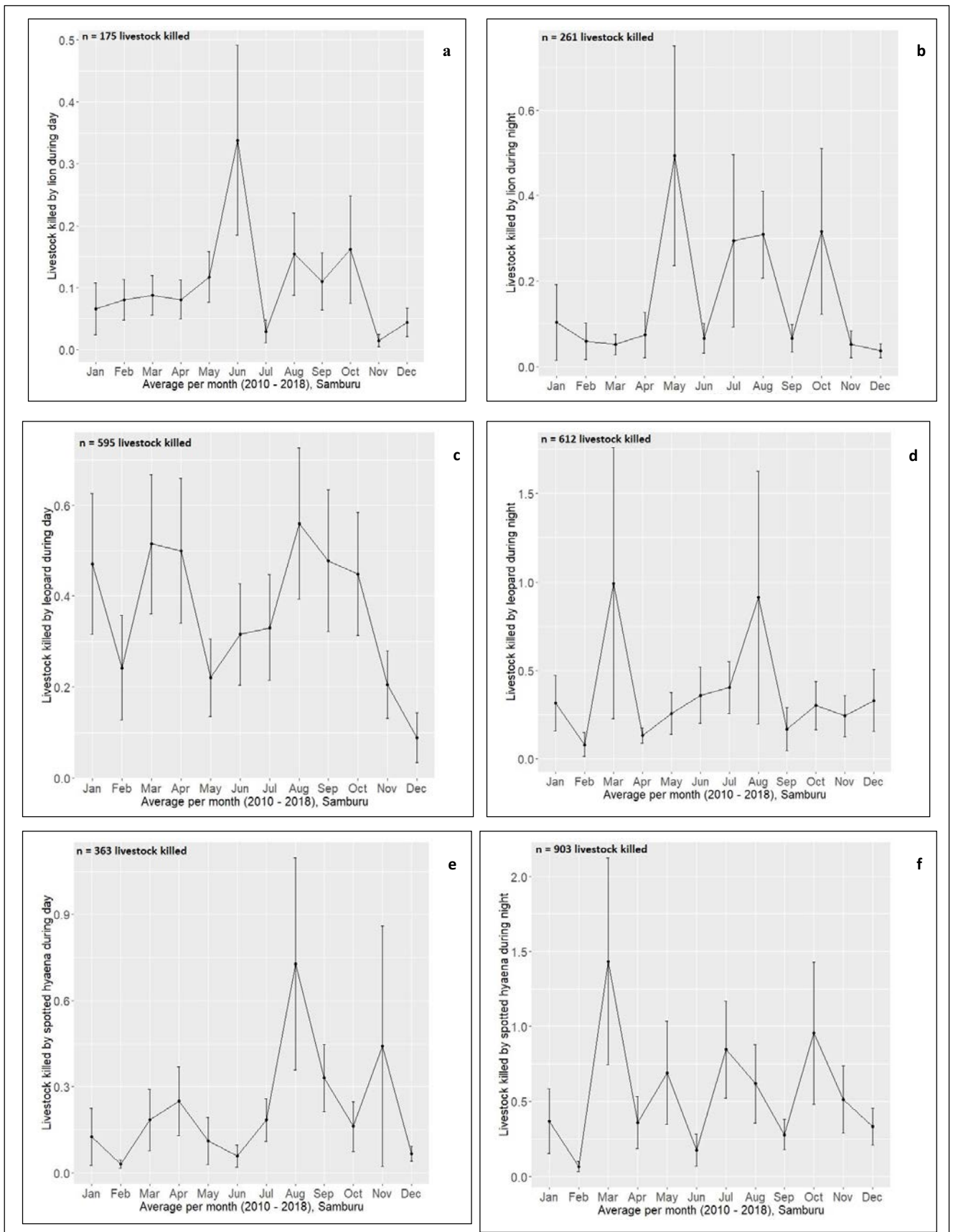


Figure 6.13. Livestock depredation patterns by lion, leopard and spotted hyaena (day vs night) in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

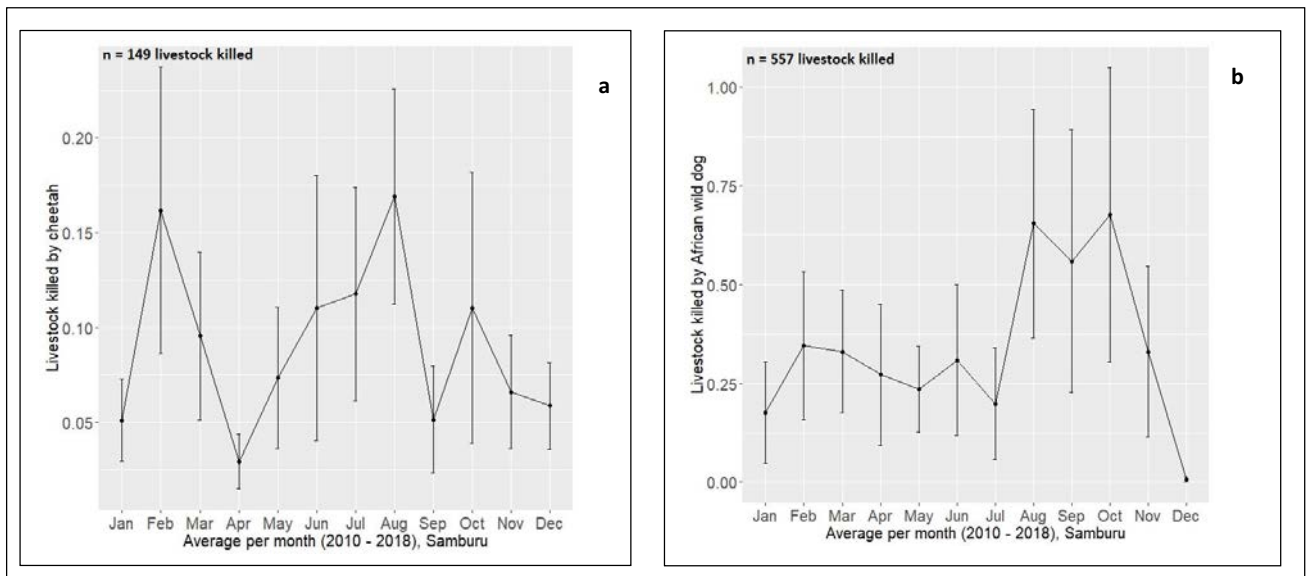


Figure 6.14. Livestock depredation patterns by cheetah and African wild dog in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

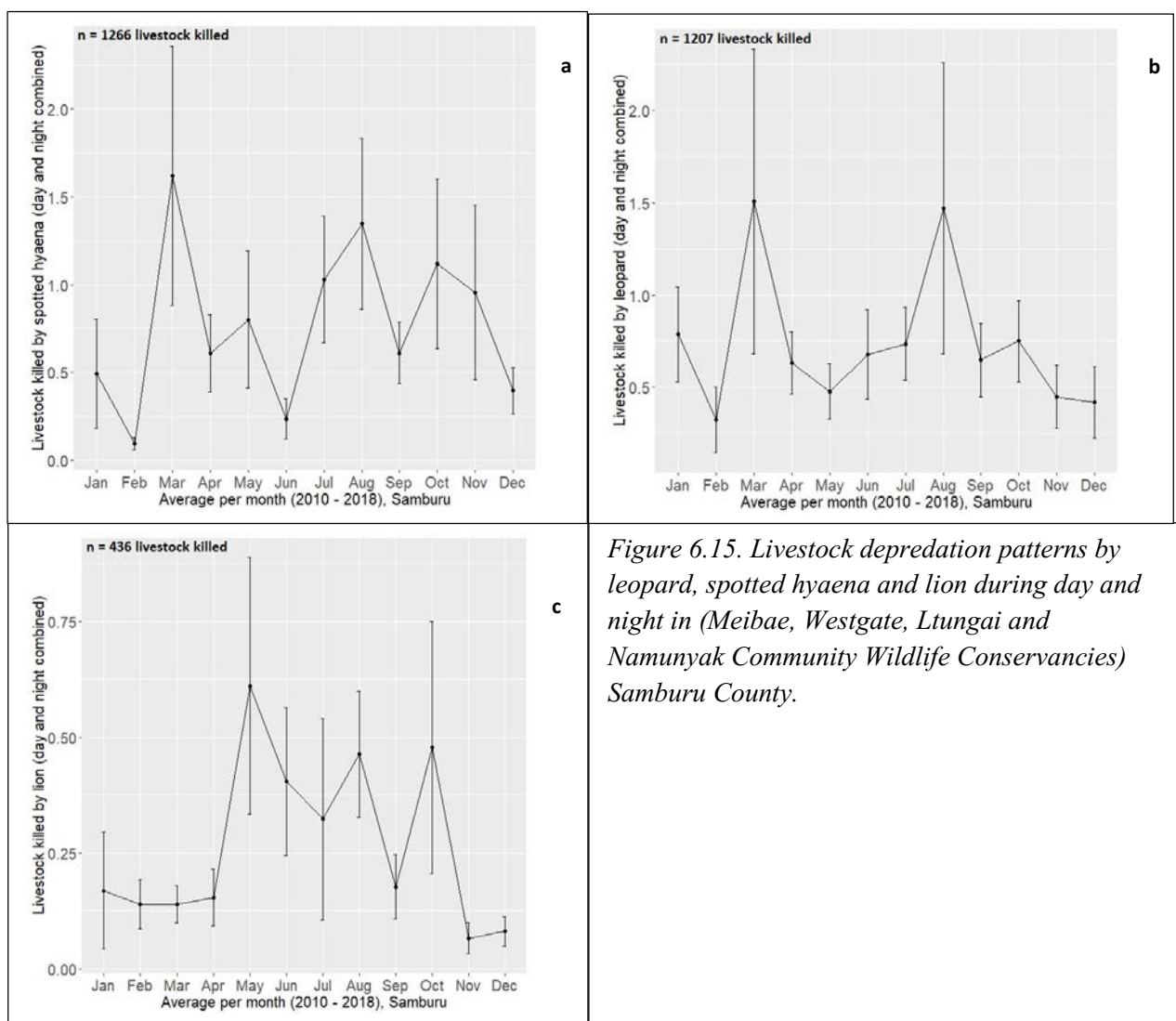


Figure 6.15. Livestock depredation patterns by leopard, spotted hyaena and lion during day and night in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

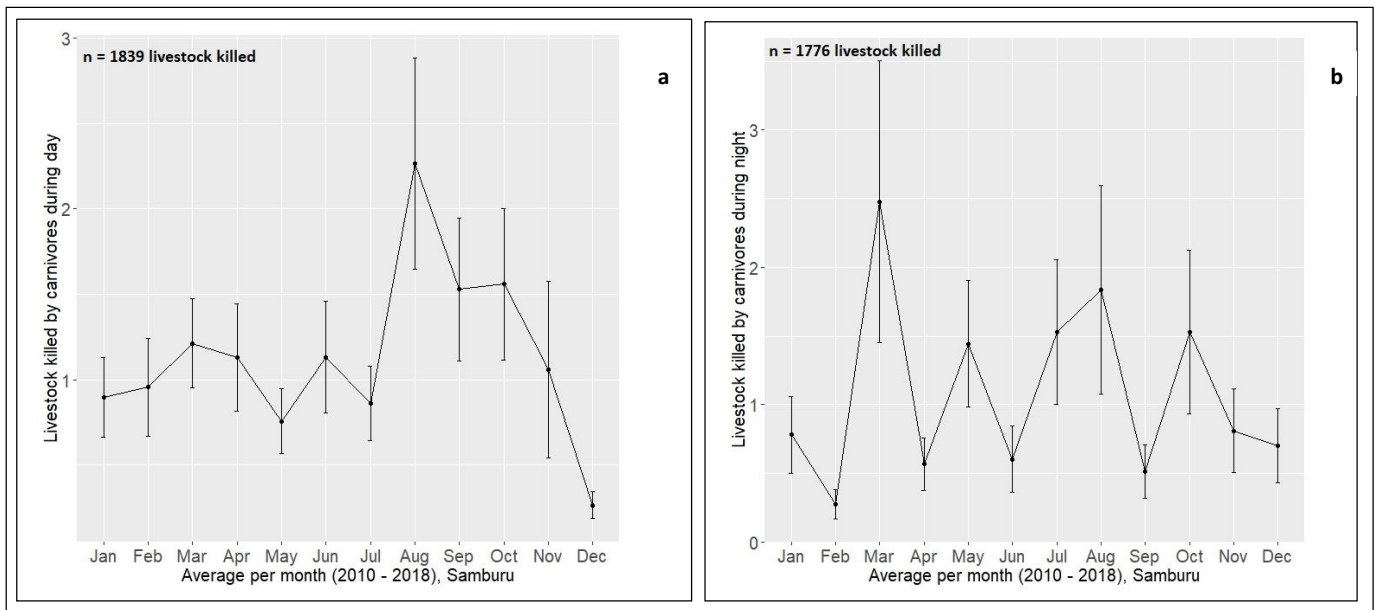


Figure 6.16. Livestock depredation patterns by large carnivores (day vs night) in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

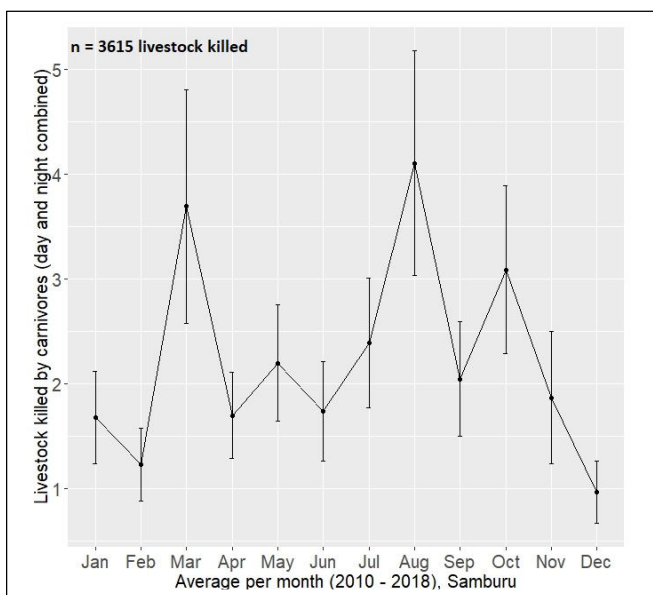


Figure 6.17. Livestock depredation patterns by large carnivores during day and night in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

#### **6.2.12. Effect of seasonality, habitat and livestock type on livestock depredation by large carnivores.**

According to Bokko, (2011); Lehloenya *et al.*, (2004); Hutchison and Macfarlane, (1958); Rakha *et al.*, (1971); Wilson, (1989); Farah *et al.*, (2004); and, Blench and MacDonald, (2000); the breeding seasons for each of the four types of livestock on average are as follows: shoats (151 days/5 months); cattle (285 days/9.5 months); camels (450 days/15 months); and, donkeys (374 days/ 12 months). This implies that in general, with consistent rain patterns and good pastures, shoats will breed twice a year, cattle once a year, donkey every 12 months (slight overlap between subsequent years) and camel once every two years. The patterns of livestock depredation by each large carnivore species exhibited peaks and troughs that conformed with the local calving seasons of livestock which were in turn influenced by seasonality and variations in lengths of breeding cycles of each livestock type (*see* Figures 6.13 to 6.17). These results mirror similar research carried out by Abade *et al.*, (2014) who stated that the potential distribution of large carnivores appeared to be strongly influenced by climatic factors (above average annual precipitation) and local habitat (areas situated close to water e.g. riverine habitat).

Livestock type (*see* Figures 6.8 to 6.12) and local habitat (*see* Figures 6.18 to 6.22) each had a significant effect on the nature and magnitude of losses attributed to livestock depredation per carnivore species and by the super group ‘large carnivores’, however when it came to lion and spotted hyaena attacks on livestock (*see* Figures 6.18a, b & 6.21), it was the interaction between local habitat and livestock that determined the nature and magnitude of losses attributed to livestock depredation.

Shoats were the most depredated livestock type by each large carnivore species (*see* Figure 6.8 to 6.10) and by the super group ‘large carnivores’ (*see* Figure 6.11 & 6.12) in Samburu County. These mirrored findings from similar past studies on large carnivore depredation of livestock (Boitani and Powell, 2012). Lions depredated on cattle on a mean average higher than they did on shoats during day only attacks (*see* Figure 6.8a), but reversed the trend for night only attacks (*see* Figure 6.8b). Unlike leopard (*see* Figure 6.10b) and spotted hyaena (*see* Figure 6.10a) combined day and night attacks, that registered significantly higher mean average depredation on shoats when compared to their depredation on other types of livestock; lion combined day and night depredation on shoats were higher, but not significantly different on the mean average compared to its rates of depredation on cattle, camels and donkeys (*see* Figure 6.10c).

Leopard depredation on shoats during day only attacks were significantly higher on mean average when compared to its rates of depredation on other types of livestock (*see* Figure 6.8c); the same trend was mirrored in its night only attacks on livestock (*see* Figure 6.8d). Spotted hyaena depredation on shoats during day only attacks were higher but not significantly different on mean average when compared to its rates of depredation on other types of livestock (*see* Figure 6.8e); at night however, its depredation on shoats were significantly higher on mean average when compared to its rates of depredation on other types of livestock (*see* Figure 6.8f). The spotted hyaena recorded the highest rate of nocturnal livestock depredation when compared to the leopard and lion (*see* Figure 6.8).

Cheetah and African wild dog livestock depredations mainly occurred during the day, and each of their depredatory attacks on shoats were significantly higher on mean average when compared to their individual rates of depredation on other types of livestock (*see* Figure 6.9). It is important to note that the trends of livestock depredation by large carnivores for day only attacks (*see* Figure 6.11a), night only attacks (*see* Figure 6.11b) and combined day and night attacks per livestock type (*see* Figure 6.12) were due to the individual attributes of attack behavior of each large carnivore species whose attributes have already been discussed.

Livestock numbers exceed wildlife in Samburu County by a ratio of 9:1 (*see* Figure 6.7). According to Woodroffe *et al.*, (2005) and Bagchi & Mishra, (2006), predators have been found to kill livestock in areas where livestock densities are higher than wild prey densities and therefore reducing livestock densities could reduce attacks by predators. Reducing stocking densities has the potential to increase the sustainability of livestock production, improve the quality of livestock, increase the carrying capacity for wild prey, and thus increase the potential to generate revenues from tourism. High stocking rates often result in overgrazing, decreased vegetation, and reduced carrying capacity (Hardin, 1992; Pimentel & Kounang, 1998). However, livestock has been an integral part of African cultures and economies for centuries, and thus encouraging reduced stocking densities would be difficult, especially in communally-owned land (Dregne, 1983; Prins, 2000). Our study sites: Namunyak (383804 ha), Meibae (101517 ha), Ltungai (39584 ha) and Westgate (36299 ha) Community Wildlife Conservancies covered approximately 60% of the total area of Samburu County, which has a total area of 965983 hectares ( $\sim 9660 \text{ km}^2$ ) (NRT, 2017). To that end, our sample size for Samburu was broadly representative of the mosaic of habitats present in Samburu County on a landscape scale.

Lion livestock depredatory attacks per site on average did not significantly vary for each livestock type in its day only (*see* Figure 6.18a) and night only (*see* Figure 6.18b) attacks on livestock; the same trend was mirrored when its day and night attacks were combined into one analysis (*see* Figure 6.21a). Spotted hyaena livestock depredatory attacks per site on average did not significantly vary for each livestock type in its day only (*see* Figure 6.18c) attacks; however, during night only (*see* Figure 6.18d) attacks, its depredatory attacks on shoats were significantly higher on average when compared to its rate of depredatory attacks on other livestock types for Ltungai Community Wildlife Conservancy, but same the trend as day only attacks, were mirrored in its rate of livestock depredatory attacks for the remaining study sites.

The same trends for night only livestock depredatory attacks by the spotted hyaena were mirrored in its combined day and night attacks (*see* Figure 6.21b). Local habitat did not have any significant effect on night depredatory attacks on livestock by the leopard. However, during the day local habitat significantly influenced leopard depredatory attacks on livestock. Leopard livestock depredatory attacks per site on average did not significantly vary for each livestock type for Ltungai and Meibae study sites; however, its depredatory attacks per site on shoats were significantly higher on average when compared to its rate of depredatory attacks on other livestock types for Namunyak and Westgate study sites (*see* Figure 6.20a). African wild dog livestock depredation per site (except Meibae) on average did not significantly vary for each livestock type (*see* Figure 6.20b); the trends of cheetah livestock depredation per site (*see* Figure 6.19) mirrored those of the African wild dog.

Even though there was no interaction between individual climatic variables that influenced livestock depredation by each carnivore species; each of their individual effects influenced the magnitude of losses attributed to large carnivore species-specific livestock depredation.

However, for lion and spotted hyaena depredations on livestock, there was an interaction between site and livestock type (*see* Tables 6.3 - 6.5 & 6.11). This meant that it was the interactions between site and livestock type that determined the nature and impact of losses attributed to livestock depredation. A classic case of livestock being found by the lion or spotted hyaena at the right place at the right time.... or conversely speaking, livestock simply being in the wrong place at the wrong time when it comes to lion or spotted hyaena attacks.

This mirrors the research findings by Hopcraft *et al.*, (2005) in the Serengeti National Park in Tanzania. They concluded that on a landscape scale, lions shift their ranges according to the seasonal movement of prey, but on a local scale (site specificity), the lions shifted their focus to areas where prey was most vulnerable to attacks rather than areas of high prey density (interaction between local habitat/site and prey). It is important to note that the trends of livestock depredation by large carnivores for night only attacks (*see* Figure 6.22a) and combined day and night attacks per site (*see* Figure 6.22b) were due to the individual attributes of attack behavior of each large carnivore species relative to local habitat.

It is widely documented in literature (Périquet, 2014; Winterbach *et al.*, 2013; Kruuk, 1972a; Schaller, 1972; Kingdon and Hoffman, 2013; Durant 1998, 2000) that lion and spotted hyaena home ranges widely overlap in the African savannah, their densities are positively correlated, and that spotted hyaenas only spatially avoid lions in situations where they do not have enough numbers to counter the intense competition with lions for prey and/or the ever present threat of potential fatalities incurred from lion encounters.

In our results (*see* Figures 6.8, 6.10 and 6.30 to 6.34), even though spotted hyaenas were responsible for the highest economic losses due to livestock depredation amongst the large carnivores; leopard depredation on livestock followed very closely in the immediate lower rank after the spotted hyaena.

Leopards are generally least affected by interspecific competition amongst large carnivores because their behavioural and dietary flexibility enables them to coexist with other large predators (Karanth and Sunquist, 2000; Marker and Dickman, 2005).

According to Constant (2014), leopard predation on livestock is most strongly influenced by distance to village and distance to water, in addition to seasonal grazing patterns, the calving season and poor livestock husbandry practices.

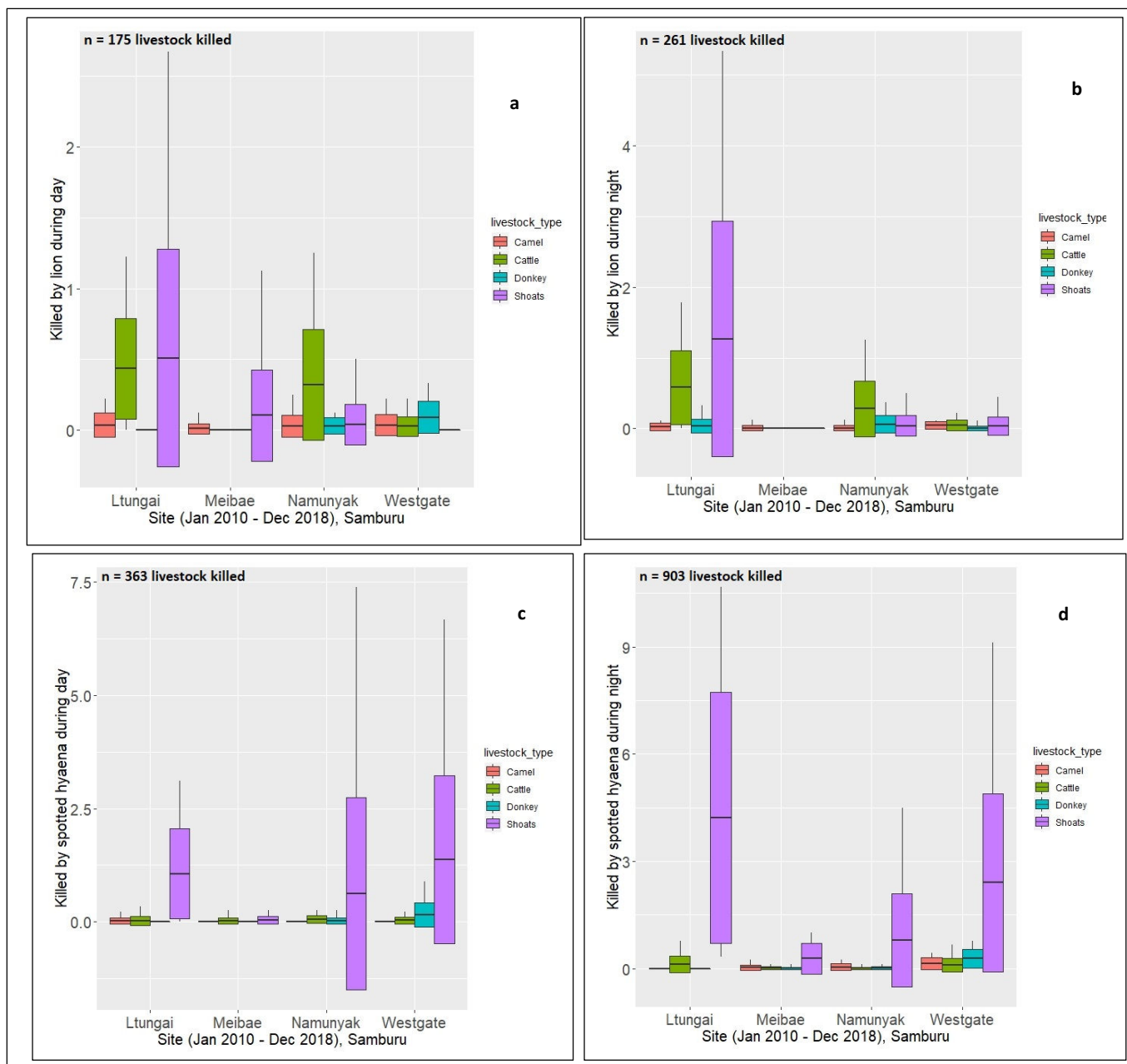


Figure 6.18. Livestock depredation by lion and spotted hyaena (day vs night) in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

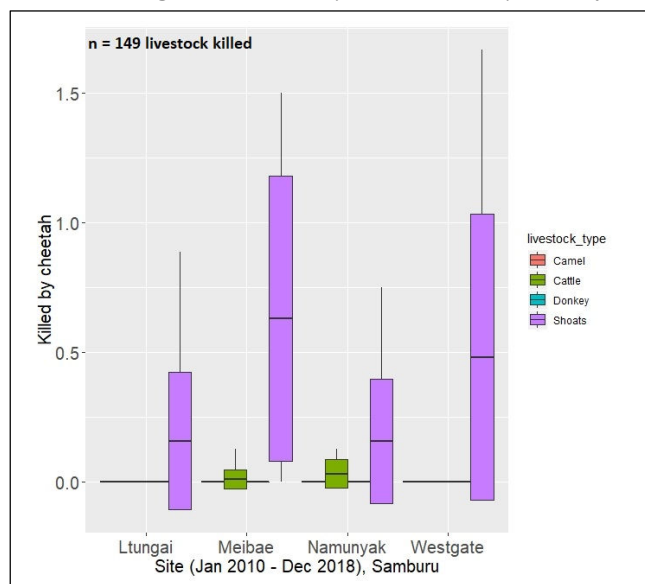


Figure 6.19. Livestock depredation by cheetah during the day in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

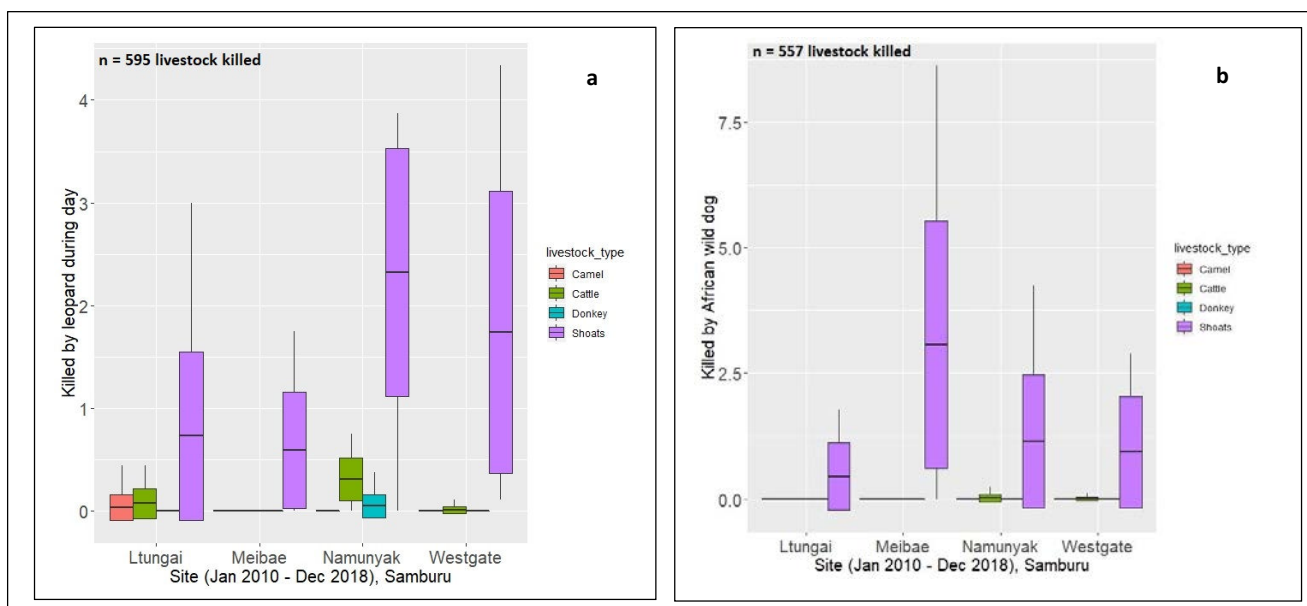


Figure 6.20. Livestock depredation by leopard and the African Wild dog during the day in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

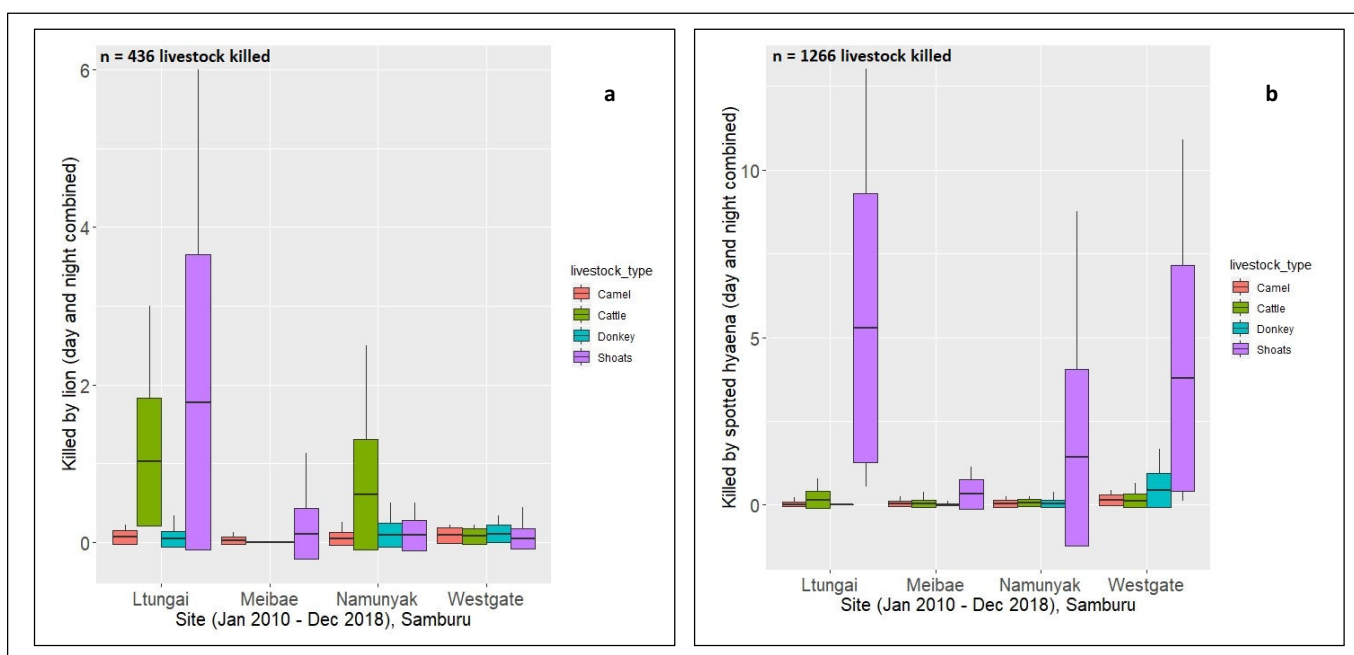


Figure 6.21. Livestock depredation by lion and spotted hyaena during day and night in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

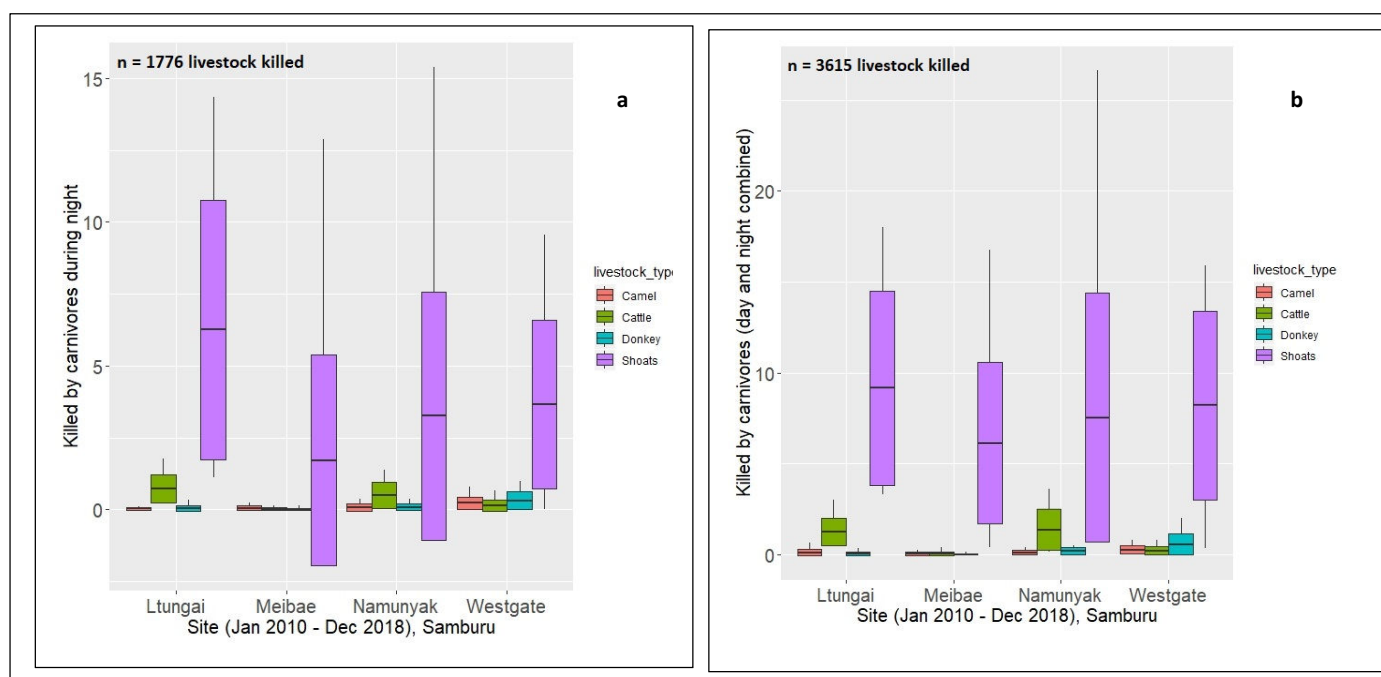


Figure 6.22. Livestock depredation by large carnivores in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

### 6.2.13. Livestock depredation by large carnivores relative to NDVI.

NDVI was observed to significantly contribute to livestock losses due to lion and cheetah depredations (*see* Figure 6.23) and the super group ‘large carnivores’ during day and night (*see* Figure 6.24) in Samburu County. Most lion and cheetah attacks on shoats were concentrated within the NDVI ranges of 0.6 to 0.9. Majority of lion and cheetah attacks on cattle were concentrated on the lower NDVI ranges of 0.1 to 0.4. It is important to note that the influence of NDVI on large carnivore livestock depredation in general (*see* Figure 6.24) was due to the lion and cheetah component in the same. Based on the NDVI results for Samburu County, it means that the lion and cheetah attacks on livestock are influenced by the spatial availability of prey which are in turn influenced by seasonality. Seasonality determines the nature of local habitat/vegetation cover (Abade *et al.*, 2014; Shah *et al.*, 2015; Miller, 2015) which can be inferred to remotely through climatic variables such as NDVI and SPI.

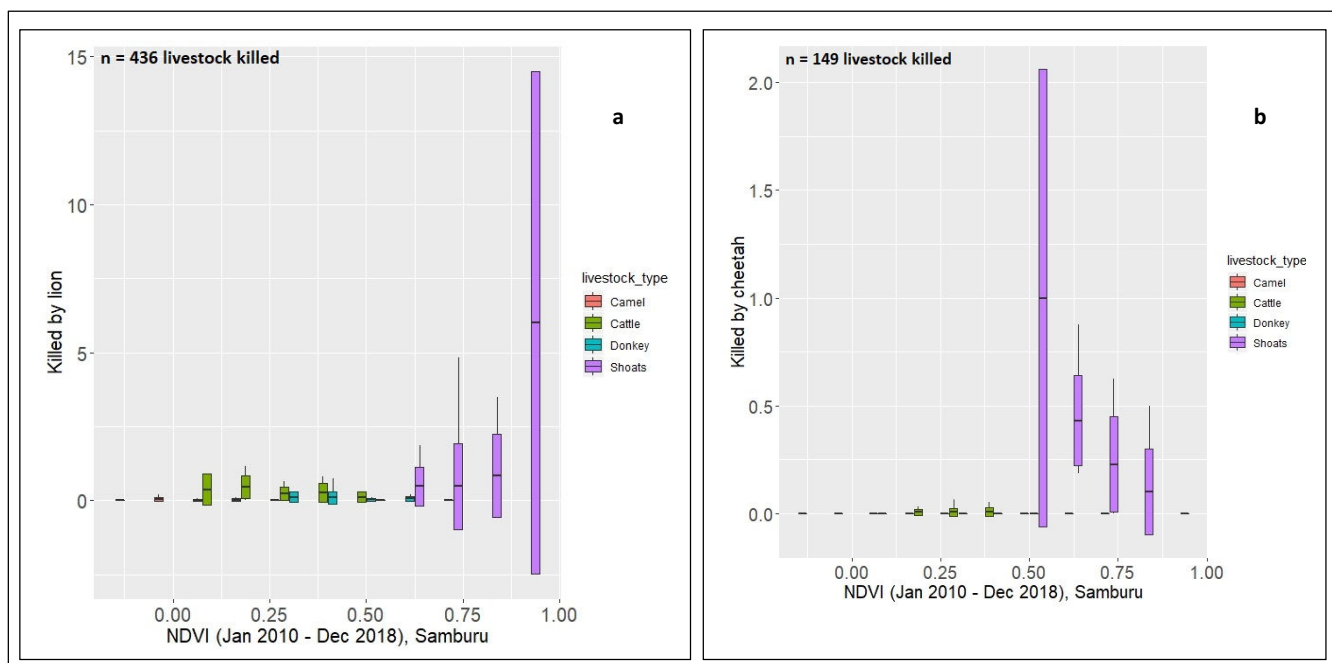


Figure 6.23. Livestock depredation by lion and cheetah relative to NDVI in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

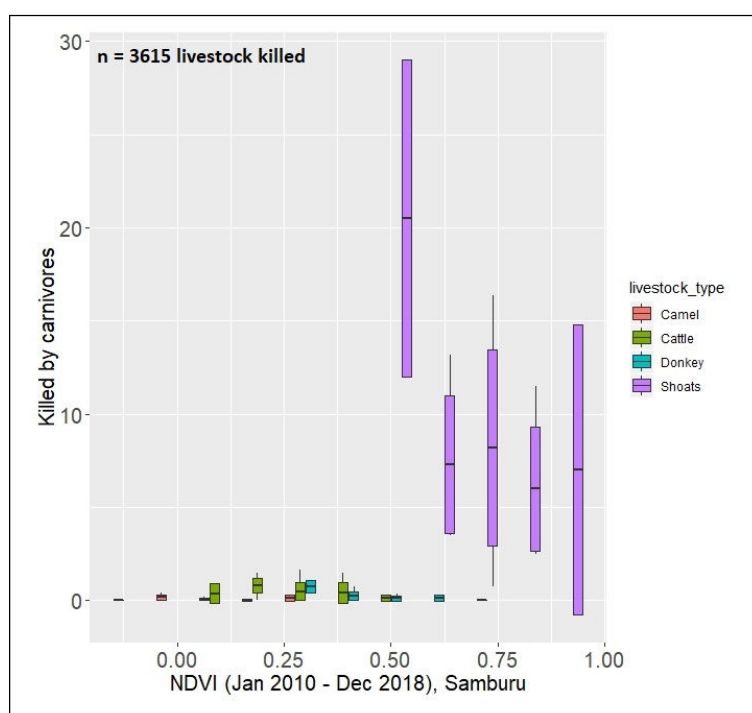


Figure 6.24. Livestock depredation by large carnivores relative to NDVI in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

#### 6.2.14. Livestock depredation by large carnivores relative to SPI.

SPI was observed to significantly contribute to livestock losses due to lion depredation (*see* Figure 6.25b) and depredation by the super group ‘large carnivores’ (*see* Figure 6.25b).

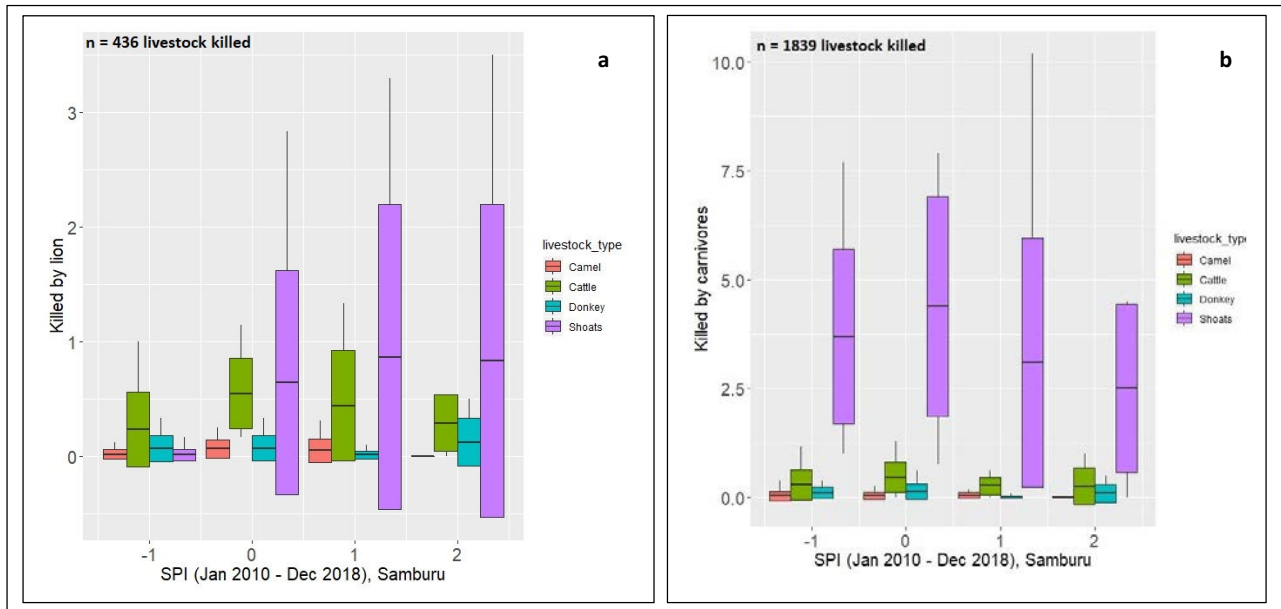


Figure 6.25. Livestock depredation by lion and large carnivores relative to SPI in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

SPI is a drought index. Positive values point to normal condition to wet condition and negative values indicate normal condition to dry condition (*see* Table 6.1 *adopted from World Meteorological Organization, 2012*). Among the large carnivores, SPI only significantly influences lion attacks on livestock in Samburu County (*see* Figure 6.25a). It is important to note that the effect of SPI on large carnivore livestock depredation in general (*see* Figure 6.25b) was due to the lion component in the same. Most lion attacks on camels were concentrated on the SPI region between 0 and positive 1 (normal conditions). Lion attacks on cattle seemed concentrated in the SPI region between negative 1 to positive 1 (normal conditions) while lion attacks on shoats seemed concentrated in the SPI region between zero to positive 2 (normal to extremely wet conditions). This information can be used to help mitigate lion depredation on livestock using earth observation data by conducting a ‘hotspot analysis’ through GIS to determine which areas are most vulnerable to lion depredation on livestock at particular seasons of the year based on climatic variables as recommended by Miller (2015).

### 6.2.15. Livestock depredation by large carnivores relative to minimum and maximum temperatures.

Minimum and maximum temperatures were observed to significantly contribute to livestock losses due to leopard (*see* Figure 6.26), cheetah (*see* Figure 6.27a) and ‘large carnivore’ (*see* Figure 6.27b) depredations.

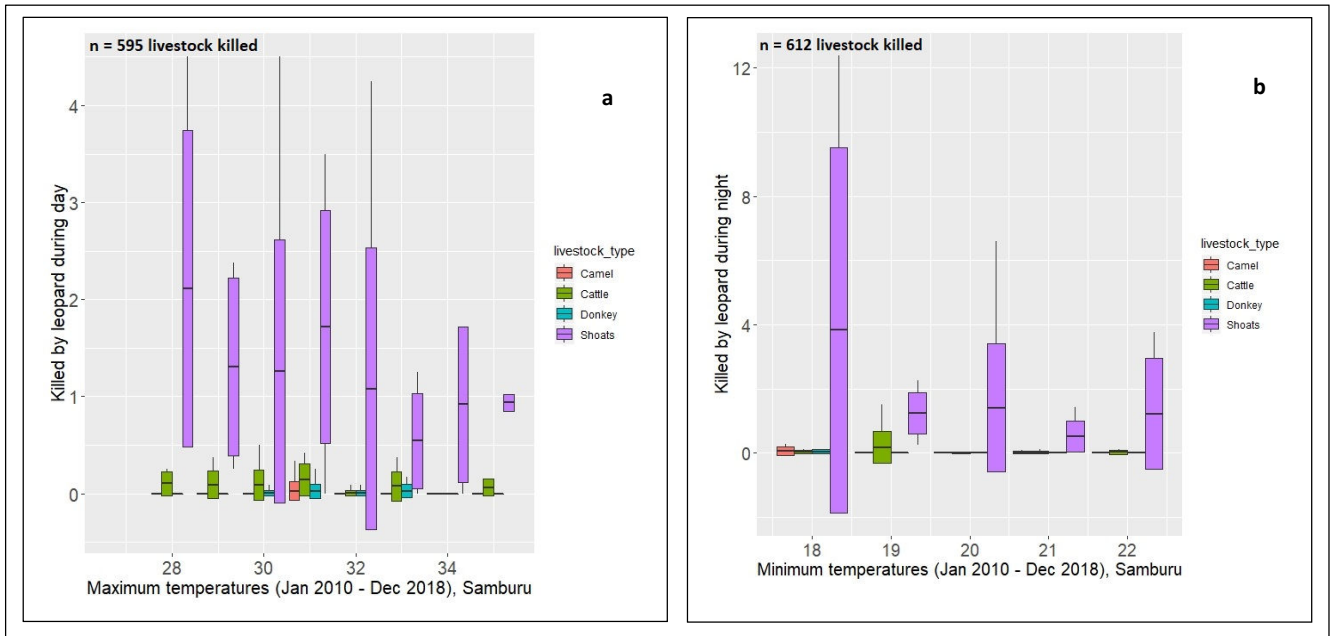


Figure 6.26. Livestock depredation by leopard relative to maximum and minimum temperatures in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

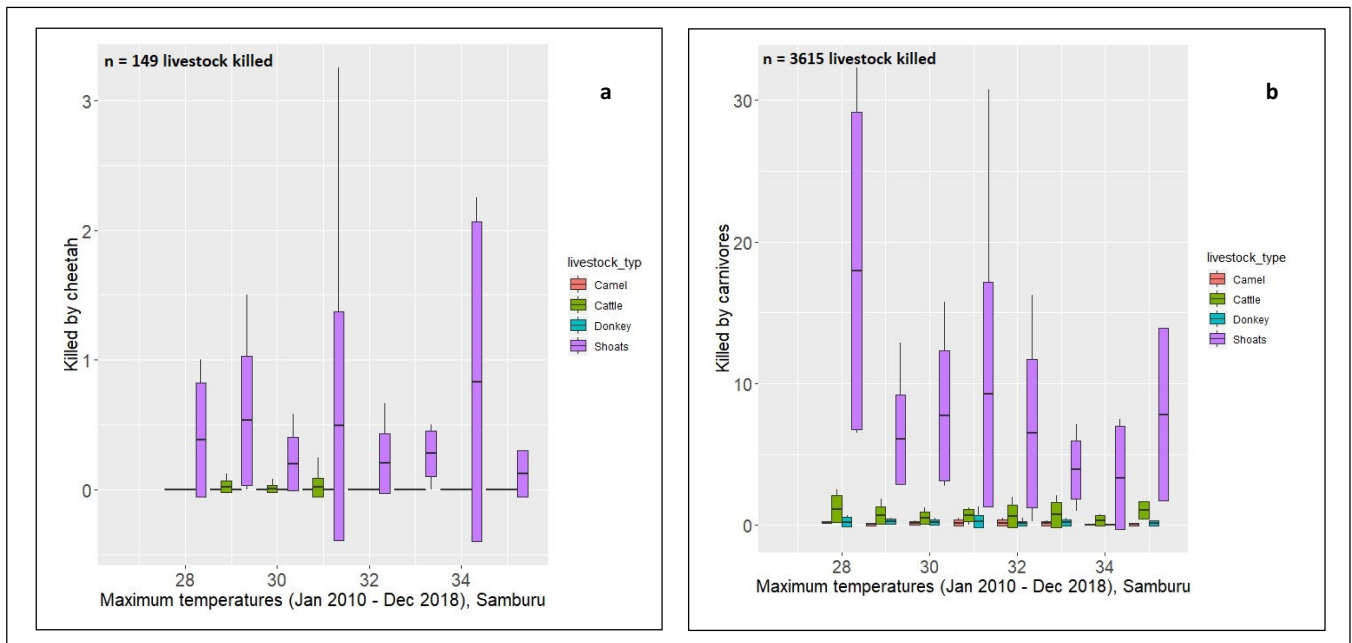


Figure 6.27. Livestock depredation by cheetah and by large carnivores relative to maximum temperatures in (Meibae, Westgate, Ltungai and Namunyak Community Wildlife Conservancies) Samburu County.

Among the large carnivores, maximum temperatures only significantly influence leopard and cheetah day attacks on livestock in Samburu County (*see* Figure 6.26a & 6.27a). Minimum temperatures only significantly influence leopard night attacks on livestock in Samburu County (*see* Figure 6.26b). It is important to note that the effect of maximum temperatures during day on large carnivore livestock depredation in general (*see* Figure 6.27b), was due to the leopard and cheetah components in the same. Most leopard and cheetah attacks on livestock during day were very pronounced at the temperature ranges between 28<sup>0</sup>C to 34<sup>0</sup>C with shoats being the most preferred livestock type. Leopard attacks on livestock during the night were most pronounced at 18<sup>0</sup>C with shoats being the most preferred livestock type. This information can be used to help mitigate leopard and cheetah depredations on livestock using maximum (day) and minimum (night) temperatures to determine which areas are most vulnerable to livestock depredation at particular seasons of the year as recommended by Miller (2015).



*Figure 6.28. A photograph of kill site where a camel was killed by lions at the Samburu National Reserve. Photo credit: Titus Adhola.*

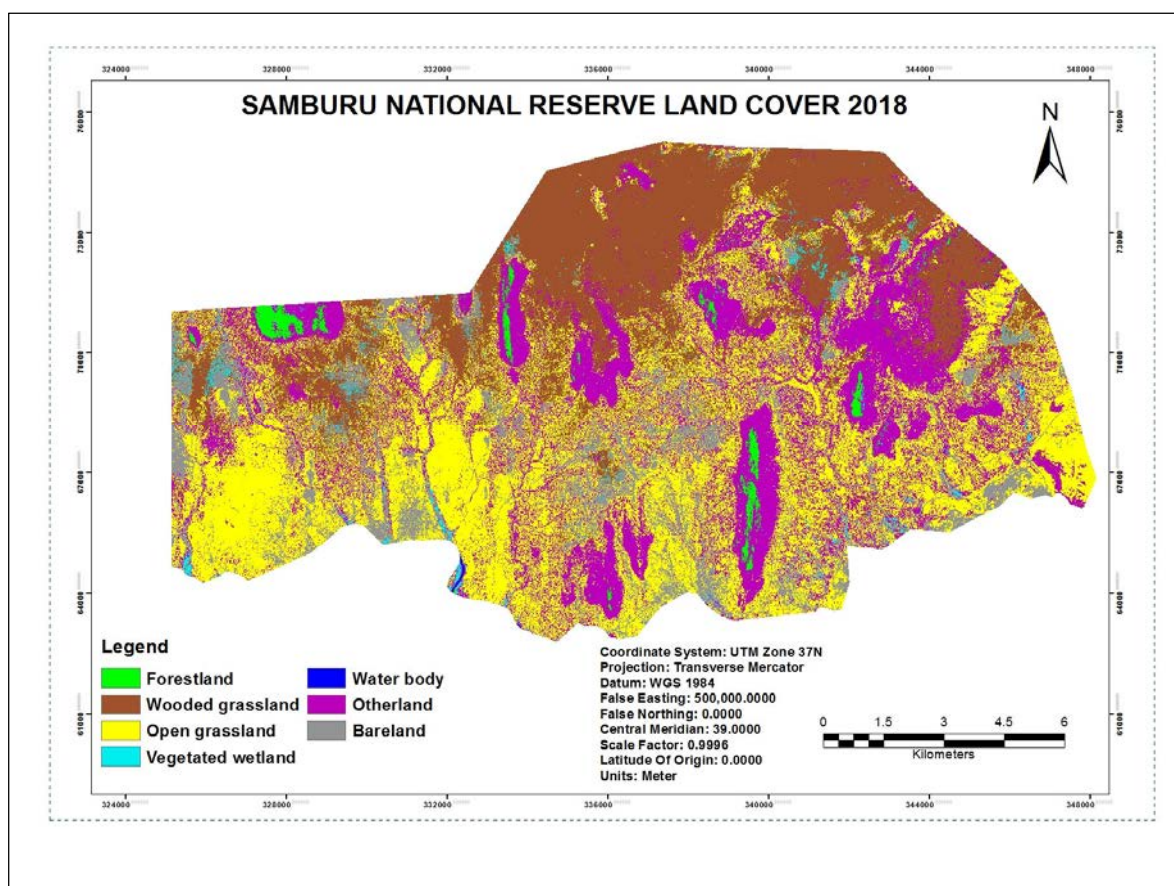


Figure 6.29. Map of Samburu National Reserve showing land cover in 2018.

The local communities often made deep excursions into the open and wooded grasslands within the park to graze their cattle during dry seasons. An undocumented number of livestock have fallen prey to carnivore attacks. During this PhD study, livestock species (cattle, shoats and camel) carcasses were discovered within the park having fallen prey to carnivore attacks. Majority of these kills were concentrated in the regions near the Ewaso Ng'iro river that separates the Samburu National Reserve in Samburu County with the Buffalo Springs National Reserve in Isiolo County. The Samburu National Reserve was one of the study areas for investigating carcass consumption patterns by the large carnivores (Chapter 4) and carnivore scat morphometry (Chapter 5).

From the DRSRS animal population census (*see* Figure 6.7), it was observed that livestock outnumber wild ungulates by a ratio of 9:1, meaning that the options of the carnivores seem limited and will most likely attack livestock within and without the park boundaries.

Due to the expansive extent of Samburu County and limited resources including time, it was not possible to groundtruth the whole county in order to produce a GIS land cover map for Samburu County within the duration of this PhD study.

### 6.2.16. Economic impact of livestock depredation by large carnivores in Samburu County from 2010 to 2018.

To determine the economic impact of livestock depredation by large carnivores, we first determined the probabilities (relative frequencies) of carnivore prey (domestic vs wild herbivores) being killed by any species of carnivore. Figure 6.7 gives the averaged relative frequencies of possible carnivore prey during any predation/depredation incident. N for possible carnivore prey was derived by averaging census output for each prey category (shoats, cattle, camel, donkey and wild herbivores) from the animal population census by DRSRS for the years 2010, 2013 and 2015 was 31,880 herbivores (domestic and wild) present in Samburu in any given year from 2010 to 2018.

The relative frequencies of shoats, cattle, camel, donkey and wild herbivore populations that made up N (31,880 herbivores) according to Figure 6.7 were: shoats (0.82): cattle (0.14): camel (0.02): donkey (0.01): wild herbivores (0.01). The relative frequency for livestock (domestic prey) was therefore 0.99.

Determining N for livestock only present in Samburu in any given year from 2010 to 2018 was derived from; multiplying the relative frequency for livestock (0.99) by (31,880) herbivores:  $0.99 \times 31,880 = 31,561$  head of livestock (domestic herbivores).

To determine the ratio of each livestock type from the livestock populations per year, wild herbivore populations were excluded from the new analysis and relative frequencies derived from the averaged population totals per stock type (*see* Table 6.17).

Stock type	Averaged population count (2010, 2013 and 2015)	Relative frequency
Shoats	26124	0.83
Cattle	4615	0.14
Camel	648	0.02
Donkey	208	0.01

*Table 6.17. Probabilities (relative frequencies) for livestock type fatalities in case of any reported depredation incident in Samburu in any given year from 2010 to 2018.*

The cumulative totals for each stock type killed per carnivore species in the entire Samburu County were determined through extrapolation the cumulative totals for each stock type killed in our study sites (2010-2018) by factor  $x$  (factor  $x$  = total area of Samburu County divided by the combined area of our study sites). Therefore, factor  $x$  (965983ha/561204ha) = 1.7. (see Table 6.18).

carnivore type	livestock killed during day after extrapolation by factor $x$ (1.7)	livestock killed during night after extrapolation by factor $x$ (1.7)	livestock killed during day and night after extrapolation by factor $x$ (1.7)
lion	298	444	742
leopard	1012	1040	2052
spotted hyaena	617	1535	2152
African wild dog	947		
cheetah	253		

*Table 6.18. Extrapolated cumulative totals of livestock killed by each carnivore species in Samburu County from 2010 to 2018.*

The postulated probability of livestock attack by large carnivores according to Table 6.17 were then used to derive the actual numbers of each livestock type killed by each carnivore species in Samburu County from 2010 to 2018 (see Tables 6.19 to 6.23).

livestock type	number killed during day by lion	number killed during night by lion	number killed during day and night by lion
shoats	247	369	616
cattle	42	62	104
camel	6	9	15
donkey	3	4	7

*Table 6.19. Cumulative totals per livestock type killed by lion in Samburu County from 2010 to 2018.*

livestock type	number killed during day by leopard	number killed during night by leopard	number killed during day and night by leopard
shoats	840	863	1703
cattle	142	146	288
camel	20	21	41
donkey	10	10	20

*Table 6.20. Cumulative totals per livestock type killed by leopard in Samburu County from 2010 to 2018.*

livestock type	number killed during day by spotted hyaena	number killed during night by spotted hyaena	number killed during day and night by spotted hyaena
shoats	512	1274	1786
cattle	86	215	301
camel	12	31	43
donkey	7	15	22

*Table 6.21. Cumulative totals per livestock type killed by spotted hyaena in Samburu County from 2010 to 2018.*

livestock type	number killed during day by African wild dog	number killed during night by African wild dog	number killed during day and night by African wild dog
shoats	786	0	786
cattle	133	0	133
camel	19	0	19
donkey	9	0	9

*Table 6.22. Cumulative totals per livestock type killed by African wild dog in Samburu County from 2010 to 2018.*

livestock type	number killed during day by cheetah	number killed during night by cheetah	number killed during day and night by cheetah
Shoats	210	0	210
Cattle	35	0	35
Camel	5	0	5
Donkey	3	0	3

*Table 6.23. Cumulative totals per livestock type killed by cheetah in Samburu County from 2010 to 2018.*

The market rates in USD for each livestock killed were computed for Samburu County whilst incorporating for the highs (seasons of good socio-economic stability) and lows (seasons with very low socio-economic stability) of market fluidity during livestock sales within the context of January 2010 to December 2018 to derive an average market rate based on comparative data from annual reports the Ministry of Agriculture, Livestock and Fisheries (*see* Table 6.24) ([http://www.lmiske.go.ke/lmis/marketReport.htm?action=submitMarketReportParameters&reportType=Yearly\\_full](http://www.lmiske.go.ke/lmis/marketReport.htm?action=submitMarketReportParameters&reportType=Yearly_full)).

livestock type	high season rates (USD)	low season rates (USD)	Average market rate (USD)
Camel	550	350	450
Cattle	450	130	290
Donkey	120	40	80
Shoats	50	20	35

*Table 6.24. Average market rates for each livestock type for Samburu County within the context of January 2010 to December 2018 using comparative data from annual reports the Ministry of Agriculture, Livestock and Fisheries.*

The market rates derived from (*see* Table 6.24) were then used to compute and compare annual livestock losses due to depredation by each carnivore species (Figures 6.30 to 6.34) in addition to the overall economic impact arising from depredation by the super group ‘large carnivores’ per livestock type (*see* Figure 6.35).

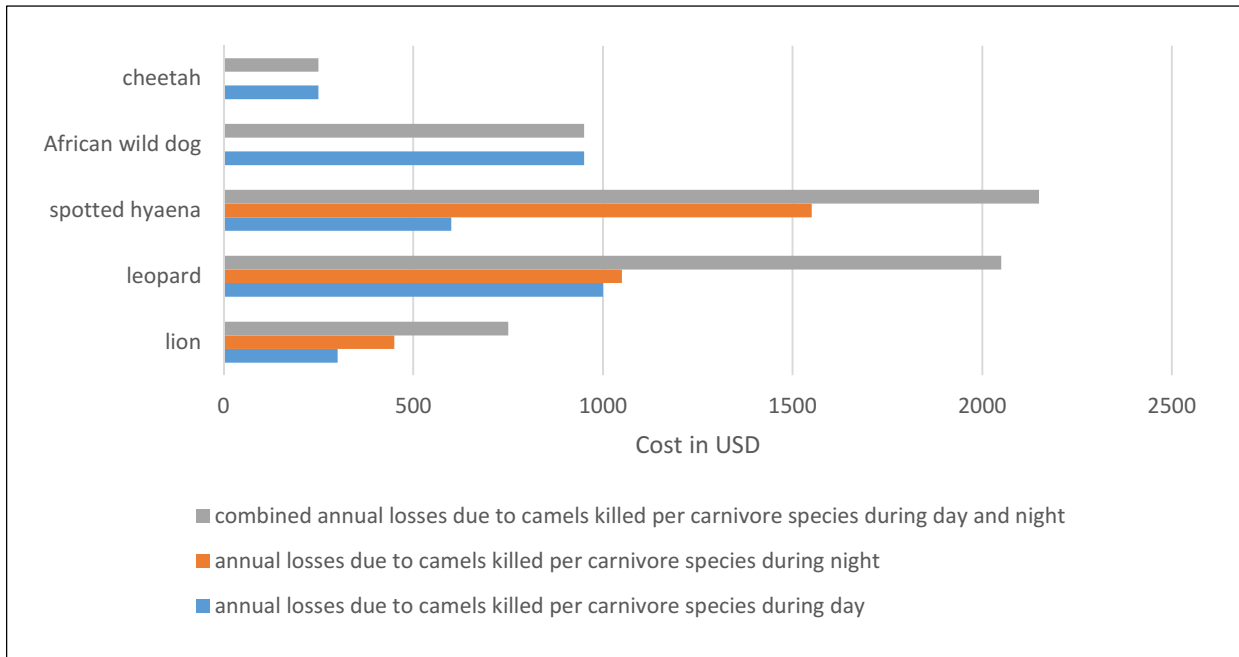


Figure 6.30. Annual economic impact attributed to camels killed by each large carnivore species in Samburu County.

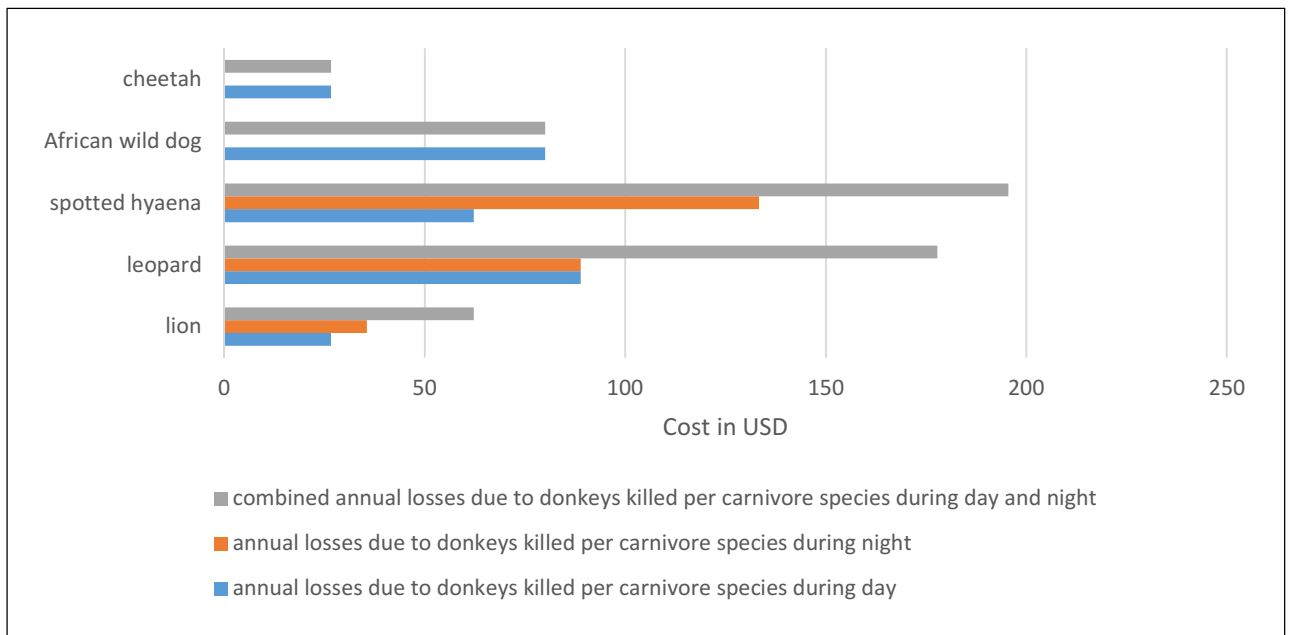


Figure 6.31. Annual economic impact attributed to donkeys killed by each large carnivore species in Samburu County.

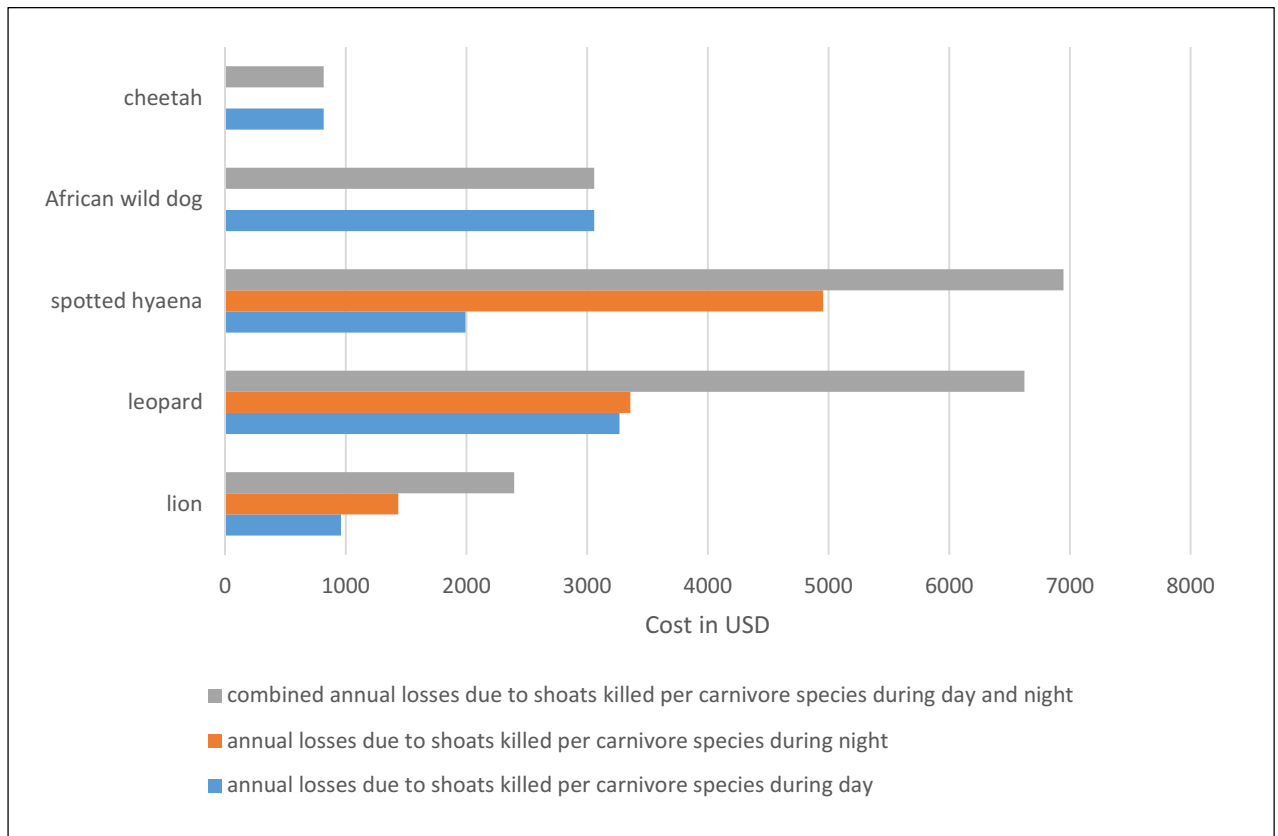


Figure 6.32. Annual economic impact attributed to shoats killed by each large carnivore species in Samburu County.

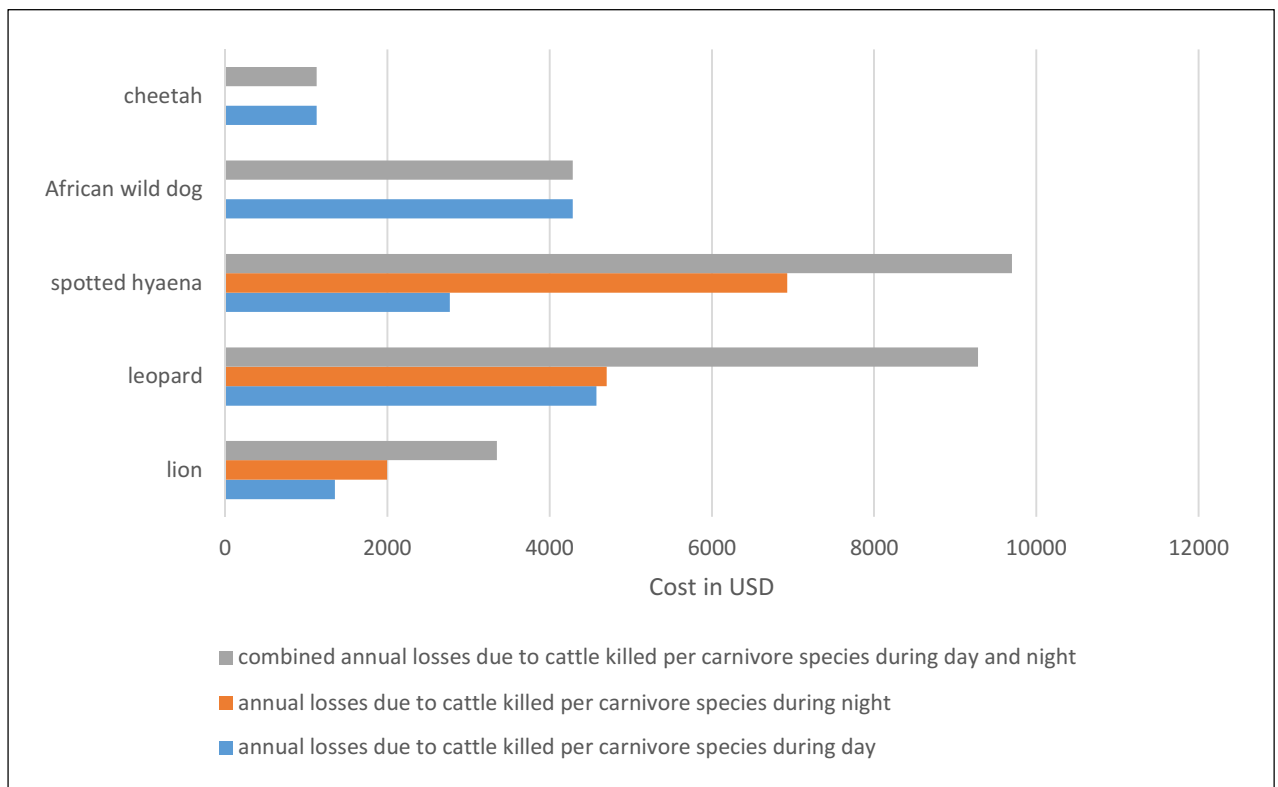


Figure 6.33. Annual economic impact attributed to cattle killed by each large carnivore species in Samburu County.

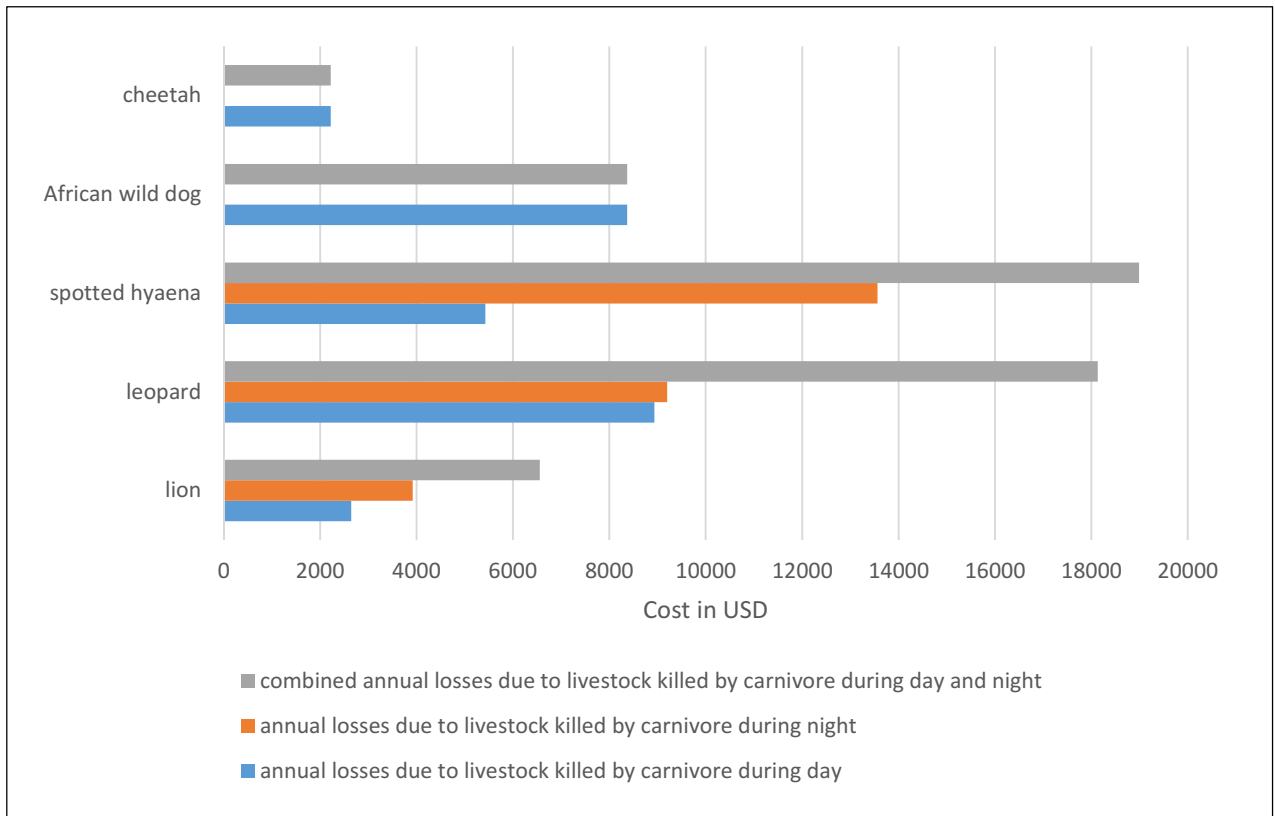


Figure 6.34. Annual economic impact attributed to livestock killed by each large carnivore species in Samburu County.

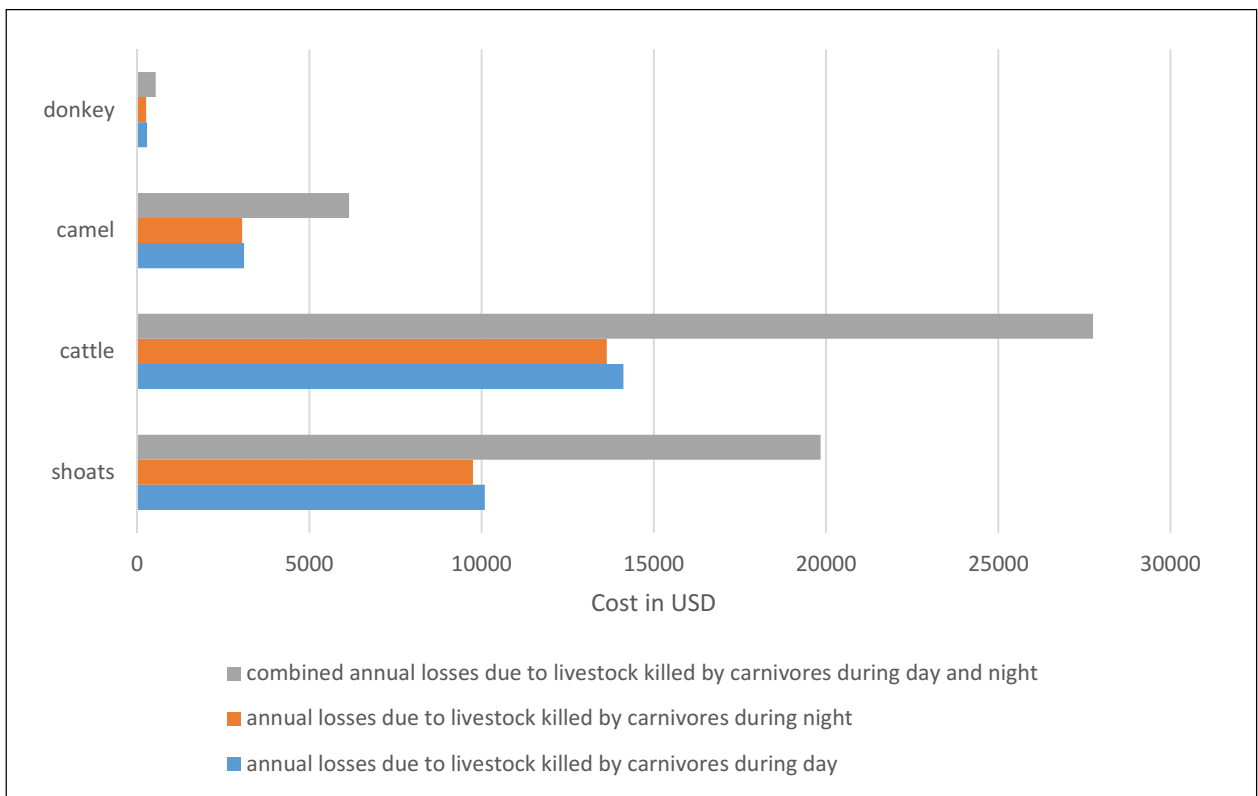


Figure 6.35. Combined economic impact implications attributed to livestock killed by large carnivores in Samburu County.

To get an overview of the economic impact of large carnivore livestock depredation in Samburu County, we first computed the relative frequencies of livestock types based on an average of three animal census counts (domestic and wild herbivores) for the years 2010, 2013 and 2015 (*see* Figure 6.7). Since the focus of this study was mainly on livestock depredation by the large carnivores in Samburu, we discarded the wild herbivore component to concentrate on the relative frequencies of livestock (domestic herbivores) only (*see* Table 6.17). The cumulative totals for each stock type killed per carnivore species in the entire Samburu County were determined through extrapolation the cumulative totals for each stock type killed per carnivore species in our study sites (*see* Table 6.18). The actual numbers of each livestock type killed by each carnivore species were then computed (*see* Tables 6.19 to 6.23). The market rates in USD for each livestock killed were then computed for Samburu County was then computed (*see* Table 6.24).

It is worth of note that even though some of the proportions of domestic herbivores killed were juvenile livestock, we did not have the means to verify this since the large carnivore livestock depredation data availed to us by our collaborator - NRT lacked such specific details. We therefore computed the market rates for adult livestock types only (*see* Table 6.24). The aim of this study was to compare the relative economic costs incurred by the Samburu pastoralist community in terms of livestock losses attributed to co-existing with each large carnivore species in particular (*see* Figures 6.30 to 6.34) and the large carnivore community in general (*see* Figure 6.35) in Samburu County. Other related information such as livestock losses due to disease, drought or theft during the study period was not available to us and therefore excluded from our results and subsequent discussions.

The spotted hyaena caused the highest economic losses due to livestock depredation per livestock type (*see* Figures 6.30 to 6.33) and livestock in general (*see* Figure 6.34). The subsequent lower in rank order after the spotted hyaena was the leopard followed by the African wild dog. It was interesting to note that the lion fell in the second lowest rank in all categories (livestock type and domestic herbivores in general). The cheetah fell in the lowest rank compared to the other large carnivore species in Samburu County. The economic impact of losses in USD due to cattle depredation by the large carnivores were the highest followed in lower rank by losses due to large carnivore predatory attacks on shoats. Economic losses due to large carnivore predatory attacks on camels were the second last in the ranked scale of losses. Least economic losses were incurred when large carnivores depredated upon donkeys (*see* Figure 6.35).

### 6.3. Key socio-cultural factors influencing human-carnivore conflict in Samburu.

This study sought to identify the effect of key socio-cultural factors within the Samburu pastoralist dominated landscape that contributed positively or negatively towards human-carnivore conflict within the county. To be able to achieve this, our project team complemented the quantitative outputs from an ethnographic survey with qualitative outputs from a community carnivore conservation workshop conducted at the tail end of this PhD study.



Figure 6.36. Photo of a Samburu lady and her daughter herding shoats. Photo credit: Titus Adhola.

Ethnographic surveys were conducted to understand the dynamic relationship between the Samburu pastoralists and the large carnivores (lion, leopard, cheetah, spotted hyaena, striped hyaena and African wild dog). All randomly selected individuals representing 75 households (n=75) approached gave their approval prior to each interview taking place. To this end the study recorded a 100% feedback on responses. Demographic variables such as gender (male/female), age (elderly/middle-aged/youth), educational background, socio-economic status (upper/middle/lower classes) based on the frequency and variety of stock types (shoats/cattle/donkey/camel) for each respondent, were scored against a set criteria of factors to eventually classify each respondent's overall view towards carnivores as positive or negative, and overall tolerance level as zero or low or high towards carnivore presence in their neighbourhood (co-existence). Only one respondent out of 74 had formal education therefore the effect of education on attitudes and perceptions towards large carnivores could not be statistically tested.

Gender		Age group			Socio-economic class		
Male	female	youth	middle age	elderly	lower	middle	upper
42	33	28	34	13	12	48	15

Table 6.25. Demographic constitution of 75 respondents interviewed during the semi-structured questionnaire surveys.

The outcome of the questionnaire surveys has been presented in three ways; a) the provisional R software (version 3.6.0) summary output; b) statistical outputs from binomial regression analyses using GLM and thereafter an ANOVA with a Chi-square test statistic; and c) a qualitative output of key responses given to open ended questions during the interviews.

Figure 6.37 highlights the relative frequencies of respondents per demography type derived from Table 6.25 as follows: in terms of gender representation, the ratio between males to females was  $0.56:0.44$ ; in terms of age group representation, the ratio between the youth, middle-aged and elderly was  $0.37:0.45:0.18$  respectively; in terms of socio-economic class, the ratio between lower, middle and upper classes was  $0.16:0.64:0.20$  respectively. The gender and age group demography types seemed well balanced in terms of constitution, but the socio-economic class was generally skewed towards the middle class.

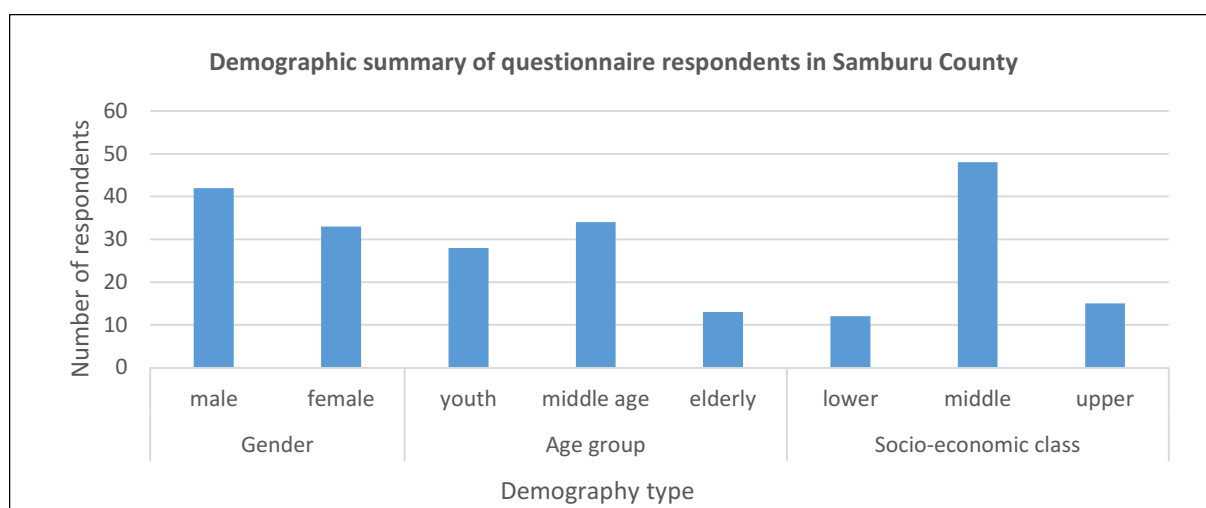


Figure 6.37. Demographic constitution of respondents in the semi-structured questionnaire survey in Samburu County ( $n = 75$ ).



Figure 6.38. Photo of a Samburu herds boy tending to shoats. Photo credit: Titus Adhola.

Figure 6.39 highlights community perceptions on the depredation rates per livestock type by the large carnivores in Samburu County. Shoats are perceived as the most attacked livestock in general and during day only attacks by the large carnivores. Cattle are perceived as the most attacked livestock during night attacks by the large carnivores.

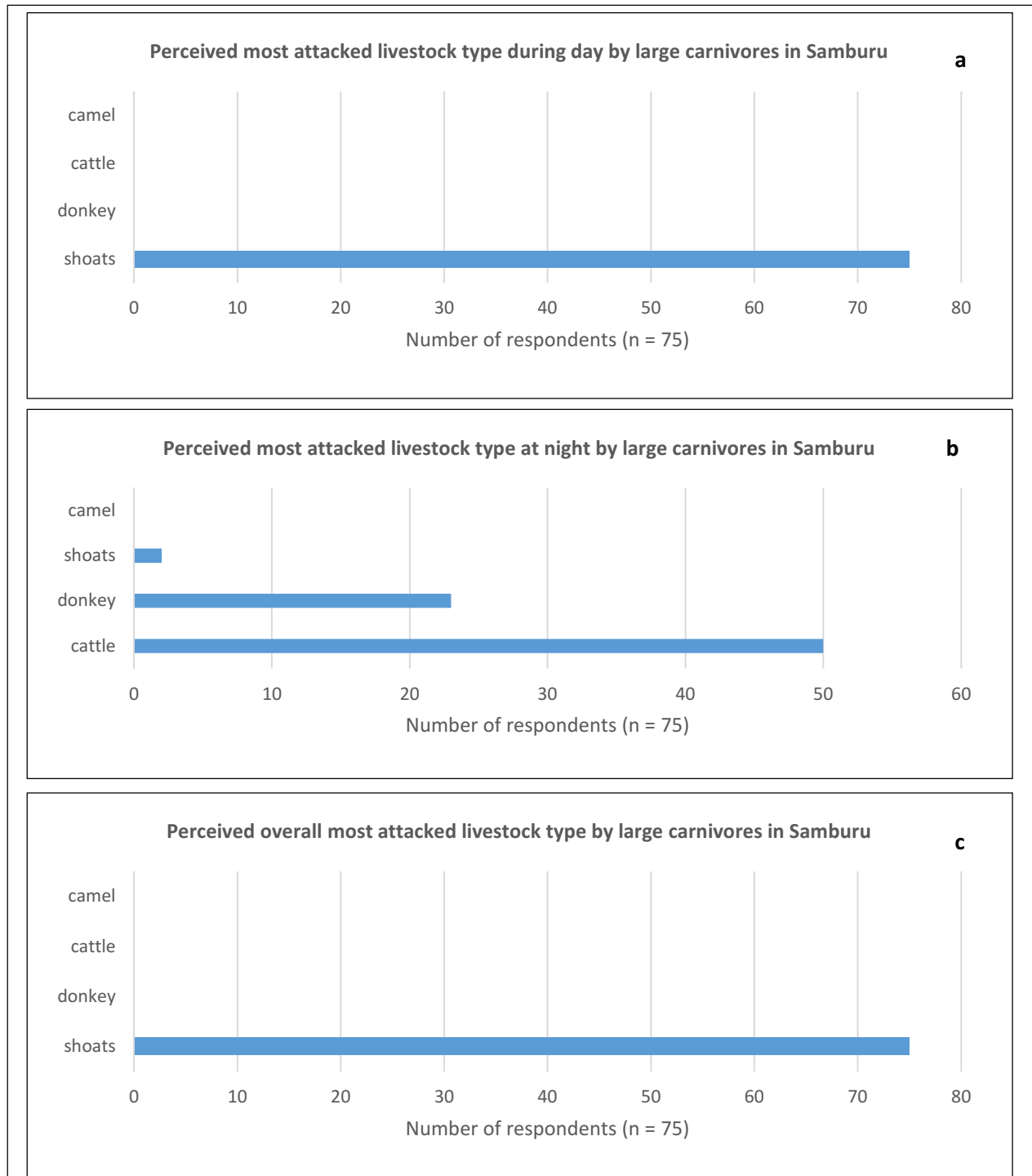


Figure 6.39. Perceived large carnivore depredation rates per livestock type in Samburu County.

Figure 6.40 highlights the perceived problematic predators of livestock. The African wild dog was perceived as the most problematic predator of shoats by the locals, while the lion was perceived as the most problematic predator of large stock (cattle, donkey and camel); the spotted hyaena was perceived as the overall most problematic predator of all livestock types. Elaborate details of the of the above said have been given in the chapter discussion.

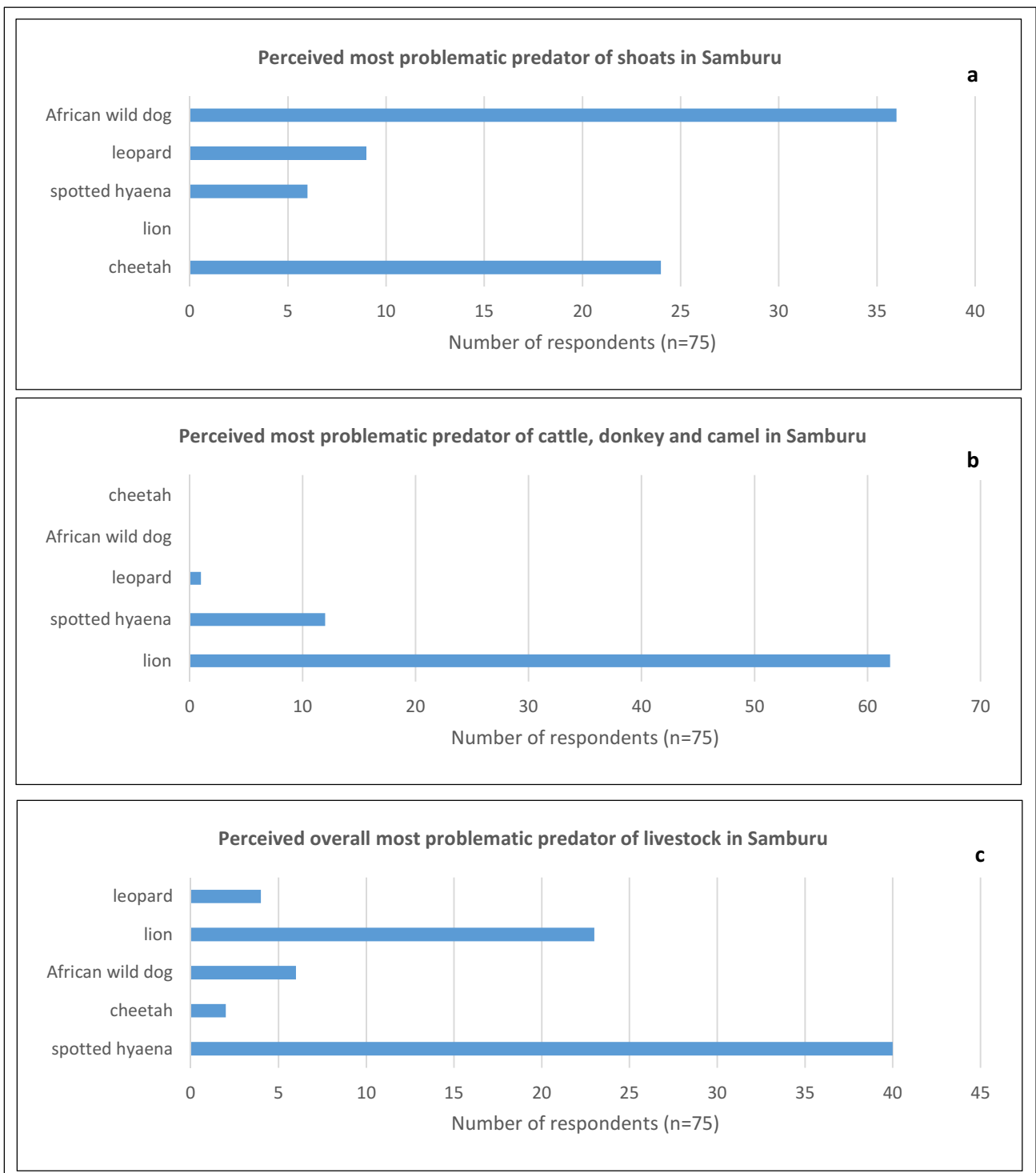


Figure 6.40. Perceived most problematic predator of livestock in Samburu County.

Figure 6.41 highlights the levels, nature, impact and extent of community perceptions, attitudes, tolerance and coexistence with carnivores. Aspects that reveal the crucial need for an increased participatory community approach in large carnivore management and conservation. Elaborate details of the said significance have been given in the chapter discussion.

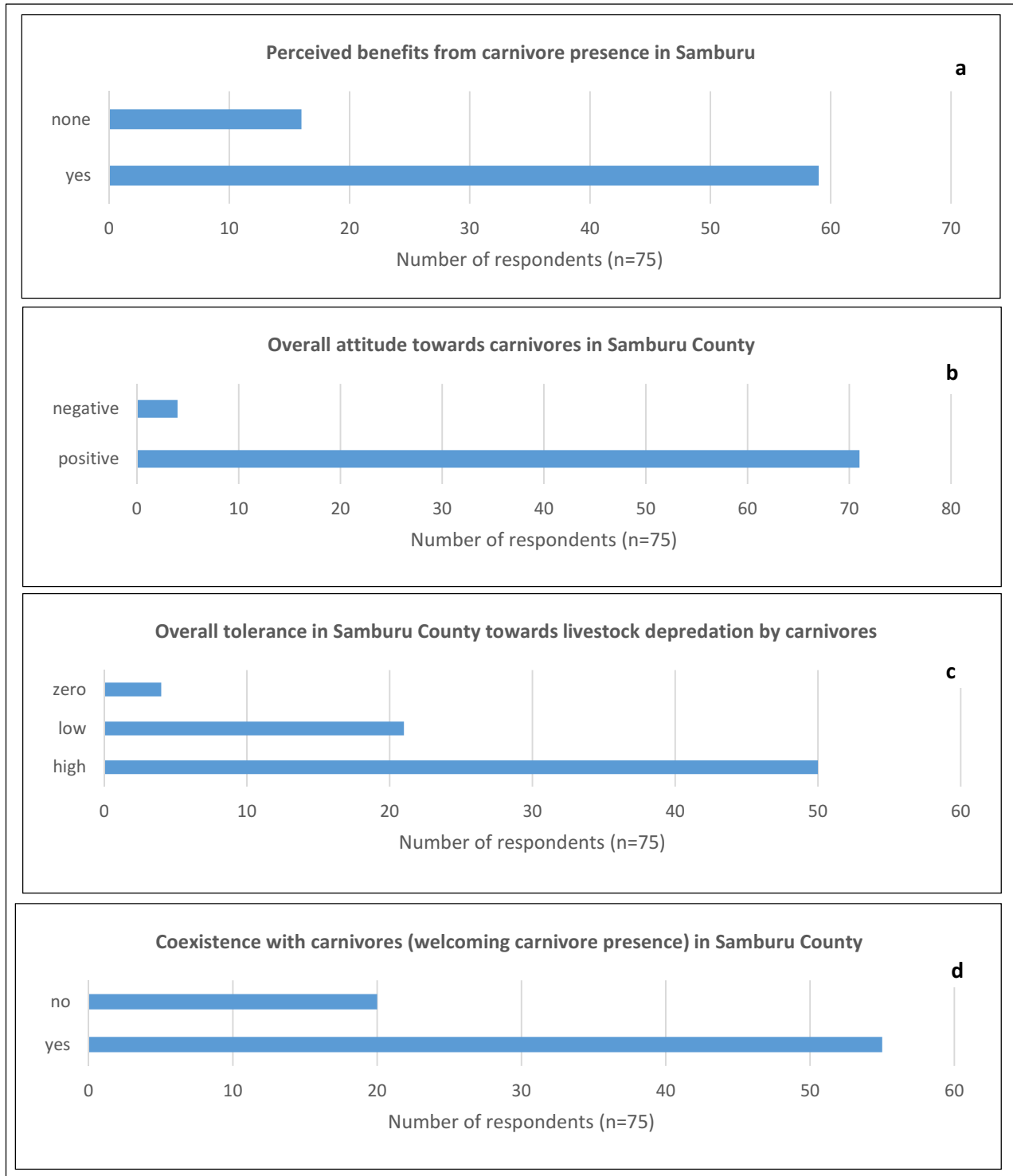


Figure 6.41. Perceptions, attitudes, tolerance and coexistence with carnivores in Samburu County.

Key demographic variables such as gender, age group, socio-economic status (upper, middle and lower classes) and length of stay in the locality were treated as independent/explanatory variables and tested against response variables such as: ability to coexist with large carnivores (*see* Table 6.26), perceived benefits of large carnivores (*see* Table 6.27), attitudes (positive vs negative) towards large carnivores (*see* Table 6.28) and tolerance towards large carnivore presence in the landscape (*see* Table 6.29). Following the recommendation by Bilder & Loughin, (2015), and Agresti, (2019); our analyses were conducted in R software (version 3.6.0) using a binomial regression analyses (GLM), followed by an ANOVA with a Chi-square statistic. Significant outcomes were then plotted graphically (*see* Figure 6.42).

Step 1: Binomial regression analysis (GLM)					
Coefficients	Estimate	Standard Error	Z value	Pr (> z )	
(Intercept)	0.7202	1.0096	0.713	0.4756	
Gender: male	1.6522	0.6552	2.521	0.0117 *	
Age group: elderly	11.5679	1455.3981	0.008	0.9937	
Age group: middle age	-0.5557	0.9693	-0.573	0.5665	
Age group: youth	-1.9563	1.0396	-1.882	0.0599 .	
Socio-economic class: middle	1.2304	0.8051	1.528	0.1264	
Socio-economic class: upper	2.0144	1.0826	1.861	0.0628 .	
Residence at locality in years	-0.1295	0.0818	-1.583	0.1134	
Significant codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					
(Dispersion parameter for binomial family taken to be 1)					
Null deviance: 86.987 on 74 degrees of freedom					
Residual deviance: 72.288 on 67 degrees of freedom					
AIC: 88.288					
Number of Fisher Scoring iterations: 14					
Step 2: Anova incorporating a Chi-sq test					
	Df	Deviance	Residual Df	Residual Deviance	Pr(>Chi)
NULL			74	86.987	
Gender	1	4.8886	73	82.099	0.02703 *
Age group	3	3.8731	70	78.226	0.27550
Socio-economic class	2	3.3975	68	74.828	0.18291
Residence at locality in years	1	2.5399	67	72.288	0.18291
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					

Table 6.26. A GLM output followed by one-way ANOVA with a Chi-sq test statistic from R software (version 3.6.0) showing the effect of demographic variables on the inherent ability of a Samburu local to coexist with large carnivores (n=75).

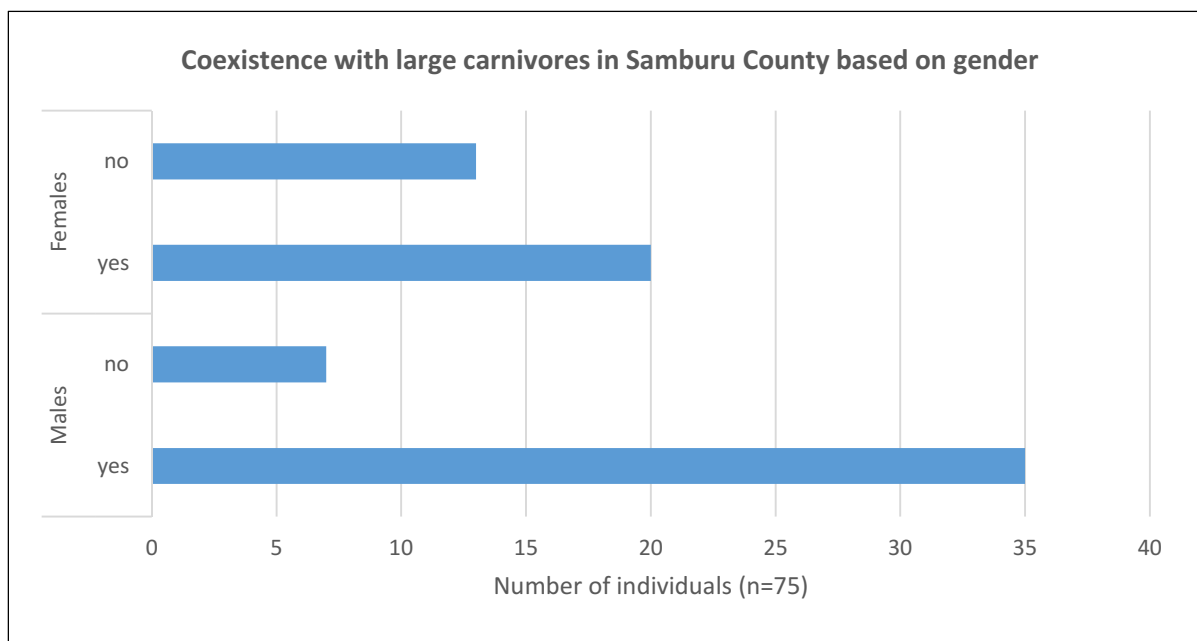


Figure 6.42. Responses of male and female respondents on the prospect of coexistence with large carnivores in the Samburu landscape(n=75).

Figure 6.42 implies that the ability to co-exist with large carnivores in the Samburu landscape is influenced by gender whether one is male or female. 83% of male respondents interviewed welcomed the idea of peaceful coexistence with carnivores while only 61% of female respondents interviewed welcomed the idea of peaceful coexistence with carnivores in the landscape.



Figure 6.43. Photo of shoats near the Ewaso Ng'iro river bank. Shoats are the most preferred livestock type by the Samburu pastoralist community due to their cheap maintenance and high fecundity rates hence easily sold off for profit. Photo credit: Titus Adhola.

Step 1: Binomial regression analysis (GLM)					
Coefficients	Estimate	Standard Error	Z value	Pr (> z )	
(Intercept)	7.411e-03	9.292e-01	0.008	0.9936	
Gender: male	1.087e+00	6.266e-01	1.736	0.0826 .	
Age group: elderly	1.360e+01	1.455e+03	0.009	0.9925	
Age group: middle age	1.267e-01	8.570e-01	0.148	0.8825	
Age group: youth	-4.048e-01	9.209e-01	-0.440	0.6602	
Socio-economic class: middle	1.412e+00	7.657e-01	1.844	0.0652	
Socio-economic class: upper	1.011e+00	9.329e-01	1.084	0.2784	
Residence at locality in years	-4.500e-02	8.103e-02	-0.555	0.5787	
Significant codes: 0 ‘***’      0.001 ‘**’      0.01 ‘*’      0.05 ‘.’      0.1 ‘ ’      1					
(Dispersion parameter for binomial family taken to be 1)					
Null deviance: 77.751 on 74 degrees of freedom					
Residual deviance: 70.729 on 67 degrees of freedom					
AIC: 86.729					
Number of Fisher Scoring iterations: 14					
Step 2: Anova incorporating a Chi-sq test					
	Df	Deviance	Residual Df	Residual Deviance	Pr(>Chi)
NULL			74	77.751	
Gender	1	2.8161	73	74.935	0.09332 .
Age group	3	0.6450	70	74.290	0.88606
Socio-economic class	2	3.2625	68	71.027	0.19568
Residence at locality in years	1	0.2981	67	70.729	0.58506
Signif. codes: 0 ‘***’      0.001 ‘**’      0.01 ‘*’      0.05 ‘.’      0.1 ‘ ’      1					

Table 6.27. A GLM output followed by one-way ANOVA with a Chi-sq test statistic from R software (version 3.6.0) showing the effect of demographic variables on the perceived benefits of large carnivore presence in the landscape (n=75).

Step 1: Binomial regression analysis (GLM)					
Coefficients	Estimate	Standard Error	Z value	Pr (> z )	
(Intercept)	2.604e+00	1.643e+00	1.585	0.113	
Gender: male	-8.490e-01	1.228e+00	-0.692	0.489	
Age group: elderly	5.994e-01	1.112e+04	0.000	1.000	
Age group: middle age	8.445e-01	1.507e+00	0.560	0.575	
Age group: youth	1.017e-01	1.377e+00	0.074	0.941	
Socio-economic class: middle	4.166e-01	1.299e+00	0.321	0.748	
Socio-economic class: upper	1.727e+01	2.819e+03	0.006	0.995	
Residence at locality in years	-2.054e-02	1.664e-01	-0.123	0.902	
Significant codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					
(Dispersion parameter for binomial family taken to be 1)					
Null deviance: 31.232 on 74 degrees of freedom					
Residual deviance: 28.016 on 67 degrees of freedom					
AIC: 44.016					
Number of Fisher Scoring iterations: 18					
Step 2: Anova incorporating a Chi-sq test					
	Df	Deviance	Residual Df	Residual Deviance	Pr(>Chi)
NULL			74	31.232	
Gender	1	0.65515	73	30.577	0.4183
Age group	3	0.72584	70	29.851	0.8671
Socio-economic class	2	1.82085	68	28.030	0.4024
Residence at locality in years	1	0.01489	67	28.016	0.9029
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					

Table 6.28. A GLM output followed by one-way ANOVA with a Chi-sq test statistic from R software (version 3.6.0) showing the effect of demographic variables on attitudes (positive vs negative) towards large carnivore presence in the landscape ( $n=75$ ).

Step 1: Binomial regression analysis (GLM)					
Coefficients	Estimate	Standard Error	Z value	Pr (> z )	
(Intercept)	2.604e+00	1.643e+00	1.585	0.113	
Gender: male	-8.490e-01	1.228e+00	-0.692	0.489	
Age group: elderly	5.994e-01	1.112e+04	0.000	1.000	
Age group: middle age	8.445e-01	1.507e+00	0.560	0.575	
Age group: youth	1.017e-01	1.377e+00	0.074	0.941	
Socio-economic class: middle	4.166e-01	1.299e+00	0.321	0.748	
Socio-economic class: upper	1.727e+01	2.819e+03	0.006	0.995	
Residence at locality in years	-2.054e-02	1.664e-01	-0.123	0.902	
Significant codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					
(Dispersion parameter for binomial family taken to be 1)					
Null deviance: 31.232 on 74 degrees of freedom					
Residual deviance: 28.016 on 67 degrees of freedom					
AIC: 44.016					
Number of Fisher Scoring iterations: 18					
Step 2: Anova incorporating a Chi-sq test					
	Df	Deviance	Residual Df	Residual Deviance	Pr(>Chi)
NULL			74	31.232	
Gender	1	0.65515	73	30.577	0.4183
Age group	3	0.72584	70	29.851	0.8671
Socio-economic class	2	1.82085	68	28.030	0.4024
Residence at locality in years	1	0.01489	67	28.016	0.9029
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					

*Table 6.29. A GLM output followed by one-way ANOVA with a Chi-sq test statistic from R software (version 3.6.0) showing the effect of demographic variables on tolerance of locals towards large carnivore presence in the landscape (n=75).*

The ethnographic study consisted of a semi-structured survey of 75 households complemented by a local community carnivore conservation workshop at the tail end of this PhD study. Demographic variables such as gender (male/female), age (elderly/middle-aged/youth), educational background, length of stay in the locality, socio-economic status (upper/middle/lower classes) based on the frequency and variety of stock types (shoats/cattle/donkey/camel) for each respondent, were scored against a set criteria of factors to eventually classify each respondent's overall view towards carnivores as positive or negative, and overall tolerance level as zero or low or high towards carnivore presence in their neighbourhood (co-existence).

Among the demographic variables listed above only gender was identified to significantly influence the inherent capability of an individual to coexist with large carnivores in the landscape (*see* Table 6.26 & Figure 6.42). This however needs to be explored further to ascertain whether there is an interplay between gender and a hidden variable that we failed to account for *e.g.* conservation knowledge.

No associations were observed between demographic variables assessed (gender, socio-economic class and age group) during binomial regression analyses (*see* Tables 6.26 to 6.29). The generally high positive attitudes and tolerance levels and peaceful coexistence with carnivores in the Samburu landscape (*see* Figures 6.41 & 6.42) can be attributed in part to the inherent conservation goodwill of the Samburu locals; and, also due to the extensive and concerted past and present conservation efforts by government agencies (University of Nairobi, National Museums of Kenya, Kenya Wildlife Service, Samburu County Government through the Samburu National Reserve Management); conservation NGO's (Northern Rangelands Trust, Action for Cheetahs in Kenya, Ewaso Lions, Save The Elephants and Grevy's Zebra Trust); past and present local and international postgraduate students and researchers affiliated with the said government agencies and/or the listed conservation NGO's. Romanach *et al.*, (2007) noted that the Samburu and Maasai were generally known to peacefully co-exist with wildlife as opposed to other tribal groups in the north Kenyan region.

When the actual depredation rates of livestock by the large carnivores were compared to the perceived rates of livestock depredation by the same, the respondents correctly identified the spotted hyaena as the most problematic predator overall (*see* Figures 6.18 to 6.21, 6.30 to 6.34, & 6.40c; and Tables 6.19 – 6.23). However, the lion was wrongly identified as the most problematic predator (*see* Figure 6.40b) for large stock (cattle, donkey and camel), a position that belonged to the spotted hyaena, followed by the leopard, followed in turn by the African wild dog (*see* Figures 6.30, 6.31 & 6.33; and Tables 6.19 – 6.23). The locals also wrongly identified the African wild dog as the most problematic predator of shoats (*see* Figure 6.40a), a position that belonged once again to the spotted hyaena, and followed closely in rank by the leopard (*see* Figure 6.32 and and Tables 6.19 – 6.23). The locals correctly identified shoats as the most attacked livestock during the day and most attacked livestock overall (*see* Tables 6.18 to 6.23 & Figure 6.39a, c). Finally, the locals wrongly identified cattle as the most attacked livestock at night (*see* Figure 6.39b) a designation that belonged to shoats (*see* Tables 6.18 to 6.23).

Globally, even though the numbers of cattle killed paled in comparison to those of shoats killed (see Tables 6.18 to 6.23), the greatest economic losses were incurred due to depredatory attacks on cattle by the large carnivores in Samburu (see Figures 6.30 to 6.33 & 6.35); this was because the financial worth of one head of cattle is worth several heads of shoats (see Table 6.24).

Even though the Samburu locals did not perceive the striped hyaena to be a threat to livestock both for our ethnography study, and the NRT coordinated large carnivore livestock depredation monitoring programme in Samburu County; it does not rule out the fact that the striped hyaena could indeed depredate on livestock. A study in the neighbouring county of Turkana by Leakey *et al.*, (1999) indicated that striped hyaenas predate on small livestock and demonstrate an opportunistic behaviour, which enables them to survive as the largest carnivore in the marginal Turkana environment in northern Kenya. We also postulate in this study that some of the records on livestock depredation attributed to the spotted hyaena may have been erroneously assigned by the locals due to their limited knowledge of the striped hyaena's livestock depredatory capabilities.

Striped hyaena are known to be strictly nocturnal, solitary foragers of insects, small animals and fruits (Kingdon and Hoffman, 2013). They were previously known to scavenge and rarely to hunt larger species of mammal (Kruuk, 1976a). However, relatively little is known about many aspects of their behaviour due to their secretive lifestyle (Kingdon and Hoffman, 2013). Despite the lack of blame from Samburu locals on livestock depredation, negative perceptions from the locals about striped hyaena persist. Due to the lack of differentiation between hyaena species, striped hyaenas are often killed when spotted hyaenas are the intended target (Wagner 2006; *pers. obs.*). Striped hyaenas are known to be very susceptible to accidental or targeted poisoning as they readily accept strychnine-poisoned bait (Hofer 1998a).

During our ethnographic study (interviews and community workshop), the locals persistently expressed their dislike for the spotted hyaena due to its notoriety in livestock depredation. According to Kruuk, (1972a,b, 1976b), Werdelin and Solounias, (1991), Frank, (1998), Mills and Hofer, (1998), Leakey *et al.*, (1999), Fourvel and Ogeto (2011), Maude (2005), and Romanach *et al.*, (2007); hyaenas are particularly detested by the general citizenry (*but see* Yigra *et al.*, 2014) and have always been negatively depicted in popular literature and/or folklore.

Our research findings for Samburu county that identify the spotted hyaena as the most proficient carnivore in livestock depredation (*see* Figures 6.18 to 6.21, 6.30 to 6.34, and Tables 6.19 – 6.23) are contrary to the findings by Frank (1998) who interviewed Laikipia livestock owners on which carnivore they wanted reduced in their area; and found that a majority of them wanted the spotted hyaena population reduced even if the study had shown that spotted hyaenas caused least damage to their livestock compared to the other predators present.

Our research findings that attribute most livestock depredatory attacks by the spotted hyaena occurring at night (*see* Figures 6.18 to 6.21, 6.30 to 6.34, and Tables 6.19 – 6.23) mirror findings by (Kruuk, 1972a; Mills, 1990; Ogada *et al.*, 2003; Kissui, 2008; Maclellan *et al.*, 2009; Yirga and Bauer, 2010) who indicate that spotted hyaena attacks livestock that are lost or else they break into poorly constructed enclosures at night. For example, our findings reveal that 71% of livestock depredatory attacks by the spotted hyaena in Samburu occur at night; Yirga and Bauer (2010) reported that 97.5 % of hyaena attacks occurred at night in Tigray, Ethiopia; Ogada *et al.*, (2003) reported that 75 % of hyaena attacks on livestock in Laikipia occurred at night. Livestock depredatory attacks by leopards in Samburu during day and night were evenly split at 50% (*see* Figure 6.26).

According to Figures 6.18 to 6.21, 6.30 to 6.34, and Tables 6.19 – 6.23; the spotted hyaena and leopard were the most proficient killers of livestock in Samburu followed by the African wild dog in a distant third position. The lion was in the second last position and only above the cheetah in terms of proficiency in livestock attacks (the striped hyaena was excluded due to lack of records). This implies that either the lion numbers are historically low in Samburu, or the locals had simply devised ways of reinforcing their livestock bomas to make them lion-proof, but not necessarily hyaena or leopard proof. This could have been based on the perception that lions were the most problematic predator of large stock (*see* Figure 6.40b), hence too much focus placed on protecting livestock from lion attacks and lesser focus erroneously placed on protecting livestock from attacks by the spotted hyaena and leopard. It is also possible that lions may bear the brunt of retaliatory attacks by the pastoralists in response to livestock depredation when in real sense a management strategy ought to be urgently formulated and implemented to protect livestock vulnerability to spotted hyaena and leopard depredation attacks (Figures 6.18 to 6.21, 6.30 to 6.34, and Tables 6.19 – 6.23).

Weber and Rabinowitz (1996) observed that large terrestrial carnivores have been eliminated from most of the world because they often prey upon livestock. Treves and Karanth (2003) stated that people kill carnivores where they are perceived to be a threat to life or livelihood. Given the great danger that humans thus pose to carnivores, Cotterill (2013) who conducted a large carnivore study in Laikipia County, on the behavioural adjustments of lions in response to a conflict landscape, noted that large carnivores will respond behaviourally to fear of conflict with humans, and that these behavioural effects of conflict have been understudied, yet need to be taken into consideration when explaining the density, distribution and behaviour of large mammalian carnivores throughout much of their remaining range. To that end, we can only speculate that the lion populations in Samburu based on low records of livestock depredatory attacks over a 9-year period (2010-2018), may have either developed a clear avoidance mechanism of human settlements, hence the lower recorded depredatory attacks on livestock relative to the spotted hyaena and leopard; their numbers are historically low in Samburu County; or their numbers may have been on an unobserved downward trend due to retributive killings by the locals either directly or indirectly; an aspect worthy of urgent further assessment.

Key highlights from feedback from respondents during the open-ended interview discussions included: shoats were the most preferred stock due to their low maintenance costs and high fecundity rates making them ideal for subsistence and profit easily attained through quick sales. Livestock diseases, drought, perennial water scarcity, livestock predators and even periodic cattle raids from neighbouring communities were listed as the major challenges encountered whilst rearing livestock to make a living. During discussions on key ways to protect livestock from carnivore attacks, the locals emphasized on measures such as: predator proof fencing or very strong fencing; good herding during the day; good local knowledge to facilitate safe routing patterns that evade covered/thick vegetation, use of guard dogs and use of boma lights. When asked about their thoughts on local solutions to human-carnivore conflict, the following talking points featured prominently in most discussions; government compensation should be given for livestock killed but regardless of compensation or lack of it, there shouldn't be any retaliatory killings of predators. These sentiments mirrored an earlier ethnographic study in Samburu and Laikipia Counties by Romanach *et al.*, (2007). The locals observed that conflicts with wildlife are inevitable therefore, there ought to be good livestock husbandry practices complemented by community wildlife education and awareness programmes and setting up of wildlife conservancy areas.

In a past ethnographic study in Tanzania (*see* Dickman, 2008, 2010), it was observed that antagonism towards large carnivores was much pronounced; and the main reasons given for conflict were the risks of wildlife damage, particularly livestock depredation, and attacks upon humans. The said study further revealed that adherence to traditional livestock husbandry techniques seemed effective at limiting depredation, but follow-up surveys revealed that views towards focal carnivores remained robust even after many months without an attack. The study concluded by making a global overview that, many different factors appeared to influence the magnitude of reported conflict, and it was clear that any mitigation efforts would have to confront the social, political, historical, economic and ecological drivers of conflict in order to develop truly appropriate and effective solutions. We derived similar sentiments from the Samburu locals during our locally organized community wildlife conservation workshop.



*Figure 6.44. Carnivore conservation workshop at the Kalama Community Wildlife Conservancy in Samburu. Photo credit: Titus Adhola*



*Figure 6.45. Photograph taken of a Samburu herds boy tending to cattle in the dried section of the Ewaso Ng'iro river bed in Samburu County. Photo credit: Titus Adhola.*

### 6.3.1. Carnivore conservation workshop in Samburu.

As part of seeking mitigation measures towards human-wildlife conflict, our project team conducted a one-day consultative community wildlife conservation workshop. We demonstrated to the local community the nature of our carnivore conservation activities in Samburu County, and engaged, discussed and deliberated with the participants from the local community on which mid-to-long term conservation strategies would work best towards mitigation of human-carnivore conflict and improved coexistence. The outputs from the community carnivore workshop held at the Kalama Community Wildlife Conservancy were then used to complement the quantitative output from our ethnographic surveys.



Figure 6.46. Photograph of Workshop organizer, Titus Adhola - PhD student, giving the background of carnivore conservation workshop at the start of the workshop. Photo credit: Titus Adhola.



Figure 6.47. Photograph of workshop participants during plenary session. Photo credit: Titus Adhola.

Key highlights of plenary session included:

- 1) The perceived lack of equitable sharing of benefits from wildlife earnings nationally with local communities inadvertently reinforces negative views towards wildlife in general and carnivores specifically.
- 2) A Samburu elder pointed out that the Samburu historically had respect for all wildlife including carnivores, but that greed associated with compensation programmes is in part to blame for the prevalence of negative attitudes today.
- 3) Namunyak Community Wildlife Conservancy has developed a ‘Consolation programme’ to help mitigate human-elephant conflict within the boundaries of Namunyak; with a planned expansion in future to include human-carnivore conflict.
- 4) The technical team emphasized on the value of community participation and good will in the collection of information that is essential in developing programmes that will improve livelihoods associated with areas of carnivore presence.
- 5) The community attendees suggested the creation of government policy that includes an insurance scheme being put in place for pastoralist communities; where they can pay some form of premium to insure their livestock against predation, and some form of consolation payments for livestock losses incurred due to encounters with wildlife.
- 6) The technical team informed the stakeholders that a follow-up to their requests to the concerned authorities would be made; and feedback communicated during the next workshop or meeting in Samburu.



*Figure 6.48. Photograph of a Samburu elder addressing participants during workshop.  
Photo credit: Titus Adhola.*

## CHAPTER 7. Conclusions and perspectives.

### 7.1.1. Résumé du Chapitre 7.

Ce travail de doctorat porte sur l'écologie, la taphonomie et la conservation des grands carnivores au Kenya dans le but de rechercher des solutions pratiques afin de répondre aux questions des conflits homme-carnivore, et donc du problème de conservation des grands prédateurs. J'ai en particulier travaillé dans ce projet sur les sites d'abattage des carnivores ainsi que sur les sites de repaires des hyènes, qui complètent les travaux précédents (Fourvel PhD, 2012; Mwebi PhD, 2013) afin de comparer et de mieux comprendre les aspects taphonomiques (ex. marques dentaires de carnivore sur les ossements des proies). Ce dernier exemple repose sur l'hypothèse que chaque espèce de carnivores (ours, loup, hyène, félins) inflige des dommages caractéristiques lors de la consommation de carcasses sur les sites de mise à mort et/ou dans les tanières. J'ai utilisé le logiciel de statistiques R-software (version 3.6.0) pour toutes les analyses statistiques.

D'après les résultats de l'analyse comparative sur les marques de perforation dentaire ('puncture') de félinés et hyéninés africains sur les os de leurs proies (sites d'abattage et de tanière), il a été possible de distinguer statistiquement les marques dentaires de perforation ('punctures') sur les os de proie entre l'hyène brune et les autres carnivores (hyène rayée, hyène tachetée, lion et léopard). Cependant, il n'a pas été possible de distinguer statistiquement entre les marques dentaires de lion, du léopard et de l'hyène tachetée, alors qu'il est possible de distinguer les marques entre hyène rayée de celles de hyène tachetée, lion et léopard. Ces résultats reflètent et contredisent des recherches antérieures similaires (voir Domínguez-Rodrigo et Piqueras, 2003; Pobiner, 2007; Gidna *et al.*, 2013, 2014; Domínguez-Rodrigo *et al.*, 2012). La taille de la proie affecte les marques dentaires des grands félins et des hyènes sur les éléments osseux de la proie, une force de morsure accrue étant requise sur les os des proies plus grandes. Cela reflète les résultats de recherches antérieures similaires (voir Binford, 1981; Blumenschine, 1986a; Brain, 1981; Mills and Mills, 1978; Haynes, 1980a, b; Kuhn *et al.*, 2009; Gifford-Gonzalez, 2018). En ce qui concerne la morphométrie des fèces de carnivores, il était possible de différencier statistiquement entre léopard et hyène tachetée selon leur poids sec global et la largeur minimale des fragments/segments dans l'ensemble de nos échantillons collectés à Samburu et sur des données complémentaires sur les hyènes tachetées. Cependant, il n'a pas été possible de différencier statistiquement selon la hauteur (ou longueur) des segments fécaux et également sur la largeur maximale (grande variabilité).

Les facteurs écologiques (climat et habitat) et socioculturels ont des effets différents sur les modèles de prédation du bétail par espèce de grand carnivore africain (lions, léopards, guépards, chiens sauvages et hyaena tachetés) dans le comté de Samburu, au nord du Kenya.

Le plus souvent, les taux perçus de prédation par les grands carnivores du bétail par rapport aux taux réels dans une communauté pastorale moderne ne se ressemblent pas. Ces perceptions sont souvent liées aux attitudes et les deux sont influencées positivement ou négativement par les connaissances en matière de conservation ou par l'absence de cette connaissance. À cette fin, identifier et exploiter les effets différentiels des facteurs écologiques et socioculturels influant sur la prédation du bétail par les grands carnivores et utiliser des technologies de pointe telles que les SIG et la télédétection, ainsi qu'intégrer des connaissances et des techniques locales en matière de conservation constitue un pas de géant vers la mise en œuvre de stratégies efficaces axées sur l'atténuation des conflits entre humains et carnivores. Même si la volonté des communautés pastorales de laisser de la place à la faune persiste, le manque perçu de partage équitable des bénéfices tirés des recettes de la faune avec les communautés locales renforce par inadvertance les points de vue négatifs sur la faune en général et les carnivores en particulier. Les responsables politiques doivent prendre en compte les sentiments marqués des communautés vis-à-vis de la coexistence avec les espèces sauvages dans l'intérêt des communautés et de la faune.

Les perceptions et les points de vue d'une communauté pastorale moderne d'Afrique de l'Est dans le comté de Samburu au Kenya par rapport aux grands carnivores africains modernes impliquent une relation qui relèvent à la fois du respect et de la peur. Respect mutuel dû aux avantages procurés par la récupération (charognage) 'gratuit' de viande, par exemple sur un site de tuerie ('kill-site') d'un lion, telle qu'une carcasse d'éléphant, de girafe, d'éland ou de buffle et la peur due au danger sérieux de devenir la proie du lion ou d'un autre grand prédateur. Les habitants soulignent également la difficulté de récupérer des carcasses de léopards cachées dans un arbre élevé. Cette situation offre une opportunité réelle de mieux aborder la nature des relations entre une communauté de pasteurs africains modernes en Afrique de l'Est et les grands carnivores (félidés, hyénidés et canidés), qui peut être utilisée comme un analogue moderne permettant de discuter sur les sociétés humaines du Pléistocène. Par conséquent, l'apport de cette étude au débat chasse-charognage dans les études de paléanthropologie est que si ces deux stratégies favorisent une communauté pastorale Africaine moderne, c'est que ce le trait doit reposer sur des fondements évolutifs issus des sociétés humaines anciennes.

### 7.1.2. Summary of Chapter 7.

This PhD study assessed the ecology, taphonomy and conservation of large carnivores in Kenya with a goal of seeking practical strategies to mitigate human-carnivore conflict. Carnivores often depredate on livestock resulting in great socioeconomic consequences to local households, with some locals resorting to retaliatory killings of carnivores. I consolidated my project data on carnivore kill sites alongside hyaena den site data (Fourvel PhD study, 2012 and Mwebi PhD study, 2013) to compare, and to better understand large carnivore taphonomy with a focus on their tooth marks on prey bones. This was based on the premise that each species of ursid, canid, hyaenid and large felid makes characteristic damage patterns on prey bones during carcass consumption at kill sites and/or den sites. I used the R-software statistical package (version 3.6.0) for all my statistical analyses.

From the comparative analysis output on large African felid and hyaenid tooth puncture marks on their prey bones at kill sites and den sites; it was possible to statistically differentiate brown hyaena tooth puncture marks from striped hyaena, spotted hyaena, lion and leopard tooth puncture marks on prey bones. However, it was not possible to statistically differentiate between lion, leopard and spotted hyaena tooth puncture marks on prey bones. It was also possible to statistically differentiate striped hyaena tooth puncture marks from spotted hyaena, lion and leopard tooth puncture marks on prey bones. These findings mirror and contradict past similar research (*see* Domínguez-Rodrigo and Piqueras, 2003; Pobiner, 2007; Gidna *et al.*, 2013, 2014; Domínguez-Rodrigo *et al.*, 2012). Prey size affects large felid and hyaenid tooth puncture marks on prey bone elements, with greater bite forces required on bones of larger prey. This mirrors the findings from past similar research (*see* Binford, 1981; Blumenschine, 1986a; Brain, 1981; Mills and Mills, 1978; Haynes, 1980a,b; Kuhn *et al.*, 2009; Gifford-Gonzalez, 2018).

In terms of carnivore scat morphometry, it was possible to statistically differentiate lion scat from leopard and spotted hyaena scats based on global dry scat weight; and minimum scat fragment width based on carnivore scats from the Samburu National Reserve, and a complimentary data set of *Crocota crocota spelaea* scats. However, it was not possible to statistically differentiate lion, leopard and spotted hyaena scats based scat fragment height and maximum scat fragment width.

Ecological (climate and habitat) and socio-cultural factors have differential effects on the patterns of livestock depredation by each species of African large carnivore (lion, leopard, cheetah, African wild dog and spotted hyaena) in Samburu County, northern Kenya.

More often than not, perceived rates of livestock depredation *vis-à-vis* actual rates of livestock depredation by large carnivores in a modern pastoralist community setting DO NOT mirror each other. Perceptions are often linked to attitudes, and both are influenced positively or negatively by conservation knowledge or lack of it. To this end, identifying and harnessing the differential effects of ecological and sociocultural factors influencing livestock depredation by large carnivores and using cutting-edge technology such as GIS and remote sensing; as well as incorporating local conservation knowledge and techniques is a giant step towards implementing effective strategies geared towards successful mitigation of human-carnivore conflict. Even though community goodwill to provide space for wildlife persists, the perceived lack of equitable sharing of benefits from wildlife earnings nationally with local communities, inadvertently reinforces negative views towards wildlife in general and carnivores specifically. Salient community sentiments towards coexistence with wildlife needs to be addressed appropriately by policy makers for the benefit of the communities and wildlife.

Perceptions and views from a modern east African pastoralist community in Samburu County in Kenya relative to the modern African large carnivores imply a relationship that borders on fear and mutual respect for the large carnivores as worthwhile competitors for available resources. Members of the Samburu pastoralist community occasionally benefit from lion kills by passively scavenging elephant, buffalo, eland or giraffe carcasses left over by the lions. The community members also highlighted on the difficulty involved attempting to scavenge from leopard kills, noting that such kills are usually cached up high in trees and on the extremities of branches of the said trees, thereby making the carcasses inaccessible to safe human reach. The above said account offers some deep insights on the nature of relationship between a modern African pastoralist community in East Africa, and modern African large felids, hyaenids and canids which can be used as a modern analog to infer past human societies in the Pleistocene. Therefore, the contribution of this study to the hunting-scavenging debate in the domain of anthropology is that, if both hunting and scavenging favours a modern African pastoralist community, then the trait must have evolutionary underpinnings from past human societies.

## 7.2. Conclusions and perspectives.

This study was based on the premise that each species of ursid, canid, hyaenid and large felid makes characteristic damage patterns on prey bones during carcass consumption at kill sites and/or den sites. I used the R-software statistical package (version 3.6.0) for all my statistical analyses. I discuss tooth puncture marks impacted on prey bones by lion, leopard and spotted hyaena, striped hyaena and brown hyaena relative to carnivore species, prey class size class and prey skeletal region found at kill sites (Kenya) and den sites (Djibouti and Namibia). Datasets on hyaenid tooth marks on prey bones at den sites were complementary; availed to this study courtesy of Jean-Baptiste Fourvel's PhD study in 2012. I then discuss the outcome of a comparative analysis of carnivore prey skeletal element proportions (NISP and MNI) at carnivore kill sites from my project study relative to those found at a spotted hyaena den site in Samburu courtesy of Ogeto Mwebi's PhD study in 2013. My discussion on lion, leopard and spotted hyaena scat morphometry; and, tooth puncture mark sizes at the epiphyseal vs diaphyseal regions of prey long bones relative to carnivore species is contextualised within the scope of my study at kill sites. Subsequently, I discuss the key ecological (habitat, climate, livestock type) and sociocultural factors that influence livestock depredation by large carnivores in Samburu County, northern Kenya. I then posit on the paleoecological relevance of my PhD study as a modern analog for past human societies with a short complement to the hunting vs scavenging debate. To conclude this chapter, I submit my conclusions and perspectives on African large carnivore conservation on a modern East African pastoralist landscape. The following are my general submissions on the above said:



*Figure 7.1. Photograph of a lion and lioness at the Samburu National Reserve. Photo credit: Titus Adhola.*

### 7.2.1. Prey size class representation of African large carnivore at kill sites and den sites.

I consolidated my project data on carnivore kill sites alongside hyaena den site data (Fourvel PhD study, 2012 and Mwebi PhD study, 2013) to compare and to better understand the relative nature of prey size class representation at African large carnivore kill sites and den sites within the context of ungulate prey of the size classes I-II & III-IV. The brown hyaena seemed to have an exclusive preference for the prey size classes III-IV at its den sites. Because brown hyaenas are predominantly scavengers of ungulate prey but occasionally kill small mammal prey (Skinner, 1976; Mills, 1978, 1982a, 1990; Mills and Mills, 1978; Owens and Owens, 1978; Skinner and Van Aarde, 1981; Siegfried, 1984; Stuart and Shaughnessy, 1984; Burgener and Gusset, 2003; Maude and Mills, 2005; Kuhn *et al.*, 2008; Kingdon and Hoffman, 2013; Goss, 1986; Skinner *et al.*, 1995; Wiesel, 2010); it can therefore be presumed that the bones of *prey size classes III-IV* found in the den were scavenged from elsewhere and brought to the den.

The leopard and striped hyaena prey preferences were skewed towards *prey of size classes I-II*. Striped hyaena are known to be strictly nocturnal, solitary foragers of insects, small animals and fruits (Kingdon and Hoffman, 2013). They were previously known to scavenge and rarely to hunt larger species of mammal (Kruuk, 1976a). Relatively little is known about many aspects of their behaviour due to their secretive lifestyle (Kingdon and Hoffman, 2013). Be that as it may, active scavenging cannot be overruled in the case of the striped hyaena den. Owen-Smith and Mills, (2008) observed that the three smallest of the African large carnivores, i.e. leopard, cheetah and wild dog, showed high similarity in prey species favoured. They concluded that despite overlap in prey size range, each carnivore showed a distinct dietary preference.

The prey size class constitution of the spotted hyaena den sites in two separate regions (Kenya & Djibouti) mirrored similar (Kenya) and exact opposite (Djibouti) of the lion's kill site preferences. The rivalry between lion and spotted hyaena, two of Africa's most dominant large carnivores, is legendary and widely documented in literature (Périquet, 2014; Winterbach *et al.*, 2013; Kruuk, 1972a; Schaller, 1972; Kingdon and Hoffman, 2013; Durant 1998, 2000) that lion and spotted hyaena home ranges widely overlap in the African savannah, their densities are positively correlated, and that spotted hyaenas only spatially avoid lions in situations where they do not have enough numbers to counter the intense competition with lions for prey and/or the ever present threat of potential fatalities incurred from lion encounters.

### **7.2.2. African large carnivore prey bone consumption at kill sites and den sites.**

Tooth marks recorded and measured in this study were limited to punctures only. The method of collection of carnivore tooth mark data sets for large carnivore kill sites in this PhD study was similar to the method used by Fourvel's PhD study in 2012; but dissimilar to the method used by Mwebi's PhD study in 2013. To this end, I investigated the effect of African large carnivore species (lion, leopard, spotted hyaena, brown hyaena and striped hyaena), prey size class (*I-II* & *III-IV*) and prey skeletal region on carnivore tooth puncture marks on prey bones at kill sites and den sites whilst incorporating part of Fourvel's PhD study material.

From the comparative analysis output on large felid and hyaenid tooth puncture marks on their prey bones at kill site and den sites; it was not possible to statistically differentiate between lion, leopard and spotted hyaena tooth puncture marks (maximum and minimum widths) on prey bones. This mirrors findings by Domínguez-Rodrigo and Piqueras, (2003), (*but see* Pobiner, 2007 and Gidna *et al*, 2014). My research findings both contradict and support findings by Domínguez-Rodrigo *et al.*, (2012) that postulated that the three major groups of carnivores (felids, hyaenids and canids) can be successfully differentiated. It was possible to statistically differentiate brown hyaena tooth puncture marks from striped hyaena, spotted hyaena, lion and leopard tooth puncture marks on prey bones. It was also possible to statistically differentiate striped hyaena tooth puncture marks from spotted hyaena, lion and leopard tooth puncture marks on prey bones.

In the analysis involving shared lion and spotted hyaena kill sites, it was not possible to accurately account for the number of lions that partly consumed their prey carcass(es) before spotted hyaena(s) visited, and either took over the carcass from the lion(s) or, waited for the lion(s) to abandon the kill(s) before moving in to consume what was left over by the lion(s). It was not possible to differentiate tooth puncture marks (maximum and minimum) of large felid and hyaenids relative to placement on diaphyseal and epiphyseal regions of long bones of their prey. Debate is rife amongst taphonomists and paleoanthropological zooarchaeologists as to whether it is possible or not, to distinguish carnivore species using tooth marks on bone (Delaney-Rivera *et al.*, 2009; Domínguez-Rodrigo and Barba 2006; Domínguez-Rodrigo and Piqueras, 2003; Selvaggio, 1994a,b; Selvaggio and Wilder 2001; Fernández-Jalvo and Andrews 2016; Pobiner, 2007; Domínguez-Rodrigo *et al.*, 2012; Gidna *et al.*, 2013, 2014; Gifford-Gonzalez, 2018).

Through this PhD study, it was statistically proven that prey size affects large felid and hyaenid tooth puncture marks (maximum and minimum widths) on prey bone elements; however, it is important to note that the perceived effect of differences in prey bone density has not been accounted for in this PhD study. It is documented that different skeletal regions accompanied by their respective differences in bone density, offer varying degrees of challenge to any mammalian carnivore during consumption of prey bones with the canids and hyaenids having a superior bone crunching capability than the large felids (*see* Binford, 1981; Blumenschine, 1986a; Brain, 1981; Binford and Bertram, 1977; Mills and Mills, 1978; Kuhn *et al.*, 2009; Haynes, 1980a,b; Gifford-Gonzalez, 2018;).

The comparative assessment of NISP and MNI values for *prey size classes I-II & III-IV* relative to carnivore kill sites and den sites indicates that high NISP values at kill sites do not necessarily lead to higher MNI values. There were more prey animals at the spotted hyaena den site than the lion, leopard, cheetah and shared lion and spotted hyaena kill sites combined. This shows that the ecological environments influence the nature of bone consumption with more bones consumed at the den site in comparison to the kill site.



*Figure 7.2. Photograph of a spotted hyaena juvenile at a kill site in Soysambu Conservancy in Nakuru. Photo credit: Titus Adhola.*

### 7.2.3. Lion, leopard and spotted hyaena scat morphometry.

In terms of carnivore scat morphometry, I was able to statistically differentiate lion scat from leopard and spotted hyaena scats based on global dry scat weight, and minimum scat fragment width based on my collected carnivore scats from the Samburu National Reserve and a complimentary data set of spotted hyaena scats. However, it was not possible to statistically differentiate lion, leopard and spotted hyaena scats based scat fragment height and maximum scat fragment width. Research on terrestrial carnivore ecology frequently relies on scat identification and analysis, ultimately, species assignment is commonly based on scat morphology (Monterroso *et al.*, 2013).

The size and the amount of scat produced by each individual varies with age, the type of ingested food, and its absorption capacity. Food characteristics also affect scat consistency (Chame, 2003). The challenge with the study of scat (scatology) is that the potential information retrieved from carnivore scats can only be useful upon correct species identification. In the recent past, the application of genetic scatology has highlighted the fact that the evaluation of scat morphology alone is prone to misidentifications among sympatric carnivore species, even when evaluated by experienced field technicians (Davison *et al.*, 2002; Janecka *et al.*, 2008; Harrington *et al.*, 2010; Boitani and Powell, 2012; Broquet *et al.*, 2007; Beja-Pereira *et al.*, 2009; Livia *et al.*, 2006; Oliveira *et al.*, 2010). Despite the potential pitfalls, scat morphology-based studies are still widely used to better understand carnivore ecology (Wilson and Delahay, 2001; Barea-Azcón *et al.*, 2006).



*Figure 7.3. Photograph of a dried lion scat with red arrow showing prey bone fragment circled in red. Photo credit: Titus Adhola.*

#### **7.2.4. Carnivore conservation in a modern East African pastoralist landscape.**

Ecological (climate and habitat) and sociocultural factors have differential effects on the patterns of livestock depredation by each species of African large carnivore (lion, leopard, cheetah, African wild dog and spotted hyaena) in Samburu County, northern Kenya. It is important to note that even though the striped hyaena occurs in Samburu County, it was not possible, to comprehensively investigate its livestock depredatory tendencies due to insufficient data.

Throughout its range, the striped hyaena occurs at low densities, but is distributed broadly across the landscape. Estimates of striped hyaena abundance are complicated by the remarkably limited amount of information available on the species. This is undoubtedly due to its shy, nocturnal, mostly solitary nature, its apparent affinity for rugged terrain, its generally negative reputation, and frequent confusion with, or lack of differentiation from, the spotted hyaena and aardwolf where the species overlap (Skinner *et al.*, 1980; Kingdon and Hoffman, 2013; Kruuk, 1976a; Leakey *et al.*, 1999; Wagner, 2006).

Data on climatic variables (rainfall, NDVI, SPI, maximum temperatures and minimum temperatures) were obtained from Remote Sensed Satellite Imagery from PROBA-V and SPOT-VGT sensors courtesy of the ICPAC-GMES project that provided a decade worth of climatic variables to this PhD study.

After assessing a nine-year data set on livestock depredation by lion, leopard, cheetah, African wild dog and spotted hyaena in Samburu from a data set availed to this PhD study courtesy of NRT; it was observed that patterns of livestock depredation by African large carnivore species exhibited peaks and troughs that conformed with the local calving seasons of livestock, which were in turn influenced by seasonality and variations in lengths of breeding cycles of each livestock type. These results mirror similar research carried out by Abade *et al.*, 2014, who stated that the potential distribution of large carnivores appeared to be strongly influenced by climatic factors (above average annual precipitation) and local habitat (areas situated close to water e.g. riverine habitat). It is apparent from this PhD study that NDVI influences lion and cheetah depredatory attacks on livestock in Samburu County. Lion and cheetah attacks on livestock are further influenced by the spatial availability of prey and seasonality.

Seasonality determines the nature of local habitat/vegetation cover (Abade *et al.*, 2014; Shah *et al.*, 2015; Miller, 2015) which can be inferred remotely through climatic variables such as NDVI and SPI. Among the large carnivores, SPI only significantly influences lion attacks on livestock in Samburu County. This information can be used to help mitigate lion depredation on livestock using earth observation data by conducting a ‘hotspot analysis’ through GIS to determine which areas are most vulnerable to lion depredation on livestock at particular seasons of the year based on climatic variables as recommended by Miller (2015).

Among the large carnivores, maximum temperatures only significantly influence leopard and cheetah day attacks on livestock in Samburu County. Minimum temperatures only significantly influence leopard night attacks on livestock in Samburu. This information can be used to help mitigate leopard and cheetah depredations on livestock using maximum (day) and minimum (night) temperatures to determine which areas are most vulnerable to livestock depredation at particular seasons of the year as recommended by Miller (2015).

Livestock type (cattle, shoats, donkey and camel) and local habitat (Westgate, Ltungai, Namunyak and Meibae Community Wildlife Conservancies) each had a differential effect on the nature and magnitude of losses attributed to livestock depredation per carnivore species. However, when it came to lion and spotted hyaena attacks on livestock; it was the interaction between local habitat and livestock that determined the nature and magnitude of losses attributed to livestock depredation in Samburu County, northern Kenya. A classic case of livestock being found by the lion or spotted hyaena at the right place at the right time.... or conversely speaking, livestock simply being in the wrong place at the wrong time when it comes to lion or spotted hyaena attacks.

In terms of the economic costs of large carnivore presence in the Samburu landscape, the study results imply that, even though spotted hyaenas were responsible for the highest economic losses due to livestock depredation per livestock type and livestock in general amongst the large carnivores; leopard depredation on livestock followed very closely in the immediate lower rank after the spotted hyaena. Leopards are generally least affected by interspecific competition amongst large carnivores because their behavioural and dietary flexibility enables them to coexist with other large predators (Karanth and Sunquist, 2000; Marker and Dickman, 2005). According to Constant (2014), leopard predation on livestock is most strongly influenced by distance to village and distance to water, in addition to seasonal grazing patterns, the calving season and poor livestock husbandry practices.

It was interesting to note that the lion fell in the second lowest rank in all categories (livestock type and domestic herbivores in general) below the spotted hyaena, leopard and African wild dog. The cheetah had the least economic impact on losses attributed to its depredatory attacks on livestock relative to the other large carnivore species (spotted hyaena, leopard, lion and African wild dog) in Samburu County.

The impact of economic losses due to cattle depredation by the large carnivores were the highest followed in lower rank by losses due to large carnivore depredatory attacks on shoats. Economic losses due to large carnivore depredatory attacks on camels were the second last in the ranked scale of losses. Least economic losses were incurred when large carnivores depredated upon donkeys. The possibility that the large carnivores prefer other livestock types relative to donkeys; being hinged on the donkeys' superior anti-depredatory behaviour towards the carnivores cannot be overruled.

When the actual depredation rates of livestock by the large carnivores were compared to the perceived rates of livestock depredation by the same; the respondents correctly identified the spotted hyaena as the most problematic predator overall. However, the lion was wrongly identified as the most problematic predator for large stock (cattle, donkey and camel), a position that belonged to the spotted hyaena, followed by the leopard, followed in turn by the African wild dog. The locals also wrongly identified the African wild dog as the most problematic predator of shoats, a position that belonged once again to the spotted hyaena, and followed closely in rank by the leopard.

The locals correctly identified shoats as the most attacked livestock during the day and most attacked livestock overall. Finally, the locals wrongly identified cattle as the most attacked livestock at night a designation that belonged to shoats. Even though the numbers of cattle killed by large carnivores in Samburu paled in comparison to those of shoats killed, the greatest economic losses were incurred due to depredatory attacks on cattle; this is mainly due to the fact that the financial worth of one head of cattle is worth several heads of shoats.

Even though the Samburu locals did not perceive the striped hyaena to be a threat to livestock; it does not rule out the fact that the striped hyaena could indeed depredate on livestock. A study in the neighbouring county of Turkana by Leakey *et al.*, (1999) indicated that striped hyaenas depredate on small livestock and demonstrate an opportunistic behaviour, which enables them to survive as the largest carnivore in the marginal Turkana environment in northern Kenya.

While conducting the ethnographic component of this study, the locals persistently expressed their dislike for the spotted hyaena due to its notoriety in livestock depredation. According to Kruuk, (1972a), Werdelin and Solounias, (1991), Frank, (1998), Mills and Hofer, (1998), Leakey *et al.*, (1999), Fourvel and Ogeto (2011), Maude (2005), and Romanach *et al.*, (2007); hyaenas are particularly detested by the general citizenry (*but see* Yigra *et al.*, 2014) and have always been negatively depicted in popular literature and/or folklore. This PhD study identifies the spotted hyaena as the most proficient large carnivore in livestock depredation in Samburu County, with the majority of its attacks on livestock occur at night. This output mirrors findings from similar research carried elsewhere (Kruuk, 1972a,b; Mills, 1990; Ogada *et al.*, 2003; Kissui, 2008; MacLennan *et al.*, 2009; Yirga and Bauer, 2010).

In the case of lower lion predatory attacks on cattle in Samburu County relative to spotted hyaena, leopard and African wild dog; it could imply that, either the lion numbers are historically low in Samburu, or the locals had simply devised ways of reinforcing their livestock bomas to make them lion proof, but not necessarily spotted hyaena or leopard proof. This could have been based on the perception that lions were the most problematic predator of large stock, hence too much focus placed on protecting livestock from lion attacks, and lesser focus erroneously placed on protecting livestock from attacks by the spotted hyaena and leopard. It is also possible that lions may bear the brunt of retaliatory attacks by the pastoralists in response to livestock depredation, when in real sense a management strategy ought to be urgently formulated and implemented to protect livestock vulnerability to spotted hyaena and leopard depredation attacks. Cotterill (2013) noted that lions will respond behaviourally to fear of conflict with humans, and that these behavioural effects of conflict have been understudied, yet need to be taken into consideration when explaining the density, distribution and behaviour of lions throughout much of their remaining range.

Key highlights from feedback from respondents during the open-ended interview discussions included: shoats being the most preferred stock due to their low maintenance costs and high fecundity rates making them ideal for subsistence and profit easily attained through quick sales. Livestock diseases, drought, perennial water scarcity, livestock predators, periodic cattle raids from neighbouring communities were listed as the major challenges encountered whilst rearing livestock to make a living. The locals observed that conflicts with wildlife are inevitable therefore, there ought to be good livestock husbandry practices complemented by community wildlife education and awareness programmes and setting up of wildlife conservancy areas.

### 7.2.5. Hunting vs scavenging, which way to go?

Understanding trade-offs involved in prey acquisition and the subsequent transport decisions made by hunter-gatherers are fundamental goals of zooarchaeologists and paleoanthropologists (Schoville and Otárola-Castillo, 2014). Zooarchaeologists frequently use the relative abundance of skeletal elements in faunal assemblages in conjunction with foraging theory models, to infer subsistence decisions made by prehistoric hunter gatherers (Potts *et al.*, 1983; Bunn, 1986; Monahan, 1996; Stiner, 1994; Marean and Frey, 1997; Klein, 1999; Parkington, 1981; Russell, 2012; Schoville and Otárola-Castillo, 2014). Interpretations on Pleistocene hominin subsistence, with special emphasis on the hunting and scavenging debate, revolve around adequate understanding on how felids consume their prey and the resulting bone modification patterns (Gidna *et al.*, 2014).

Perceptions and views from a modern east African pastoralist community in Samburu County in Kenya relative to the modern African large carnivores imply a relationship that borders on mutual respect and fear. Mutual respect due to the benefits gained from passively scavenging free meat, for example, from a modern lion kill such as an elephant, giraffe, eland or buffalo carcass; and, fear due to the grave danger of falling prey to the lion or other large predator. The community members also highlighted on the difficulty involved attempting to scavenge from leopard kills, noting that such kills are usually cached up high in trees and on the extremities of branches of the said trees, thereby making the carcasses inaccessible to safe human reach.

It is debatable whether the hominin groups were passive or aggressive in scavenging such kills made by the phylogenetic counterparts of the leopard from up trees during the Pleistocene. If any scavenging were to be made by hominins from the lion's phylogenetic counterparts in the Pleistocene, then they would have to do so after it was safe enough to scavenge from the abandoned kills either before or after the spotted hyaena's phylogenetic counterparts swooped in to scavenge the same abandoned kill. These postulations mirror Blumenschine's (1986b) study on the ecology of scavenging in the Ngorongoro and Serengeti (Tanzania) ecosystems; and Tunnell's (1990) study of carcass availability in Maasai Mara (Kenya) and Tappen's (2001) study in Virunga National Park (Democratic Republic of Congo).

To this end, the contribution of this study to the hunting-scavenging debate in the domain of anthropology is that, if both hunting and scavenging favours a modern African pastoralist community, then the trait must have evolutionary underpinnings from past human societies.

### 7.3. General conclusions.

- Samburu County is unique in the sense that it hosts populations of the six large carnivore species found in Eastern Africa, namely; lion, leopard, spotted hyaena, striped hyaena, African wild dog and cheetah; and is therefore an ideal surrogate, for implementing community wildlife awareness and conservation strategies geared towards mitigation of human-wildlife conflict.
- From the comparative analysis output on large African felid and hyaenid tooth puncture marks on their prey bones at kill site and den sites; it was possible to statistically differentiate brown hyaena tooth puncture marks from striped hyaena, spotted hyaena, lion and leopard tooth puncture marks on prey bones. However, it was not possible to statistically differentiate between lion, leopard and spotted hyaena tooth puncture marks (maximum and minimum widths) on prey bones. It was also possible to statistically differentiate striped hyaena tooth puncture marks from spotted hyaena, lion and leopard tooth puncture marks on prey bones. These findings mirror and contradict past similar research (*see* Domínguez-Rodrigo and Piqueras, 2003; Pobiner, 2007; Gidna *et al.*, 2013, 2014; Domínguez-Rodrigo *et al.*, 2012)
- Prey size affects large carnivore tooth puncture marks on prey bone elements.
- Ecological (climate and habitat) and sociocultural factors have differential effects on the livestock depredatory tendencies of each species of African large carnivore.
- The contribution of this study to the hunting-scavenging debate is that if both hunting and scavenging favours a modern pastoralist community, then the trait must have evolutionary underpinnings from past human societies.
- The perceived lack of equitable sharing of benefits from wildlife earnings nationally with local communities, inadvertently reinforces negative views towards wildlife in general and carnivores specifically.
- Community goodwill to provide space for wildlife persists.

#### 7.4. General perspectives.

- More often than not, perceived rates of livestock depredation *vis-à-vis* actual rates of livestock depredation by large carnivores in a modern pastoralist community setting DO NOT mirror each other. Perceptions are often linked to attitudes and both are influenced positively or negatively by conservation knowledge or lack of it. To this end, identifying and harnessing the differential effects of ecological and sociocultural factors influencing livestock depredation by large carnivores and using cutting-edge technology such as GIS and remote sensing; as well as incorporating local conservation knowledge and techniques is a giant step towards implementing effective strategies geared towards successful mitigation of human-carnivore conflict.
- It is very necessary and urgent to champion for increased local community input in carnivore management and conservation initiatives, in close collaboration with government agencies and project partnerships to implement effective conflict resolution schemes; including addressing pertinent policy hurdles to foster a productive sociocultural and political environment that has significant benefits for both human and wildlife populations.
- It is recommended to conduct more carnivore scat morphometry studies side by side the more advanced, accurate, and widely accepted metagenomics (extracting DNA from faecal samples; to amplify DNA through PCR; utilizing Next Generation Sequencing especially for faecal samples; and bioinformatics associated with molecular genetics techniques) to address conservation challenges in management of wildlife populations across human dominated landscapes.
- Successful neotaphonomic differentiation of large felid, canid and hyaenid tooth marks on prey bones has practical applications in solving wildlife crime (*whodunit scenarios*); therefore, more comparative investigations on large carnivore prey carcass consumption patterns in disparate landscapes under different regimes such as actualistic settings and/or ecological (kill sites and den sites) settings are highly recommended.
- Future carnivore conservation workshops and/or conferences should address pertinent issues such as association between livestock depredation and illegal killings of large carnivores.
- Salient community sentiments towards coexistence with wildlife needs to be addressed appropriately by policy makers for the benefit of the communities and wildlife.

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*Appendix I: Carnivore tooth puncture marks on prey bones at kill sites in Kenya.*

Locality	Carnivore	Prey	Prey Weight class	Skeletal part	Location on skeletal part	Puncture maximum width (mm)	Puncture minimum width (mm)
SC	P.leo	impala	II	skull	axial	2.6	1.9
SC	P.leo	impala	II	mandible	axial	4.9	3.6
SC	P.leo	impala	II	mandible	axial	5.8	4.6
SC	P.leo	impala	II	scapula	appendicular	1.8	1.8
SC	P.leo	impala	II	humerus	appendicular	3.1	2.4
SC	P.leo	impala	II	podials	appendicular	4.2	2.7
SC	P.leo	impala	II	podials	appendicular	4.1	3
SC	P.leo	impala	II	podials	appendicular	4.2	2.2
SNR	P.pardus	cow	III	skull	axial	9.7	9.5
SNR	P.pardus	cow	III	skull	axial	9.1	8.4
SNR	P.pardus	cow	III	skull	axial	4.9	3
SNR	P.pardus	cow	III	skull	axial	3.8	3
SNR	P.pardus	cow	III	skull	axial	4.4	2.8
SNR	P.pardus	cow	III	skull	axial	3.1	2.4
SNR	P.pardus	cow	III	maxillae	axial	13.5	12.8
SNR	P.pardus	cow	III	maxillae	axial	3.2	2.9
SNR	P.pardus	cow	III	cervical vertebra	axial	1.7	1.7
SNR	P.pardus	cow	III	cervical vertebra	axial	2	2
SNR	P.pardus	cow	III	cervical vertebra	axial	7.7	4.5
SNR	P.pardus	cow	III	cervical vertebra	axial	3.2	3
SNR	P.pardus	cow	III	cervical vertebra	axial	4.4	4.4
SNR	P.pardus	cow	III	cervical vertebra	axial	5.4	3.3
SNR	P.pardus	cow	III	scapula	appendicular	4.6	3.7
SNR	P.pardus	cow	III	scapula	appendicular	6.5	4.5
SNR	P.pardus	cow	III	femur	appendicular	4.7	3.5
SNR	P.pardus	cow	III	femur	appendicular	6.6	3.8
SNR	P.pardus	cow	III	femur	appendicular	5.8	4.8
SNR	P.pardus	cow	III	femur	appendicular	3.5	3.5
SNR	P.pardus	cow	III	femur	appendicular	4.7	3.5
SNR	P.pardus	cow	III	femur	appendicular	6.9	4.6
SNR	P.pardus	cow	III	femur	appendicular	4.4	2.9
SNR	P.pardus	cow	III	femur	appendicular	6	3.6
SNR	P.pardus	cow	III	femur	appendicular	5.8	4.2
SNR	P.pardus	cow	III	podials	appendicular	4.6	3.8
SNR	P.pardus	cow	III	podials	appendicular	4.3	2.6

SNR	P.pardus	cow	III	podials	appendicular	2.8	2.5
SNR	P.pardus	cow	III	podials	appendicular	2.8	2.2
SC	P.leo	Impala	II	scapula	appendicular	14.2	12.4
SNR	P.leo/C.crocata	beisa oryx	III	maxillae	axial	7.2	4.5
SC	P.leo	thompsons gazelle	I	skull	axial	3.3	3.3
SC	P.leo	thompsons gazelle	I	pelvis	appendicular	13	6.6
SC	P.leo	thompsons gazelle	I	pelvis	appendicular	5	3.2
SNR	P.pardus	gerenuk	II	skull	axial	16	9.2
SNR	P.pardus	gerenuk	II	maxillae	axial	11.7	9.5
SNR	P.pardus	gerenuk	II	radiusulna	appendicular	3.2	2.2
SNR	P.pardus	gerenuk	II	pelvis	appendicular	7.3	6.5
SNR	P.pardus	gerenuk	II	pelvis	appendicular	3.4	2.5
SNR	P.pardus	gerenuk	II	pelvis	appendicular	2.7	2.5
SNR	P.pardus	gerenuk	II	pelvis	appendicular	2.7	2
SNR	P.pardus	gerenuk	II	pelvis	appendicular	1.7	1.6
SC	P.pardus	impala	II	scapula	appendicular	5.7	3.5
SC	P.pardus	impala	II	radiusulna	appendicular	5.5	4.7
SC	P.pardus	impala	II	radiusulna	appendicular	7.8	6.6
SC	P.pardus	impala	II	radiusulna	appendicular	5.7	3.5
SC	P.pardus	impala	II	pelvis	appendicular	8.7	5.2
SC	P.leo	eland	IV	cervical vertebra	axial	6	5
SC	P.leo	eland	IV	cervical vertebra	axial	4	3
SC	P.leo	eland	IV	cervical vertebra	axial	8.5	4.6
SC	P.leo	eland	IV	cervical vertebra	axial	5.7	3.9
SC	P.leo	eland	IV	cervical vertebra	axial	4.1	3
SC	P.leo	eland	IV	thoracic vertebra	axial	4	4
SC	P.leo	eland	IV	thoracic vertebra	axial	7.5	4.7
SC	P.leo	eland	IV	thoracic vertebra	axial	4.8	3.9
SC	P.leo	eland	IV	thoracic vertebra	axial	3.7	2.4
SC	P.leo	eland	IV	thoracic vertebra	axial	3.3	2.7
SC	P.leo	eland	IV	lumbar vertebra	axial	5.4	4.7
SC	P.leo	eland	IV	ribs	axial	2.3	1.7
SNR	P.leo/C.crocata	elephant	V	scapula	appendicular	8	6.4
SNR	P.leo/C.crocata	elephant	V	scapula	appendicular	4.7	4.3
SNR	P.leo/C.crocata	elephant	V	scapula	appendicular	5.1	5
SNR	P.leo/C.crocata	elephant	V	scapula	appendicular	6.5	5
SNR	P.leo/C.crocata	elephant	V	humerus	appendicular	14.2	6.9

SNR	P.leo/C.crocata	elephant	V	humerus	appendicular	10.8	8.1
SNR	P.leo/C.crocata	elephant	V	humerus	appendicular	7.5	5.1
SNR	P.leo/C.crocata	elephant	V	radiusulna	appendicular	10.9	6.3
SNR	P.leo/C.crocata	elephant	V	radiusulna	appendicular	6.4	5.4
SC	P.leo	impala	II	skull	axial	4.9	4
SC	P.leo	impala	II	sacrum	axial	3.8	3.1
SC	P.leo	impala	II	sacrum	axial	4.2	2.6
SC	P.leo	impala	II	sacrum	axial	3	2.5
SC	P.leo	impala	II	sacrum	axial	3.5	2.6
SC	P.leo	impala	II	sacrum	axial	6.7	3.7
SC	P.leo	impala	II	sacrum	axial	2.7	2
SC	P.leo	impala	II	humerus	appendicular	3.2	2.3
SC	P.leo	impala	II	humerus	appendicular	2.7	2.3
SC	P.leo	impala	II	humerus	appendicular	3.4	2.6
SC	P.leo	impala	II	pelvis	appendicular	3.6	3
SC	P.leo	common zebra	III	sacrum	axial	7.6	5.8
SC	P.leo	common zebra	III	sacrum	axial	5	4.5
SC	P.leo	common zebra	III	sacrum	axial	3.5	3
SC	P.leo	common zebra	III	pelvis	appendicular	7.4	6.7
SC	P.leo	common zebra	III	skull	axial	9.4	6.8
SC	P.leo	common zebra	III	skull	axial	4.5	4
SC	P.leo	common zebra	III	mandible	axial	10.7	8.8
SC	P.leo	common zebra	III	mandible	axial	13	10.9
SC	P.leo	common zebra	III	mandible	axial	9.9	9.4
SC	P.leo	common zebra	III	pelvis	appendicular	7.4	6.7
SC	P.leo	common zebra	III	skull	axial	19	12.7
SC	P.leo	common zebra	III	skull	axial	12.9	9.4
SC	P.leo	common zebra	III	cervical vertebra	axial	3.8	2.8
SC	P.leo	common zebra	III	cervical vertebra	axial	4	3
SC	P.leo	common zebra	III	cervical vertebra	axial	3.4	2.7
SC	P.leo	common zebra	III	cervical vertebra	axial	4	3.3
SC	P.leo	common zebra	III	cervical vertebra	axial	4.3	3.4
SC	P.leo	common zebra	III	cervical vertebra	axial	4.5	4
SC	P.leo	common zebra	III	ribs	axial	6.7	5.2
SC	P.leo	common zebra	III	ribs	axial	6.5	4.9
SC	P.leo	common zebra	III	ribs	axial	2.9	2.2
SC	P.leo	common zebra	III	ribs	axial	3.3	2.6

SC	P.leo	common zebra	III	ribs	axial	7.6	4.9
SC	P.leo	common zebra	III	scapula	appendicular	8.4	5.7
SC	P.leo	common zebra	III	scapula	appendicular	4	3.6
SC	P.leo	common zebra	III	scapula	appendicular	4.5	3.5
SC	P.leo	common zebra	III	scapula	appendicular	5.3	4.5
SC	P.leo	common zebra	III	scapula	appendicular	6.6	5.9
SC	P.leo	common zebra	III	scapula	appendicular	9.8	8.8
SC	P.leo	common zebra	III	radiusulna	appendicular	6.3	5.2
SC	P.leo	common zebra	III	radiusulna	appendicular	6.8	5.1
SC	P.leo	common zebra	III	radiusulna	appendicular	7.4	6
SC	P.leo	common zebra	III	radiusulna	appendicular	5.8	4.3
SNR	P.leo	grevys zebra	IV	scapula	appendicular	5.4	4.5
SC	P.leo/C.crocata	buffalo	IV	mandible	appendicular	16.4	14
SC	P.leo/C.crocata	buffalo	IV	cervical vertebra	axial	4.7	4.3
SC	P.leo/C.crocata	buffalo	IV	ribs	axial	8.9	7
SC	P.leo/C.crocata	buffalo	IV	pelvis	appendicular	4.8	3.3
SC	P.leo/C.crocata	buffalo	IV	pelvis	appendicular	5.2	4.6
SC	P.leo/C.crocata	buffalo	IV	pelvis	appendicular	10	7.4
SC	P.leo/C.crocata	buffalo	IV	pelvis	appendicular	6.4	4.6
SC	P.leo/C.crocata	buffalo	IV	pelvis	appendicular	10	8
SC	P.leo/C.crocata	buffalo	IV	pelvis	appendicular	6.8	4.9
SC	P.leo/C.crocata	buffalo	IV	pelvis	appendicular	6.5	5.4
SC	P.leo/C.crocata	buffalo	IV	femur	appendicular	6.3	5.6
SC	P.leo/C.crocata	buffalo	IV	femur	appendicular	11.9	9
SC	P.leo/C.crocata	buffalo	IV	femur	appendicular	11.8	8
SC	P.leo/C.crocata	buffalo	IV	femur	appendicular	4.9	4
SC	P.leo/C.crocata	buffalo	IV	femur	appendicular	6.7	5.8
SC	P.leo/C.crocata	buffalo	IV	femur	appendicular	9.1	6.4
SC	P.leo/C.crocata	buffalo	IV	femur	appendicular	5.2	3.9
SC	P.leo/C.crocata	buffalo	IV	femur	appendicular	4.7	4
SC	P.leo/C.crocata	buffalo	IV	femur	appendicular	4.6	3.2
SC	P.leo/C.crocata	buffalo	IV	femur	appendicular	3.8	3
SC	P.leo/C.crocata	buffalo	IV	femur	appendicular	4.8	3.6
SNR	P.leo/C.crocata	camel	IV	scapula	appendicular	7.5	6
SNR	P.leo/C.crocata	camel	IV	scapula	appendicular	9	6
SNR	P.pardus	goat	I	skull	axial	6.5	4.6
SNR	P.pardus	goat	I	scapula	appendicular	2.8	2.1

SNR	P.pardus	goat	I	scapula	appendicular	3.3	2.3
SNR	P.pardus	goat	I	scapula	appendicular	3	2.4
SNR	P.pardus	goat	I	scapula	appendicular	3.1	2.6
SNR	P.pardus	african civet	I	cervical vertebra	axial	6.5	4
SNR	P.pardus	african civet	I	scapula	appendicular	8.2	4.6
SNR	P.leo	impala	II	humerus	appendicular	3.4	2.9
SNR	P.leo	impala	II	humerus	appendicular	2.4	2
SNR	P.leo	impala	II	humerus	appendicular	2.5	2
SNR	P.leo	impala	II	humerus	appendicular	2.8	2.3
SNR	P.leo	impala	II	humerus	appendicular	3.2	2.7
SNR	P.leo/C.crocuta	impala	II	pelvis	appendicular	12.7	10.4

*Appendix II: Effect of placement (diaphyseal vs epiphyseal) on carnivore tooth punctures at kill sites in Kenya.*

Locality	Carnivore	Prey	Age	Prey weight class	Skeletal part	Location on skeletal part	Puncture maximum width (mm)	Puncture minimum width (mm)
SC	lion	impala	adult	II	humerus	epiphyseal	3.1	2.4
SNR	leopard	cow	juvenile	III	femur	diaphyseal	4.7	3.5
SNR	leopard	cow	juvenile	III	femur	diaphyseal	6.6	3.8
SNR	leopard	cow	juvenile	III	femur	diaphyseal	5.8	4.8
SNR	leopard	cow	juvenile	III	femur	epiphyseal	3.5	3.5
SNR	leopard	cow	juvenile	III	femur	epiphyseal	4.7	3.5
SNR	leopard	cow	juvenile	III	femur	epiphyseal	6.9	4.6
SNR	leopard	cow	juvenile	III	femur	epiphyseal	4.4	2.9
SNR	leopard	cow	juvenile	III	femur	epiphyseal	6	3.6
SNR	leopard	cow	juvenile	III	femur	epiphyseal	5.8	4.2
SNR	leopard	gerenuk	adult	II	radiusulna	epiphyseal	3.2	2.2
SC	leopard	impala	adult	II	radiusulna	diaphyseal	5.5	4.7
SC	leopard	impala	adult	II	radiusulna	diaphyseal	7.8	6.6
SC	leopard	impala	adult	II	radiusulna	epiphyseal	5.7	3.5
SNR	lion and spotted hyaena	elephant	juvenile	V	humerus	epiphyseal	14.2	6.9
SNR	lion and spotted hyaena	elephant	juvenile	V	humerus	epiphyseal	10.8	8.1
SNR	lion and spotted hyaena	elephant	juvenile	V	humerus	epiphyseal	7.5	5.1
SNR	lion and spotted hyaena	elephant	juvenile	V	radiusulna	epiphyseal	10.9	6.3
SNR	lion and spotted hyaena	elephant	juvenile	V	radiusulna	epiphyseal	6.4	5.4
SC	lion	impala	adult	II	humerus	diaphyseal	3.2	2.3
SC	lion	impala	adult	II	humerus	diaphyseal	2.7	2.3
SC	lion	impala	adult	II	humerus	diaphyseal	3.4	2.6
SC	lion	common zebra	juvenile	III	radiusulna	diaphyseal	6.3	5.2
SC	lion	common zebra	juvenile	III	radiusulna	diaphyseal	6.8	5.1
SC	lion	common zebra	juvenile	III	radiusulna	diaphyseal	7.4	6
SC	lion	common zebra	juvenile	III	radiusulna	diaphyseal	5.8	4.3
SC	lion and spotted hyaena	buffalo	juvenile	IV	femur	epiphyseal	6.3	5.6
SC	lion and spotted hyaena	buffalo	juvenile	IV	femur	epiphyseal	11.9	9
SC	lion and spotted hyaena	buffalo	juvenile	IV	femur	epiphyseal	11.8	8
SC	lion and spotted hyaena	buffalo	juvenile	IV	femur	epiphyseal	4.9	4
SC	lion and spotted hyaena	buffalo	juvenile	IV	femur	epiphyseal	6.7	5.8
SC	lion and spotted hyaena	buffalo	juvenile	IV	femur	epiphyseal	9.1	6.4
SC	lion and spotted hyaena	buffalo	juvenile	IV	femur	epiphyseal	5.2	3.9
SC	lion and spotted hyaena	buffalo	juvenile	IV	femur	epiphyseal	4.7	4
SC	lion and spotted hyaena	buffalo	juvenile	IV	femur	epiphyseal	4.6	3.2
SC	lion and spotted hyaena	buffalo	juvenile	IV	femur	epiphyseal	3.8	3
SC	lion and spotted hyaena	buffalo	juvenile	IV	femur	epiphyseal	4.8	3.6
SNR	lion	impala	adult	II	humerus	epiphyseal	3.4	2.9
SNR	lion	impala	adult	II	humerus	epiphyseal	2.4	2
SNR	lion	impala	adult	II	humerus	epiphyseal	2.5	2
SNR	lion	impala	adult	II	humerus	epiphyseal	2.8	2.3
SNR	lion	impala	adult	II	humerus	epiphyseal	3.2	2.7

*Appendix III. Carnivore tooth puncture marks on prey bones at hyaena dens in Namibia and Djibouti. Data availed to this PhD study courtesy of Fourvel (2012).*

Country	Locality	Carnivore	Prey	Prey weight class	Skeletal part	Position on prey skeletal part	Puncture maximum width (mm)	Puncture minimum width (mm)
Djibouti	yangula ari	C.crocuta	Gazella sp	I	mandible	axial	7	6
Djibouti	yangula ari	C.crocuta	Gazella sp	I	mandible	axial	3	2
Djibouti	yangula ari	C.crocuta	Gazella sp	I	mandible	axial	2.5	2
Djibouti	yangula ari	C.crocuta	Gazella sp	I	mandible	axial	5	5
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	8	5
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	10	7.5
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	11	7
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	10	6
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	6	4
Djibouti	yangula ari	C.crocuta	camel	IV	humerus	appendicular	8	5
Djibouti	yangula ari	C.crocuta	camel	IV	humerus	appendicular	7	7
Djibouti	yangula ari	C.crocuta	camel	IV	humerus	appendicular	4	4
Djibouti	yangula ari	C.crocuta	camel	IV	humerus	appendicular	6	6
Djibouti	yangula ari	C.crocuta	camel	IV	tibia	appendicular	14	13.5
Djibouti	yangula ari	C.crocuta	camel	IV	tibia	appendicular	8	8
Djibouti	yangula ari	C.crocuta	camel	IV	tibia	appendicular	14	13
Djibouti	yangula ari	C.crocuta	small ungulate	I	metacarpal	appendicular	3	3
Djibouti	yangula ari	C.crocuta	small ungulate	I	metacarpal	appendicular	4.5	3
Djibouti	yangula ari	C.crocuta	medium ungulate	II	podials	appendicular	8	4
Djibouti	yangula ari	C.crocuta	medium ungulate	II	podials	appendicular	7	5.5
Djibouti	yangula ari	C.crocuta	medium ungulate	II	radiusulna	appendicular	2.5	2.5
Djibouti	yangula ari	C.crocuta	medium ungulate	II	metapodial	appendicular	8	7
Djibouti	yangula ari	C.crocuta	Gazella sp	I	tibia	appendicular	7	3
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	5	4
Djibouti	yangula ari	C.crocuta	goat	I	mandible	axial	3	2
Djibouti	yangula ari	C.crocuta	goat	I	mandible	axial	4	2
Djibouti	yangula ari	C.crocuta	goat	I	mandible	axial	7	4
Djibouti	yangula ari	C.crocuta	small ungulate	I	tibia	appendicular	3	2
Djibouti	yangula ari	C.crocuta	small ungulate	I	tibia	appendicular	5	3
Djibouti	yangula ari	C.crocuta	small ungulate	I	radiusulna	appendicular	2	2
Djibouti	yangula ari	C.crocuta	small ungulate	I	radiusulna	appendicular	2	2

Djibouti	yangula ari	C.crocuta	small ungulate	I	radiusulna	appendicular	4	3
Djibouti	yangula ari	C.crocuta	goat	I	radiusulna	appendicular	5	4
Djibouti	yangula ari	C.crocuta	goat	I	radiusulna	appendicular	4.5	4
Djibouti	yangula ari	C.crocuta	goat	I	radiusulna	appendicular	9	7
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	6	4
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	8	5
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	3	2
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	4	3.5
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	9.5	5.5
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	5.5	5
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	7	4
Djibouti	yangula ari	C.crocuta	wild ass	III	femur	appendicular	5	4
Djibouti	yangula ari	C.crocuta	camel	IV	metatarsal	appendicular	10	9
Djibouti	yangula ari	C.crocuta	camel	IV	metatarsal	appendicular	9	5
Djibouti	yangula ari	C.crocuta	camel	IV	metatarsal	appendicular	6	6
Djibouti	yangula ari	C.crocuta	camel	IV	metatarsal	appendicular	9	6
Djibouti	yangula ari	C.crocuta	small ungulate	I	femur	appendicular	5	5
Djibouti	yangula ari	C.crocuta	small ungulate	I	femur	appendicular	4	3
Djibouti	yangula ari	C.crocuta	small ungulate	I	femur	appendicular	5	4
Djibouti	yangula ari	C.crocuta	small ungulate	I	femur	appendicular	5	3
Djibouti	yangula ari	C.crocuta	small ungulate	I	mandible	axial	3	2
Djibouti	yangula ari	C.crocuta	small ungulate	I	mandible	axial	7	5
Djibouti	yangula ari	C.crocuta	small ungulate	I	mandible	axial	4	2
Djibouti	yangula ari	C.crocuta	small ungulate	I	mandible	axial	4	3
Djibouti	yangula ari	C.crocuta	small ungulate	I	radiusulna	appendicular	3	3
Djibouti	yangula ari	C.crocuta	small ungulate	I	radiusulna	appendicular	5	5
Djibouti	yangula ari	C.crocuta	small ungulate	I	radiusulna	appendicular	2	2
Djibouti	yangula ari	C.crocuta	small ungulate	I	radiusulna	appendicular	7	4
Djibouti	yangula ari	C.crocuta	small ungulate	I	radiusulna	appendicular	4	4
Djibouti	yangula ari	C.crocuta	small ungulate	I	humerus	appendicular	6	4
Djibouti	yangula ari	C.crocuta	small ungulate	I	humerus	appendicular	5	3
Djibouti	yangula ari	C.crocuta	small ungulate	I	humerus	appendicular	3	3
Djibouti	yangula ari	C.crocuta	small ungulate	I	humerus	appendicular	5	2
Djibouti	yangula ari	C.crocuta	small ungulate	I	humerus	appendicular	4.5	4
Djibouti	yangula ari	C.crocuta	goat	I	humerus	appendicular	3	3

Djibouti	yangula ari	C.crocuta	goat	I	humerus	appendicular	5	3
Djibouti	yangula ari	C.crocuta	goat	I	humerus	appendicular	3	3
Djibouti	yangula ari	C.crocuta	goat	I	humerus	appendicular	5	2
Djibouti	yangula ari	C.crocuta	goat	I	humerus	appendicular	3	3
Djibouti	yangula ari	C.crocuta	goat	I	humerus	appendicular	3	2
Djibouti	datagabou	H.hyaena	small ungulate	I	scapula	appendicular	5	3
Djibouti	datagabou	H.hyaena	goat	I	skull	axial	8	4
Djibouti	datagabou	H.hyaena	small ungulate	I	scapula	appendicular	7	4
Djibouti	datagabou	H.hyaena	small ungulate	I	scapula	appendicular	3	3
Djibouti	datagabou	H.hyaena	small ungulate	I	scapula	appendicular	3	3
Djibouti	datagabou	H.hyaena	small ungulate	I	femur	appendicular	4	3
Djibouti	datagabou	H.hyaena	goat	I	vertebrae	axial	5	3
Djibouti	datagabou	H.hyaena	goat	I	mandible	axial	2.5	2
Djibouti	datagabou	H.hyaena	goat	I	metacarpal	appendicular	8	7
Djibouti	datagabou	H.hyaena	goat	I	pelvis	appendicular	3.5	3
Djibouti	datagabou	H.hyaena	small ungulate	I	metacarpal	appendicular	9	5
Djibouti	datagabou	H.hyaena	goat	I	pelvis	appendicular	4	2.5
Djibouti	datagabou	H.hyaena	goat	I	pelvis	appendicular	5	3.5
Djibouti	datagabou	H.hyaena	small ungulate	I	radiusulna	appendicular	14	7
Djibouti	datagabou	H.hyaena	small ungulate	I	radiusulna	appendicular	10	8
Djibouti	datagabou	H.hyaena	small ungulate	I	scapula	appendicular	4	4
Djibouti	datagabou	H.hyaena	small ungulate	I	vertebrae	axial	3	3
Djibouti	datagabou	H.hyaena	small ungulate	I	femur	appendicular	4	4
Djibouti	datagabou	H.hyaena	small ungulate	I	tibia	appendicular	4	3
Djibouti	datagabou	H.hyaena	small ungulate	I	pelvis	appendicular	4	4
Djibouti	datagabou	H.hyaena	small ungulate	I	pelvis	appendicular	5	3
Djibouti	datagabou	H.hyaena	small ungulate	I	pelvis	appendicular	3	2
Djibouti	datagabou	H.hyaena	Gazella sp	I	metacarpal	appendicular	4	3
Djibouti	datagabou	H.hyaena	wild ass	III	podials	appendicular	4	3
Djibouti	datagabou	H.hyaena	wild ass	III	podials	appendicular	7	6
Djibouti	datagabou	H.hyaena	wild ass	III	podials	appendicular	4	4
Djibouti	datagabou	H.hyaena	Gazella sp	I	metatarsal	appendicular	5	4
Djibouti	datagabou	H.hyaena	Gazella sp	I	metatarsal	appendicular	5	4.5
Djibouti	datagabou	H.hyaena	small ungulate	I	cervical vertebra	axial	3.2	2.6
Djibouti	datagabou	H.hyaena	small ungulate	I	cervical vertebra	axial	3.6	3.3

Djibouti	datagabou	H.hyaena	goat	I	scapula	appendicular	4.9	3.6
Djibouti	datagabou	H.hyaena	goat	I	scapula	appendicular	5.5	3.5
Djibouti	datagabou	H.hyaena	goat	I	scapula	appendicular	2	2
Djibouti	datagabou	H.hyaena	goat	I	scapula	appendicular	3.5	2
Djibouti	datagabou	H.hyaena	small ungulate	I	humerus	appendicular	3	3
Djibouti	datagabou	H.hyaena	small ungulate	I	humerus	appendicular	8	6
Djibouti	datagabou	H.hyaena	goat	I	radiusulna	appendicular	1	1
Djibouti	datagabou	H.hyaena	goat	I	radiusulna	appendicular	1	1
Djibouti	datagabou	H.hyaena	goat	I	podials	appendicular	2	1
Djibouti	datagabou	H.hyaena	goat	I	podials	appendicular	1	1
Djibouti	datagabou	H.hyaena	goat	I	metacarpal	appendicular	2	2
Djibouti	datagabou	H.hyaena	goat	I	metacarpal	appendicular	2	2
Djibouti	datagabou	H.hyaena	small ungulate	I	cervical vertebra	axial	3	2
Djibouti	datagabou	H.hyaena	small ungulate	I	cervical vertebra	axial	3	2
Djibouti	datagabou	H.hyaena	small ungulate	I	tibia	appendicular	3	3
Djibouti	datagabou	H.hyaena	small ungulate	I	tibia	appendicular	2	2
Djibouti	datagabou	H.hyaena	small ungulate	I	tibia	appendicular	4	2.5
Djibouti	datagabou	H.hyaena	small ungulate	I	scapula	appendicular	4.8	3.8
Djibouti	datagabou	H.hyaena	small ungulate	I	scapula	appendicular	3	2.3
Djibouti	datagabou	H.hyaena	small ungulate	I	scapula	appendicular	2.7	2.2
Djibouti	datagabou	H.hyaena	small ungulate	I	sacrum	axial	2	1
Djibouti	datagabou	H.hyaena	small ungulate	I	sacrum	axial	2	2
Djibouti	datagabou	H.hyaena	small ungulate	I	sacrum	axial	5	5
Djibouti	datagabou	H.hyaena	small ungulate	I	lumbar vertebra	axial	2	2
Djibouti	datagabou	H.hyaena	small ungulate	I	lumbar vertebra	axial	2	2
Djibouti	datagabou	H.hyaena	small ungulate	I	lumbar vertebra	axial	4	3
Djibouti	datagabou	H.hyaena	small ungulate	I	podials	appendicular	2	2
Djibouti	datagabou	H.hyaena	small ungulate	I	podials	appendicular	2	2
Djibouti	datagabou	H.hyaena	small ungulate	I	podials	appendicular	2	1
Djibouti	datagabou	H.hyaena	goat	I	pelvis	appendicular	2.5	2.5
Djibouti	datagabou	H.hyaena	goat	I	pelvis	appendicular	5	3.5
Djibouti	datagabou	H.hyaena	goat	I	pelvis	appendicular	4	4
Djibouti	datagabou	H.hyaena	goat	I	pelvis	appendicular	3	2
Djibouti	datagabou	H.hyaena	small ungulate	I	lumbar vertebra	axial	2.5	2
Djibouti	datagabou	H.hyaena	small ungulate	I	lumbar vertebra	axial	1	1

Djibouti	datagabou	H.hyaena	small ungulate	I	lumbar vertebra	axial	4	3
Djibouti	datagabou	H.hyaena	small ungulate	I	lumbar vertebra	axial	1.5	1.5
Djibouti	datagabou	H.hyaena	small ungulate	I	lumbar vertebra	axial	3	2
Djibouti	datagabou	H.hyaena	small ungulate	I	cervical vertebra	axial	3	3
Djibouti	datagabou	H.hyaena	small ungulate	I	cervical vertebra	axial	8	7
Djibouti	datagabou	H.hyaena	small ungulate	I	cervical vertebra	axial	3	3
Djibouti	datagabou	H.hyaena	small ungulate	I	cervical vertebra	axial	4	3
Djibouti	datagabou	H.hyaena	small ungulate	I	cervical vertebra	axial	5	4
Djibouti	datagabou	H.hyaena	small ungulate	I	cervical vertebra	axial	4	3
Djibouti	datagabou	H.hyaena	small ungulate	I	cervical vertebra	axial	6	4.5
Djibouti	datagabou	H.hyaena	small ungulate	I	cervical vertebra	axial	4	3
Djibouti	datagabou	H.hyaena	small ungulate	I	cervical vertebra	axial	7	5
Djibouti	datagabou	H.hyaena	goat	I	skull	axial	5	5
Djibouti	datagabou	H.hyaena	goat	I	skull	axial	5	3
Djibouti	datagabou	H.hyaena	goat	I	skull	axial	9	9
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	6.4	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	7.1	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	7.6	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	5.8	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	10.2	
Namibia	uniab	P.brunnea	gemsbok	III	radiusulna	appendicular	16.1	
Namibia	uniab	P.brunnea	gemsbok	III	radiusulna	appendicular	7.4	
Namibia	uniab	P.brunnea	gemsbok	III	radiusulna	appendicular	7	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	10.6	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	8.6	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	5.8	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	8.4	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	5	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	3.6	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	4.9	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	10.5	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	6.8	
Namibia	uniab	P.brunnea	gemsbok	III	radiusulna	appendicular	5.7	
Namibia	uniab	P.brunnea	gemsbok	III	radiusulna	appendicular	7.2	
Namibia	uniab	P.brunnea	gemsbok	III	radiusulna	appendicular	9	

Namibia	uniab	P.brunnea	gemsbok	III	radiusulna	appendicular	4.3	
Namibia	uniab	P.brunnea	gemsbok	III	radiusulna	appendicular	9.1	
Namibia	uniab	P.brunnea	gemsbok	III	radiusulna	appendicular	5.6	
Namibia	uniab	P.brunnea	gemsbok	III	radiusulna	appendicular	4	
Namibia	uniab	P.brunnea	gemsbok	III	radiusulna	appendicular	6.3	
Namibia	uniab	P.brunnea	gemsbok	III	metatarsal	appendicular	12.1	
Namibia	uniab	P.brunnea	gemsbok	III	metatarsal	appendicular	11.1	
Namibia	uniab	P.brunnea	gemsbok	III	metatarsal	appendicular	7.6	
Namibia	uniab	P.brunnea	gemsbok	III	metatarsal	appendicular	23.1	
Namibia	uniab	P.brunnea	gemsbok	III	metatarsal	appendicular	8.1	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	8.5	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	12.7	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	10.8	
Namibia	uniab	P.brunnea	gemsbok	III	femur	appendicular	7.2	

*Appendix IV. Large carnivore kill sites inventory indicating nature of damage(s) and/or modification(s) on prey bones collected at each kill site.*

Kill site	locality	vegetation type	carnivore	prey killed by carnivore	age of prey	sex of prey	skeletal part collected	prey bone damage/modification type(s)
kill site 1	Soysambu Conservancy	acacia woodland	lion	impala	adult	female	skull	punctures, crenulated edges
							mandible	punctures
							scapula	punctures, crenulated edges, grooves, pits
							radius/ulna	pits, crenulated edges
							humerus	punctures, grooves, pits, crenulated edges
							podials	punctures, grooves, pits
kill site 2	Samburu National Reserve	riverine	leopard	cow	juvenile	*indeterminate	skull	punctures, claw marks
							maxillae	punctures, grooves
							mandible	crenulated edges
							cervical vertebra	punctures
							scapula	punctures, crenulated edges
							femur	punctures, pits
							tibia	pits
							metatarsal	spiral fractures
kill site 3	Soysambu Conservancy	acacia woodland	lion	impala	adult	male	podials	punctures, pits, gnawing
							scapula	punctures
							pelvis	intensive chewing
kill site 4	Samburu National Reserve	shrubland	lion/spotted hyaena	beisa oryx	adult	female	ribs	segmental fractures
							skull	comminuted fractures
							maxillae	punctures
							cervical vertebra	none
							scapula	none
kill site 5	Soysambu Conservancy	acacia woodland	lion	thompsons gazelle	adult	male	humerus	segmental fractures
							skull	punctures, pits
							maxillae	none
							mandible	none
							cervical vertebra	gnawing
							thoracic vertebra	none

kill site 5	Soysambu Conservancy	acacia woodland	lion	thompsons gazelle	adult	male	lumbar vertebra	none
							sacrum	none
							ribs	none
							humerus	none
							radius/ulna	none
							metacarpal	none
							pelvis	punctures
							femur	none
							tibia	grooves
kill site 6	Samburu National Reserve	mixed woodland	leopard	gerenuk	adult	male	podials	none
							skull	punctures
							mandible	none
							cervical vertebra	none
							thoracic vertebra	none
							lumbar vertebra	none
							sacrum	gnawing
							humerus	gnawing
							radius/ulna	gnawing, punctures
kill site 7	Soysambu Conservancy	acacia woodland	leopard	impala	adult	male	pelvis	punctures
							podials	none
							thoracic vertebra	none
							lumbar vertebra	none
							sacrum	none
							scapula	punctures, grooves, gnawing, pits
							humerus	gnawing
							radius/ulna	punctures, grooves, pits, partial chewing
							pelvis	punctures, grooves, partial chewing
kill site 7	Soysambu Conservancy	acacia woodland	leopard	impala	adult	male	metacarpal	none
							femur	pits, partial chewing
							tibia	none

kill site 7	Soysambu Conservancy	acacia woodland	leopard	impala	adult	male	metatarsal	grooves
							podials	none
kill site 8	Soysambu Conservancy	grassland	lion	eland	juvenile	<i>*indeterminate</i>	skull	intensive chewing, grooves, comminuted fractures
							maxillae	none
							mandible	none
							cervical vertebra	punctures, gnawing
							thoracic vertebra	punctures, gnawing
							lumbar vertebra	gnawing
							sacrum	gnawing
							ribs	gnawing
							humerus	gnawing
							radius/ulna	intensive chewing
							metacarpal	none
							pelvis	crenulated edges
							podials	none
kill site 9	Samburu National Reserve	shrubland	lion & spotted hyaena	elephant	juvenile	<i>*indeterminate</i>	scapula	punctures, crenulated edges, partial chewing
							radius/ulna	punctures, grooves, partial chewing
kill site 10	Soysambu Conservancy	acacia woodland	lion	impala	adult	female	skull	intensive chewing, punctures
							lumbar vertebra	gnawing
							sacrum	punctures
							scapula	pits, partial chewing
							humerus	grooves, punctures, partial chewing
							radius/ulna	gnawing
							metacarpal	none
							pelvis	punctures, partial chewing
							femur	avulsion fractures, partial chewing
							tibia	none
							metatarsal	none
							podials	none
kill site 11	Soysambu Conservancy	grassland	lion	common zebra	juvenile	<i>*indeterminate</i>	lumbar vertebra	gnawing

							sacrum	punctures
							ribs	segmental fractures
kill site 11	Soysambu Conservancy	grassland	lion	common zebra	juvenile	<i>*indeterminate</i>	pelvis	punctures, partial chewing
							skull	comminuted fractures, partial chewing, punctures
							maxillae	none
							mandible	punctures, avulsion fractures
							thoracic vertebra	gnawing
							ribs	segmental fractures
							scapula	partial chewing
							pelvis	punctures, partial chewing
kill site 12	Soysambu Conservancy	mixed woodland	lion	common zebra	juvenile	<i>*indeterminate</i>	podials	none
							skull	punctures
							maxillae	none
							mandible	none
							cervical vertebra	punctures, pits, gnawing
							ribs	segmental fractures
							scapula	punctures, partial chewing
							humerus	avulsion fractures, grooves, pits
							radius/ulna	punctures, pits, grooves
							metacarpal	stepwise fractures
							pelvis	partial chewing
							femur	avulsion fractures, grooves, pits
							tibia	grooves, pits, gnawing
							metatarsal	none
kill site 13	Soysambu Conservancy	shrubland	lion	common zebra	juvenile	<i>*indeterminate</i>	podials	none
							mandible	none
kill site 14	Samburu National Reserve	riverine	lion	grevys zebra	juvenile	<i>*indeterminate</i>	scapula	punctures
							skull	intensive chewing
							mandible	punctures
kill site 15	Soysambu Conservancy	shrubland	lion & spotted hyaena	African buffalo	juvenile	<i>*indeterminate</i>	cervical vertebra	punctures

kill site 15	Soysambu Conservancy	shrubland	lion & spotted hyaena	African buffalo	juvenile	<i>*indeterminate</i>	ribs	punctures, pits, grooves, segmental fractures
							pelvis	punctures, partial chewing
							femur	avulsion fractures, intensive chewing, punctures
							tibia	spiral fractures
							metatarsal	stepwise fractures
kill site 16	Samburu National Reserve	shrubland	lion & spotted hyaena	camel	adult	<i>*indeterminate</i>	scapula	punctures, gnawing
kill site 17	Samburu National Reserve	shrubland	lion & leopard	goat	adult	<i>*indeterminate</i>	skull	segmental fractures, punctures, intensive chewing
							scapula	intensive chewing, punctures
							femur	stepwise fractures, avulsion fractures
kill site 18	Samburu National Reserve	riverine	leopard	african civet	adult	<i>*indeterminate</i>	skull	none
							maxillae	none
							mandible	none
							cervical vertebra	punctures
							thoracic vertebra	none
							lumbar vertebra	none
							sacrum	none
							scapula	crenulated edges, punctures
							humerus	gnawing
							radius/ulna	gnawing
							pelvis	crenulated edges
							femur	gnawing
							tibia	gnawing
							podials	gnawing
kill site 19	Samburu National Reserve	shrubland	lion	impala	adult	<i>*indeterminate</i>	skull	segmental fractures, intensive chewing
							humerus	spiral fractures, punctures, grooves, gnawing
							radius/ulna	grooves, partial chewing
							femur	stepwise fractures, avulsion fractures
							metacarpal	none
kill site 20	Samburu National Reserve	shrubland	lion & spotted hyaena	impala	adult	male	podials	none
							skull	intensive chewing

kill site 20	Samburu National Reserve	shrubland	lion & spotted hyaena	impala	adult	male	maxillae	none
							cervical vertebra	none
							lumbar vertebra	gnawing
							sacrum	intensive chewing
							scapula	crenulated edges
							femur	spiral fractures
							pelvis	crenulated edges
kill site 21	Samburu National Reserve	riverine	lion & spotted hyaena	greater kudu	adult	female	skull	crenulated edges, pits, comminuted fractures
							maxillae	none
							mandible	none
kill site 22	Samburu National Reserve	grassland	cheetah	gerenuk	juvenile	<i>*indeterminate</i>	maxillae	comminuted fractures
							mandible	comminuted fractures
							scapula	intensive chewing
kill site 23	Soysambu Conservancy	acacia woodland	leopard	impala	adult	<i>*indeterminate</i>	humerus	intensive chewing
							radius/ulna	grooves, gnawing, pits
							metacarpal	grooves
							tibia	intensive chewing
							metatarsal	none
							podials	none
kill site 24	Soysambu Conservancy	acacia woodland	lion	common zebra	juvenile	<i>*indeterminate</i>	skull	segmental fractures, intensive chewing
							cervical vertebra	none
							thoracic vertebra	none
							lumbar vertebra	none
							sacrum	none
							ribs	none
							scapula	none
							humerus	none
							radius/ulna	none
							metacarpal	none
							pelvis	none

kill site 24	Soysambu Conservancy	acacia woodland	lion	common zebra	juvenile	<i>*indeterminate</i>	femur	none
							tibia	none
							metatarsal	none
							podials	none
kill site 25	Samburu National Reserve	shrubland	lion & spotted hyaena	camel	adult	<i>*indeterminate</i>	cervical vertebra	none
							thoracic vertebra	gnawing
							ribs	segmental fractures
							metatarsal	none
kill site 26	Samburu National Reserve	shrubland	lion & spotted hyaena	camel	adult	<i>*indeterminate</i>	podials	none
							thoracic vertebra	gnawing
							ribs	segmental fractures
							scapula	none
kill site 27	Soysambu Conservancy	mixed woodland	leopard	black backed jackal	adult	female	skull	none
							maxillae	none
							mandible	none
							cervical vertebra	none
kill site 28	Samburu National Reserve	riverine	leopard	sheep	juvenile	<i>*indeterminate</i>	skull	intensive chewing
							ribs	segmental fractures, crenulated edges, pits, grooves
							scapula	grooves, pits, crenulated edges

*Appendix V. A comparative sample showing nature of damage(s) and/or modification(s) on prey bones at leopard and lion kill sites.*



**Appendix V (a).** Skull of an adult male gerenuk collected from a leopard kill site in Samburu National Reserve. Photo credit: Titus Adhola.



**Appendix V (b).** Skull of an adult female impala collected from a lion kill site in Soysambu Conservancy. Photo credit: Titus Adhola.



**Appendix V (c).** Talus and calcaneum of a juvenile cow collected from a leopard kill site in Samburu National Reserve. Photo credit: Titus Adhola.



**Appendix V (d).** Talus and calcaneum of an adult male thomson's gazelle collected from a lion kill site in Soysambu Conservancy. Photo credit: Titus Adhola.



**Appendix V (e).** Left and right humerus of an adult impala collected from a leopard kill site in Soysambu Conservancy. Photo credit: Titus Adhola.



**Appendix V (f).** Right and left humerus of an adult female impala adult collected from a lion kill site in Soysambu Conservancy. Photo credit: Titus Adhola.

*Appendix VI. Morphometry of carnivore scats found at SNR in Kenya alongside complementary spotted hyaena data from Lunel-Viel in France availed to this PhD study courtesy of Dr. Jean-Philip Brugal.*

<b>Species</b>	<b>Global scat weight (G)</b>	<b>Scat fragment height (mm)</b>	<b>Maximum scat fragment width (mm)</b>	<b>minimum scat fragment width (mm)</b>
P.leo	210	31.4	39.4	31.4
P.leo	220	47.8	40.4	47.8
P.leo	110	37	35.8	37
P.leo	200	52.6	35.7	52.6
P.leo	370	44	44.7	44
P.leo	165	39.9	35.3	39.9
P.leo	290	29	38.9	29
P.leo	140	70.6	40.1	70.6
P.leo	150			
P.leo	350			
P.pardus	110	29.4	23.6	29.4
P.pardus	70	49.3	23.5	49.3
P.pardus	140	17.1	27.7	17.1
P.pardus	60			
P.pardus	90	42.5	23.3	42.5
P.pardus	35	33.1	16.2	33.1
P.pardus	220		41.8	
P.pardus	100		29.8	
P.pardus	100		37.1	
P.pardus	65			
C.crocuta	130	43.4	30.6	43.4
C.crocuta	80	11.7	25.8	11.7
C.crocuta	100	18.5	23.4	18.5
C.crocuta	100			
C.crocuta	110	34.5	31.5	34.5
C.crocuta	135	34.9	35.2	34.9
C.crocuta	190	46.5	33	46.5
C.crocuta	110			
C.crocuta	150	21	36.9	21
C.crocuta	130	23	42.9	23
Crocuta crocuta spelaea		15.7	29.7	
Crocuta crocuta spelaea		15.8	22.5	
Crocuta crocuta spelaea		18.8	27.3	
Crocuta crocuta spelaea		19.7	32.6	
Crocuta crocuta spelaea		20.5	31.6	
Crocuta crocuta spelaea		21.7	21.7	
Crocuta crocuta spelaea		21.9	28.4	
Crocuta crocuta spelaea		22.1	30.5	
Crocuta crocuta spelaea		22.2	32.6	
Crocuta crocuta spelaea		22.2	37.6	
Crocuta crocuta spelaea		22.9	29.7	
Crocuta crocuta spelaea		23.1	23.3	
Crocuta crocuta spelaea		23.3	27	

Crocuta crocuta spelaea		23.3	30.6	
Crocuta crocuta spelaea		23.3	30.9	
Crocuta crocuta spelaea		23.4	32	
Crocuta crocuta spelaea		23.6	29.8	
Crocuta crocuta spelaea		23.6	30.2	
Crocuta crocuta spelaea		23.8	33.1	
Crocuta crocuta spelaea		24.6	24	
Crocuta crocuta spelaea		24.9	36.1	
Crocuta crocuta spelaea		25.3	24.7	
Crocuta crocuta spelaea		25.5	17	
Crocuta crocuta spelaea		25.5	17.5	
Crocuta crocuta spelaea		25.7	29	
Crocuta crocuta spelaea		25.7	33.6	
Crocuta crocuta spelaea		26.2	30.9	
Crocuta crocuta spelaea		26.5	32.9	
Crocuta crocuta spelaea		26.5	34.5	
Crocuta crocuta spelaea		27	36	
Crocuta crocuta spelaea		27.2	25.6	
Crocuta crocuta spelaea		27.3	27.8	
Crocuta crocuta spelaea		27.5	33.7	
Crocuta crocuta spelaea		27.9	24.6	
Crocuta crocuta spelaea		28	37.1	
Crocuta crocuta spelaea		28.3	29.7	
Crocuta crocuta spelaea		28.3	30.8	
Crocuta crocuta spelaea		29.2	15.7	
Crocuta crocuta spelaea		30.2	33.3	
Crocuta crocuta spelaea		30.3	30.5	
Crocuta crocuta spelaea		30.5	24	
Crocuta crocuta spelaea		30.5	24.6	
Crocuta crocuta spelaea		30.5	26.9	
Crocuta crocuta spelaea		30.5	27.9	
Crocuta crocuta spelaea		30.8	41.9	
Crocuta crocuta spelaea		31	20.8	
Crocuta crocuta spelaea		31.2	19.7	
Crocuta crocuta spelaea		31.4	41.7	
Crocuta crocuta spelaea		31.9	26.4	
Crocuta crocuta spelaea		32	42	
Crocuta crocuta spelaea		32.3	21.8	
Crocuta crocuta spelaea		32.3	41	
Crocuta crocuta spelaea		32.6	29.4	
Crocuta crocuta spelaea		32.8	29.5	
Crocuta crocuta spelaea		32.8	40.6	
Crocuta crocuta spelaea		32.9	34.2	
Crocuta crocuta spelaea		33	36.7	
Crocuta crocuta spelaea		33.1	29.1	
Crocuta crocuta spelaea		33.4	44.7	

Crocuta crocuta spelaea		33.5	37.4	
Crocuta crocuta spelaea		33.5	47	
Crocuta crocuta spelaea		33.6	21.9	
Crocuta crocuta spelaea		33.8	31.9	
Crocuta crocuta spelaea		33.8	35.6	
Crocuta crocuta spelaea		33.9	30	
Crocuta crocuta spelaea		33.9	41.2	
Crocuta crocuta spelaea		33.9	48.7	
Crocuta crocuta spelaea		34.4	47.8	
Crocuta crocuta spelaea		35.3	45.4	
Crocuta crocuta spelaea		35.4	24.4	
Crocuta crocuta spelaea		35.4	39.5	
Crocuta crocuta spelaea		35.4	52.4	
Crocuta crocuta spelaea		35.6	25.8	
Crocuta crocuta spelaea		35.6	38.2	
Crocuta crocuta spelaea		36	39.6	
Crocuta crocuta spelaea		36.3	30.4	
Crocuta crocuta spelaea		36.3	32.3	
Crocuta crocuta spelaea		36.3	54	
Crocuta crocuta spelaea		36.9	37.1	
Crocuta crocuta spelaea		37	29.3	
Crocuta crocuta spelaea		38.7	30	
Crocuta crocuta spelaea		38.8	30.4	
Crocuta crocuta spelaea		38.8	35.2	
Crocuta crocuta spelaea		39.1	33	
Crocuta crocuta spelaea		39.1	50.6	
Crocuta crocuta spelaea		40	34.2	
Crocuta crocuta spelaea		40.8	45.5	
Crocuta crocuta spelaea		42	27	
Crocuta crocuta spelaea		42.4	21.8	
Crocuta crocuta spelaea		42.4	32.5	
Crocuta crocuta spelaea		43	26.7	
Crocuta crocuta spelaea		43.3	47.1	
Crocuta crocuta spelaea		43.5	36.7	
Crocuta crocuta spelaea		44.3	30.7	
Crocuta crocuta spelaea		44.5	28.9	
Crocuta crocuta spelaea		45.6	36	
Crocuta crocuta spelaea		45.7	33.4	
Crocuta crocuta spelaea		46.1	27.8	
Crocuta crocuta spelaea		46.9	44.1	
Crocuta crocuta spelaea		51.1	39.8	
Crocuta crocuta spelaea		52.8	41	
Crocuta crocuta spelaea		53.6	49.9	
Crocuta crocuta spelaea		54.9	36.4	
Crocuta crocuta spelaea		54.9	47.3	
Crocuta crocuta spelaea		55.5	29.5	

*Appendix VII. Animal census data (domestic and wild herbivores) availed to this PhD study courtesy of DRSRS.*

<b>Species</b>	<b>2010 census</b>	<b>2013 census</b>	<b>2015 census</b>
Camel	913	430	601
Gerenuk	16	7	16
Impala	1	0	0
Common Zebra	171	202	47
Grevy's zebra	10	18	8
Warthog	1	4	14
Shoats	16168	25330	36874
Beisa oryx	8	9	1
Lesser kudu	1	6	12
Donkey	192	242	189
Eland	4	0	2
Giraffe	52	21	17
Grants gazelle	29	17	4
Cattle	3001	5596	5249
Elephant	76	45	36
Total	20644	31927	43070

*Appendix VIII. Climatic variables for Samburu County (2009 – 2018) availed to this PhD study courtesy of the **ICPAC-GMES** project.*

<b>Year</b>	<b>Month</b>	<b>Rainfall (mm)</b>	<b>NDVI</b>	<b>SPI</b>	<b>Maximum Temperature (°c)</b>	<b>Minimum temperature (°c)</b>
2009	January	3.53	0.32	0	30	19
2009	February	0.27	0.29	0	31	20
2009	March	1.03	0.28	-1	33	20
2009	April	41.03	0.28	-1	32	20
2009	May	50.48	0.32	0	31	20
2009	June	0.89	0.32	0	31	19
2009	July	4.77	0.27	-1	29	18
2009	August	0.77	0.24	0	30	18
2009	September	0.99	0.25	-1	31	19
2009	October	44.66	0.27	1	30	20
2009	November	24.82	0.36	-1	30	20
2009	December	97.53	0.35	1	30	20
2010	January	27.99	0.40	1	30	20
2010	February	89.91	0.33	2	32	22
2010	March	106.96	0.42	1	30	21
2010	April	101.71	0.49	0	31	22
2010	May	54.00	0.49	0	30	21
2010	June	7.74	0.37	-1	30	19
2010	July	11.47	0.32	1	29	18
2010	August	9.34	0.32	1	29	19
2010	September	8.45	0.32	0	31	19
2010	October	5.59	0.31	0	31	21
2010	November	38.57	0.30	-1	30	19
2010	December	0.59	0.30	-1	31	18
2011	January	1.05	0.27	-1	31	19
2011	February	6.92	0.27	1	33	19
2011	March	20.85	0.27	0	32	20
2011	April	16.56	0.29	-1	32	21
2011	May	27.31	0.34	-1	31	20
2011	June	16.73	0.31	0	31	19

2011	July	13.96	0.31	0	30	18
2011	August	18.19	0.31	0	29	19
2011	September	18.58	0.32	1	30	19
2011	October	76.07	0.35	2	29	20
2011	November	179.84	0.50	2	28	20
2011	December	58.59	0.56	0	30	19
2012	January	0.00	0.44	-1	31	18
2012	February	1.94	0.34	0	32	19
2012	March	3.12	0.29	-1	32	20
2012	April	147.12	0.34	1	31	21
2012	May	75.02	0.52	1	29	20
2012	June	11.35	0.40	0	29	19
2012	July	19.41	0.34	0	27	18
2012	August	7.72	0.35	1	29	18
2012	September	13.09	0.33	0	30	19
2012	October	67.61	0.36	1	30	20
2012	November	44.18	0.45	-1	29	20
2012	December	68.85	0.45	1	29	20
2013	January	4.98	0.42	1	30	20
2013	February	0.93	0.31	-1	32	20
2013	March	78.43	0.30	1	31	21
2013	April	156.20	0.50	1	29	21
2013	May	10.75	0.50	-1	29	19
2013	June	18.08	0.37	0	28	19
2013	July	11.18	0.33	1	27	18
2013	August	6.16	0.32	0	28	18
2013	September	9.03	0.32	0	30	19
2013	October	2.89	0.31	0	31	20
2013	November	84.38	0.43	0	28	20
2013	December	20.88	0.49	0	30	20
2014	January	0.06	0.39	-1	30	19
2014	February	26.39	0.33	1	31	21
2014	March	45.58	0.36	1	31	20

2014	April	40.98	0.44	0	30	20
2014	May	8.82	0.37	-1	30	20
2014	June	10.15	0.30	-1	29	19
2014	July	7.48	0.23	-1	28	19
2014	August	32.40	0.22	1	29	19
2014	September	2.60	0.36	1	30	19
2014	October	18.89	0.33	1	31	21
2014	November	37.13	0.37	0	29	20
2014	December	17.21	0.44	0	29	19
2015	January	0.00	0.34	-1	31	20
2015	February	4.77	0.29	0	33	20
2015	March	11.02	0.26	0	32	20
2015	April	117.23	0.37	0	31	21
2015	May	29.15	0.45	0	30	20
2015	June	15.47	0.33	0	30	19
2015	July	5.96	0.31	0	30	19
2015	August	2.67	0.30	-1	31	19
2015	September	1.21	0.28	-1	33	20
2015	October	20.00	0.28	0	33	22
2015	November	85.45	0.40	1	31	21
2015	December	57.05	0.52	1	32	20
2016	January	28.38	0.46	1	32	21
2016	February	4.96	0.36	0	34	20
2016	March	17.39	0.32	0	35	22
2016	April	110.13	0.29	0	33	22
2016	May	37.77	0.50	0	31	20
2016	June	17.86	0.42	0	30	19
2016	July	5.00	0.36	-1	30	19
2016	August	4.35	0.34	0	31	19
2016	September	1.37	0.30	0	31	19
2016	October	3.68	0.28	-1	34	20
2016	November	36.28	0.30	0	31	21
2016	December	2.84	0.36	-1	32	19

2017	January	2.85	0.34	0	33	18
2017	February	6.99	0.29	1	33	20
2017	March	1.11	0.26	-1	35	21
2017	April	29.90	0.27	-1	34	21
2017	May	32.35	0.38	1	32	21
2017	June	1.21	0.34	0	32	19
2017	July	13.70	0.27	0	31	19
2017	August	18.39	0.30	1	32	19
2017	September	5.68	0.30	1	32	20
2017	October	88.43	0.30	1	33	21
2017	November	70.90	0.43	1	31	20
2017	December	0.06	0.46	-1	33	18
2018	January	0.13	0.31	0	33	18
2018	February	1.57	0.27	0	35	19
2018	March	122.58	0.31	2	30	20
2018	April	277.46	0.49	2	29	20
2018	May	96.68	0.58	1	30	20
2018	June	44.37	0.50	2	28	19
2018	July	7.77	0.40	1	28	18
2018	August	9.02	0.34	0	29	19
2018	September	2.88	0.33	0	31	19
2018	October	20.67	0.31	0	31	20
2018	November	6.94	0.34	-1	30	20
2018	December	33.25	0.42	1	31	20

*Appendix IX. Sample of semi-structured questionnaire used to collect ethnographic data for this PhD Study in Samburu County.*

**Household questionnaire**

Household code (location/boma n<sup>o</sup>).....Date.....  
 Interview location.....  
 GPS co-ordinates.....Survey no.....  
 County.....  
 Division.....  
 Interviewer's ..... name  
 .....  
 Language used to conduct interview.....

**Questionnaire: Community perceptions towards large African carnivores in Samburu.**

*This questionnaire is for research purposes only, conducted in selected households within community conservancies in Samburu County. Any information you share will be kept confidential. Your answers will not affect government policies, such as taxes or compensation.*

**Interviewee's details**

1. Property/community ..... name ..... where ..... you live.....
2. Property type: Group ranch/conservancy..... Squatter ..... other (specify).....
3. Mother tongue/ ethnic language.....
4. Male..... Female.....
5. Age (specify interviewee relationship to the entire household).....
6. How long have you lived here.....  
Where were you living before moving to this place (if moved in recently)
7. Highest level of education.....
8. How many family members: men....., women....., young men....., young women....., boys..... and girls..... live in this household?
9. Do you or any member of family own livestock yes..... no.....  
If yes which of the following types: camel..... cow.....donkey.... sheep....goat  
If no move to question #20
10. How are the livestock kept at night? In a shelter..... in the open..... other.....  
Do you keep all your livestock together in one place at night?  
yes..... no.....  
If yes, where are they kept?.....  
If no, how are they kept?.....
11. Do you herd all the animals together as one group during the day? Yes..... No.....  
If no, how are they taken to pastures each day?  
.....
12. Who herds the livestock during the day?  
family member..... professional/hired herder(s)..... free ranging.....other.....  
If yes for family member, which family member(s)?  
If yes for professional/hired herder, age and gender: e.g. young men only, boys etc
13. Do you own any dogs? yes..... no.....  
If yes, how many..... and for what purpose(s)?.....

14. How do you graze livestock with young ones?.....
15. In which areas do you prefer to graze your cattle?.....
16. Which is the most common livestock type kept by this household (donkey, cow, camel, sheep/goats)?.....  
Do you have any reason(s) for this preference?.....
17. Which of the following categories best suits the general number of livestock in your household: a few ..... moderate..... a lot/many.....
18. What main challenges do you (or your family) face(s) when rearing your livestock from day to day?  
.....  
.....
19. Which type(s) of livestock (donkey, cow, camel, sheep/goats) in your household are the most prone to attack by wild carnivores in general and where (in bomas at night or while grazing during day) or other (specify).....list in order of decreasing frequency, starting with most frequently taken e.g. goats/sheep, cows e.t.c.  
.....  
.....
20. What do you think about the wild animals living in the area around this household?  
.....  
.....

### **Community Practices and Attitudes towards predators**

21. Given a choice, would you prefer to have the following predators on your property? Any reason(s) why? (pictures of the carnivores listed to be shown to respondent)

Predator	yes	no	don't know	reason(s)
Cheetah				
Lion				
Spotted hyaena				
Leopard				
African wild dog				
Stripped hyaena				

22. In your opinion, what is the best way to deal with large carnivores that stray into villages and kill livestock? (choose only one option)
- They should be killed before they attack livestock
  - They should be captured by KWS and returned to the park and prevented from ever coming back to community land
  - People should be taught how to avoid them, and how to prevent their cattle from being attacked, but the carnivores should not be killed in retaliation
  - There ought to be compensation for the livestock lost to carnivores, but even without compensation, I don't think the carnivores should be killed in retaliation
23. Please rank the following predators in terms of their effect upon cattle in the district (1=highest impact, 6= lowest impact), and then rank them in terms of effect on goats and sheep (1= highest impact, 6= lowest impact). (Interviewer: write n/a if interviewee does not think the predator attacks livestock.)

Predator	Cattle	Goats and sheep
Leopard		
Wild dog		
Lion		
Spotted hyaena		
Stripped hyaena		
Cheetah		

### Comments

24. What do you think are the most effective ways of protecting livestock from predators?

.....

.....

.....

25. Do you use these methods? If not, why not?

.....

.....

.....

26. Are there any solutions you would suggest to promote the co-existence of people and predators?

.....

.....

.....

.....

**THANK YOU FOR PARTICIPATING IN THIS SURVEY!**

**Interviewer's comments (to be filled by interviewer AFTER interview is complete):**

*Appendix X. Livestock depredation by large carnivores in Samburu County from January 2010 to December 2018. Data availed to this PhD study courtesy of NRT.*

Year	Month	Local habitat	Livestock type	Killed by lion during day	Killed by lion at night	Total killed by lion	Killed by leopard during day	Killed by leopard at night	Total killed by leopard	Killed by spotted hyaena during day	Killed by spotted hyaena at night	Total killed by spotted hyaena	Killed by cheetah during day	Killed by cheetah at night	Total killed by cheetah	Killed by African wild dog during day	Killed by African wild dog at night	Total killed by African wild dog	Killed by carnivores during day	Killed by carnivores at night	Total killed by carnivores
2010	January	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	January	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2010	February	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	February	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	March	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2010	April	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Ltungai	Shoats	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2010	April	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	April	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	May	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	May	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	May	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	May	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	May	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	May	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	May	Westgate	Donkey	1	0	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	2
2010	May	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	May	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	May	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	May	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	May	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	May	Ltungai	Shoats	0	28	28	0	0	0	6	6	0	0	0	0	0	0	0	34	34	34
2010	May	Ltungai	Cattle	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0	5	5	5
2010	May	Ltungai	Donkey	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3
2010	May	Ltungai	Camel	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
2010	June	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	June	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	June	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2010	June	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	June	Westgate	Shoats	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	4	4
2010	June	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	June	Westgate	Donkey	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2010	June	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	June	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	June	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	June	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	June	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	June	Ltungai	Shoats	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2	2
2010	June	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	June	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	June	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Namunyak	Cattle	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Westgate	Shoats	0	0	0	1	6	7	0	2	2	3	0	3	0	0	0	4	8	12
2010	July	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Westgate	Donkey	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	2	2
2010	July	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	July	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	August	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2010	August	Namunyak	Cattle	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
2010	August	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	August	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	August	Westgate	Shoats	0	0	0	0	5	5	0	3	3	0	0	0	0	0	0	0	8	8
2010	August	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	August	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	August	Westgate	Camel	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2010	August	Meibae	Shoats	0	0	0	2	0	2	0	0	0	1	0	1	0	0	0	3	0	3
2010	August	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	August	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	August	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	August	Ltungai	Shoats	0	0	0	2	0	2	28	0	28	1	0	1	15	0	15	46	0	46
2010	August	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	August	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	August	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	September	Namunyak	Shoats	0	0	0	5	0	5	0	0	0	0	0	0	0	0	0	5	0	5
2010	September	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	September	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	September	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	September	Westgate	Shoats	0	0	0	1	1	2	0	0	0	1	0	1	0	0	0	2	1	3
2010	September	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	September	Westgate	Donkey	1	0	1	0	0	0	0	3	3	0	0	0	0	0	0	1	3	4
2010	September	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	September	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	September	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	September	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	September	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	September	Ltungai	Shoats	0	0	0	1	0	1	9	0	9	0	0	0	0	0	0	10	0	10
2010	September	Ltungai	Cattle	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
2010	September	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2010	September	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	October	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	October	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	October	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	October	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	October	Westgate	Shoats	0	0	0	1	3	4	1	0	1	0	0	0	0	0	0	2	3	5
2010	October	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	October	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	October	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	October	Meibae	Shoats	0	0	0	4	0	4	0	0	0	1	0	1	0	0	0	5	0	5
2010	October	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	October	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	October	Meibae	Camel	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2	2
2010	October	Ltungai	Shoats	1	0	1	8	0	8	9	0	9	0	0	0	0	0	0	18	0	18
2010	October	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	October	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	October	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Westgate	Shoats	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
2010	November	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2010	November	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	November	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	December	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	December	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	December	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	December	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	December	Westgate	Shoats	0	0	0	7	5	12	1	0	1	0	0	0	0	0	0	8	5	13
2010	December	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	December	Westgate	Donkey	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
2010	December	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	December	Meibae	Shoats	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
2010	December	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	December	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	December	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	December	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	December	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	December	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	December	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	January	Namunyak	Shoats	0	0	0	14	0	14	0	0	0	0	0	0	0	0	0	14	0	14
2011	January	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	January	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	January	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	January	Westgate	Shoats	0	0	0	7	1	8	0	0	0	0	0	0	0	0	0	7	1	8
2011	January	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	January	Westgate	Donkey	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2011	January	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	January	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	January	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	January	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2011	January	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	January	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	January	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	January	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	January	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Namunyak	Shoats	0	0	0	6	0	6	0	0	0	0	0	0	0	0	0	6	0	6
2011	February	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Meibae	Shoats	0	0	0	0	0	0	0	0	0	3	0	3	0	0	0	3	0	3
2011	February	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	February	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	March	Namunyak	Shoats	0	0	0	8	0	8	0	0	0	0	0	0	0	0	0	8	0	8
2011	March	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	March	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	March	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	March	Westgate	Shoats	0	0	0	3	2	5	0	1	1	0	0	0	0	0	0	3	3	6
2011	March	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	March	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	March	Westgate	Camel	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2	2
2011	March	Meibae	Shoats	0	0	0	0	0	0	0	0	0	2	0	2	7	0	7	9	0	9

2011	March	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	March	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	March	Meibae	Camel	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2011	March	Ltungai	Shoats	0	0	0	0	0	0	8	10	18	0	0	0	0	0	0	8	10	18
2011	March	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	March	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	March	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	April	Namunyak	Shoats	0	0	0	9	0	9	0	0	0	0	0	0	0	0	0	9	0	9
2011	April	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	April	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	April	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	April	Westgate	Shoats	0	0	0	7	0	7	10	1	11	0	0	0	0	0	0	17	1	18
2011	April	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	April	Westgate	Donkey	1	0	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	2
2011	April	Westgate	Camel	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
2011	April	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	April	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	April	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	April	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	April	Ltungai	Shoats	0	0	0	1	3	4	0	0	0	1	0	1	0	0	0	2	3	5
2011	April	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	April	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	April	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	May	Namunyak	Shoats	0	0	0	0	1	1	0	0	0	2	0	2	0	0	0	2	1	3
2011	May	Namunyak	Cattle	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2011	May	Namunyak	Donkey	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3
2011	May	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	May	Westgate	Shoats	0	0	0	0	0	0	0	14	14	0	0	0	0	0	0	14	14	14
2011	May	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	May	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2011	May	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	May	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	May	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	May	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	May	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	May	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	May	Ltungai	Cattle	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	2	0	2
2011	May	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	May	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	June	Namunyak	Shoats	4	0	4	9	14	23	0	14	14	0	0	0	0	0	0	13	28	41
2011	June	Namunyak	Cattle	1	2	3	1	0	1	0	0	0	0	0	0	0	0	0	2	2	4
2011	June	Namunyak	Donkey	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2011	June	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	June	Westgate	Shoats	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	3	0	3
2011	June	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	June	Westgate	Donkey	0	0	0	0	0	0	1	2	3	0	0	0	0	0	0	1	2	3
2011	June	Westgate	Camel	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2	2
2011	June	Meibae	Shoats	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	2	0	2
2011	June	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	June	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	June	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	June	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	June	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	June	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	June	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	July	Namunyak	Shoats	0	0	0	1	2	3	0	0	0	0	0	0	0	0	0	1	2	3
2011	July	Namunyak	Cattle	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2011	July	Namunyak	Donkey	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	2	0	2
2011	July	Namunyak	Camel	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	3	3
2011	July	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2011	July	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	July	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	July	Westgate	Camel	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2011	July	Meibae	Shoats	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2011	July	Meibae	Cattle	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2011	July	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	July	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	July	Ltungai	Shoats	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2011	July	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	July	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	July	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	August	Namunyak	Shoats	0	0	0	10	12	22	3	1	4	2	0	2	0	0	0	15	13	28
2011	August	Namunyak	Cattle	1	2	3	0	0	0	1	0	1	1	0	1	0	0	0	3	2	5
2011	August	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	August	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	August	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	August	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	August	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	August	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	August	Meibae	Shoats	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2011	August	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	August	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	August	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	August	Ltungai	Shoats	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1	1
2011	August	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	August	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	August	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	September	Namunyak	Shoats	0	0	0	4	0	4	0	1	1	0	0	0	0	0	4	1	5	5
2011	September	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	September	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2011	September	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2011	September	Westgate	Shoats	0	0	0	1	0	1	0	1	1	0	0	0	1	0	1	2	1	3
2011	September	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	September	Westgate	Donkey	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2011	September	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	September	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	September	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	September	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	September	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	September	Ltungai	Shoats	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0	3	0	3
2011	September	Ltungai	Cattle	0	0	0	0	0	0	2	2	4	0	0	0	0	0	0	2	2	4
2011	September	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	September	Ltungai	Camel	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	2	0	2
2011	October	Namunyak	Shoats	0	0	0	5	0	5	0	0	0	0	0	0	0	0	0	5	0	5
2011	October	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	October	Namunyak	Donkey	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2011	October	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	October	Westgate	Shoats	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	2	2
2011	October	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	October	Westgate	Donkey	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2011	October	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	October	Meibae	Shoats	0	0	0	4	0	4	0	1	1	2	0	2	0	0	0	6	1	7
2011	October	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	October	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	October	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	October	Ltungai	Shoats	0	0	0	0	0	0	0	6	6	0	0	0	0	0	0	0	0	0
2011	October	Ltungai	Cattle	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2011	October	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	October	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	November	Namunyak	Shoats	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1

2011	November	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	November	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	November	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	November	Westgate	Shoats	0	0	0	0	0	0	0	8	8	0	0	0	0	0	0	0	8	8
2011	November	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	November	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	November	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	November	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	November	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	November	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	November	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	November	Ltungai	Shoats	0	0	0	0	0	0	0	20	20	0	0	0	0	0	0	0	20	20
2011	November	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	November	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	November	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	December	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	December	Namunyak	Cattle	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2011	December	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	December	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	December	Westgate	Shoats	0	0	0	1	0	1	0	1	1	0	0	0	1	0	1	2	1	3
2011	December	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	December	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	December	Westgate	Camel	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2011	December	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	December	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	December	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	December	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	December	Ltungai	Shoats	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	3	3
2011	December	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	December	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2011	December	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	January	Namunyak	Shoats	0	0	0	10	12	22	0	0	0	0	0	0	0	0	10	12	22
2012	January	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	January	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	January	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	January	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	January	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	January	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	January	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	January	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0
2012	January	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	January	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	January	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	January	Ltungai	Shoats	0	0	0	0	0	0	5	5	0	0	0	0	0	0	0	5	5
2012	January	Ltungai	Cattle	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2012	January	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	January	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	February	Namunyak	Shoats	0	0	0	14	9	23	0	0	0	0	0	0	0	0	14	9	23
2012	February	Namunyak	Cattle	1	0	1	1	0	1	0	0	0	0	0	0	0	0	15	9	24
2012	February	Namunyak	Donkey	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	1
2012	February	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	February	Westgate	Shoats	0	0	0	2	0	2	1	0	1	0	0	0	0	0	3	0	3
2012	February	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	February	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	February	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	February	Meibae	Shoats	0	0	0	0	0	0	0	0	0	4	0	4	0	0	4	0	4
2012	February	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	February	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	February	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	February	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2012	February	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	February	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	February	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	March	Namunyak	Shoats	0	0	0	10	6	16	0	0	0	0	0	0	1	0	1	11	6	17
2012	March	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	March	Namunyak	Donkey	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
2012	March	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	March	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	March	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	March	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	March	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	March	Meibae	Shoats	0	0	0	0	0	0	0	0	0	5	0	5	0	0	0	5	0	5
2012	March	Meibae	Cattle	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	2	0	2
2012	March	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	March	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	March	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	8	0	8	8	0	8
2012	March	Ltungai	Cattle	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2012	March	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	March	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	April	Namunyak	Shoats	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
2012	April	Namunyak	Cattle	0	7	7	2	0	2	0	0	0	0	0	0	0	0	0	2	7	9
2012	April	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	April	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	April	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	April	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	April	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	April	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	April	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	April	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	April	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2012	April	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	April	Ltungai	Shoats	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	2	0	2
2012	April	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	April	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	April	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	May	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	May	Namunyak	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2012	May	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	May	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	May	Westgate	Shoats	0	0	0	0	13	13	0	0	0	0	0	0	0	0	0	0	13	13
2012	May	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	May	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	May	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	May	Meibae	Shoats	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	2	0	2
2012	May	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	May	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	May	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	May	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	May	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	May	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	May	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	June	Namunyak	Shoats	0	0	0	7	0	7	0	0	0	0	0	0	0	0	0	7	0	7
2012	June	Namunyak	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2012	June	Namunyak	Donkey	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2012	June	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	June	Westgate	Shoats	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0	2	0	2
2012	June	Westgate	Cattle	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
2012	June	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	June	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	June	Meibae	Shoats	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1

2012	June	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	June	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	June	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	June	Ltungai	Shoats	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
2012	June	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	June	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	June	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	July	Namunyak	Shoats	0	0	0	0	1	1	0	0	0	0	0	0	15	0	15	15	1	16
2012	July	Namunyak	Cattle	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
2012	July	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	July	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	July	Westgate	Shoats	0	0	0	0	2	2	2	0	2	5	0	5	0	0	0	7	2	9
2012	July	Westgate	Cattle	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
2012	July	Westgate	Donkey	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1
2012	July	Westgate	Camel	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	2	2
2012	July	Meibae	Shoats	0	0	0	0	0	0	0	5	5	0	0	0	0	0	0	0	5	5
2012	July	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	July	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	July	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	July	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	July	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	July	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	July	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	August	Namunyak	Shoats	0	4	4	1	0	1	0	0	0	0	0	0	0	0	0	1	4	5
2012	August	Namunyak	Cattle	2	2	4	2	0	2	0	0	0	0	0	0	0	0	0	4	2	6
2012	August	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	August	Namunyak	Camel	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2012	August	Westgate	Shoats	0	0	0	2	0	2	0	0	0	2	0	2	0	0	0	4	0	4
2012	August	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	August	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2012	August	Westgate	Camel	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2012	August	Meibae	Shoats	0	0	0	0	0	0	0	3	3	2	0	2	7	0	7	9	3	12
2012	August	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	August	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	August	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	August	Ltungai	Shoats	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	3	3
2012	August	Ltungai	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2012	August	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	August	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	September	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	September	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	September	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	September	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	September	Westgate	Shoats	0	0	0	14	0	14	5	8	13	0	0	0	5	0	5	24	8	32
2012	September	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	September	Westgate	Donkey	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0	3	0	3
2012	September	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	September	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	7	0	7	7	0	7
2012	September	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	September	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	September	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	September	Ltungai	Shoats	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2012	September	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	September	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	September	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	October	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	31	0	31	31	0	31
2012	October	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	October	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	October	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	October	Westgate	Shoats	0	0	0	5	0	5	3	7	10	0	0	0	0	0	0	8	7	15

2012	October	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	October	Westgate	Donkey	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
2012	October	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	October	Meibae	Shoats	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2	2
2012	October	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	October	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	October	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	October	Ltungai	Shoats	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2012	October	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	October	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	October	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Westgate	Shoats	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	2	0	2
2012	November	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	13	0	13	13	0	13
2012	November	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	November	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	December	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	December	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	December	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2012	December	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	December	Westgate	Shoats	0	0	0	0	1	1	1	6	7	1	0	1	0	0	0	2	7	9
2012	December	Westgate	Cattle	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2012	December	Westgate	Donkey	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	3	3	3
2012	December	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	December	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	December	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	December	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	December	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	December	Ltungai	Shoats	0	0	0	2	0	2	0	2	2	0	0	0	0	0	0	2	2	4
2012	December	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	December	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	December	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	January	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Namunyak	Shoats	0	0	0	0	0	0	1	0	1	0	0	0	4	0	4	5	0	5

2013	February	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Meibae	Shoats	0	0	0	0	0	0	1	0	1	1	0	1	0	0	0	2	0	2
2013	February	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	February	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	March	Namunyak	Shoats	0	0	0	0	1	1	0	0	0	0	0	0	16	0	16	16	1	17
2013	March	Namunyak	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2013	March	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	March	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	March	Westgate	Shoats	0	0	0	1	0	1	0	80	80	0	0	0	0	0	0	1	80	81
2013	March	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	March	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	March	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	March	Meibae	Shoats	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2013	March	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	March	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	March	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	March	Ltungai	Shoats	0	0	0	8	0	8	0	0	0	0	0	0	8	0	8	16	0	16
2013	March	Ltungai	Cattle	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2013	March	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2013	March	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	April	Namunyak	Shoats	0	0	0	3	0	3	0	0	0	0	0	0	0	0	3	0	3
2013	April	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	April	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	April	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	April	Westgate	Shoats	0	0	0	0	2	2	0	1	1	0	0	0	1	0	1	1	3
2013	April	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	April	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	April	Westgate	Camel	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1
2013	April	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	April	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	April	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	April	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	April	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	April	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	April	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	April	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	May	Namunyak	Shoats	0	0	0	0	3	3	0	0	0	0	0	0	10	0	10	10	3
2013	May	Namunyak	Cattle	0	0	0	3	6	9	0	0	0	1	0	1	2	0	2	6	6
2013	May	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	May	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	May	Westgate	Shoats	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	1	1
2013	May	Westgate	Cattle	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	1	2
2013	May	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	May	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	May	Meibae	Shoats	0	0	0	0	0	0	2	0	2	0	0	0	9	0	9	11	0
2013	May	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	May	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	May	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	May	Ltungai	Shoats	0	0	0	7	0	7	0	0	0	0	0	0	0	0	0	7	0

2013	May	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	May	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	May	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	June	Namunyak	Shoats	0	0	0	5	15	20	0	0	0	0	0	0	7	0	7	12	15	27
2013	June	Namunyak	Cattle	0	0	0	1	2	3	0	0	0	0	0	0	0	0	0	1	2	3
2013	June	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	June	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	June	Westgate	Shoats	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
2013	June	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	June	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	June	Westgate	Camel	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2013	June	Meibae	Shoats	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2013	June	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	June	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	June	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	June	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	June	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	June	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	June	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	July	Namunyak	Shoats	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	4	4
2013	July	Namunyak	Cattle	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2013	July	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	July	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	July	Westgate	Shoats	0	4	4	2	4	6	9	17	26	0	0	0	0	0	0	11	25	36
2013	July	Westgate	Cattle	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
2013	July	Westgate	Donkey	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	2	2	2
2013	July	Westgate	Camel	0	0	0	0	2	2	0	1	1	0	0	0	0	0	0	3	3	3
2013	July	Meibae	Shoats	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2013	July	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	July	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2013	July	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	July	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	July	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	July	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	July	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	August	Namunyak	Shoats	0	0	0	7	96	103	0	0	0	2	0	2	0	0	0	9	96	105
2013	August	Namunyak	Cattle	7	3	10	0	0	0	0	0	0	0	0	0	0	0	0	7	3	10
2013	August	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	August	Namunyak	Camel	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2013	August	Westgate	Shoats	0	0	0	11	3	14	2	6	8	1	0	1	0	0	0	14	9	23
2013	August	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	August	Westgate	Donkey	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
2013	August	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	August	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	August	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	August	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	August	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	August	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
2013	August	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	August	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	August	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	September	Namunyak	Shoats	0	0	0	7	0	7	0	0	0	0	0	0	0	0	0	7	0	7
2013	September	Namunyak	Cattle	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3
2013	September	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	September	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	September	Westgate	Shoats	0	0	0	7	3	10	0	0	0	2	0	2	0	0	0	9	3	12
2013	September	Westgate	Cattle	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
2013	September	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	September	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	September	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	37	0	37	37	0

2013	September	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	September	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	September	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	September	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	September	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	September	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	September	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	October	Namunyak	Shoats	0	0	0	12	1	13	0	6	6	0	0	0	0	0	0	12	7	19
2013	October	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	October	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	October	Namunyak	Camel	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2013	October	Westgate	Shoats	0	0	0	3	13	16	0	6	6	0	0	0	4	0	4	7	19	26
2013	October	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	October	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	October	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	October	Meibae	Shoats	0	0	0	0	0	0	0	1	1	0	0	0	36	0	36	36	1	37
2013	October	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	October	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	October	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	October	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	October	Ltungai	Cattle	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
2013	October	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	October	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	November	Namunyak	Shoats	0	0	0	6	0	6	0	0	0	0	0	0	0	0	0	6	0	6
2013	November	Namunyak	Cattle	1	0	1	2	0	2	0	0	0	0	0	0	0	0	0	3	0	3
2013	November	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	November	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	November	Westgate	Shoats	0	0	0	2	12	14	0	19	19	0	0	0	0	0	0	2	31	33
2013	November	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	November	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2013	November	Westgate	Camel	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	2	2
2013	November	Meibae	Shoats	1	0	1	0	0	0	0	0	0	3	0	3	26	0	26	30	30
2013	November	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	November	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	November	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	November	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	November	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	November	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	November	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	December	Namunyak	Shoats	0	0	0	0	6	6	0	0	0	0	0	0	0	0	0	6	6
2013	December	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	December	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	December	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	December	Westgate	Shoats	0	0	0	1	1	2	2	5	7	2	0	2	0	0	0	5	11
2013	December	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	December	Westgate	Donkey	1	0	1	0	0	1	1	2	0	0	0	0	0	0	0	2	3
2013	December	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	December	Meibae	Shoats	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	1
2013	December	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	December	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	December	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	December	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	1
2013	December	Ltungai	Cattle	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	2
2013	December	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	December	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	January	Namunyak	Shoats	0	0	0	2	16	18	0	0	0	0	0	0	0	0	2	16	18
2014	January	Namunyak	Cattle	0	0	0	1	0	1	0	0	0	1	0	1	0	0	2	0	2
2014	January	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	January	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	January	Westgate	Shoats	0	0	0	2	1	3	4	0	4	1	0	1	0	0	0	7	8

2014	January	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	January	Westgate	Donkey	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2014	January	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	January	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	15	0	15	15	0	15
2014	January	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	January	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	January	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	January	Ltungai	Shoats	0	0	0	7	0	7	0	4	4	0	0	0	0	0	0	7	4	11
2014	January	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	January	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	January	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	February	Namunyak	Shoats	0	0	0	0	2	2	0	0	0	1	0	1	0	0	0	1	2	3
2014	February	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	February	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	February	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	February	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	February	Westgate	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2014	February	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	February	Westgate	Camel	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2	2
2014	February	Meibae	Shoats	0	0	0	2	0	2	0	0	0	4	0	4	22	0	22	28	0	28
2014	February	Meibae	Cattle	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
2014	February	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	February	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	February	Ltungai	Shoats	0	0	0	0	0	0	0	0	8	0	8	0	0	0	8	0	8	8
2014	February	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	February	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	February	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	March	Namunyak	Shoats	0	0	0	8	2	10	0	5	5	0	0	0	0	0	8	7	15	15
2014	March	Namunyak	Cattle	2	0	2	1	0	1	0	0	0	0	0	0	0	0	3	0	3	3
2014	March	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2014	March	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	March	Westgate	Shoats	0	0	0	4	0	4	0	0	0	0	0	0	0	0	0	4	0	4
2014	March	Westgate	Cattle	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2014	March	Westgate	Donkey	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2014	March	Westgate	Camel	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2014	March	Meibae	Shoats	0	0	0	6	103	109	0	0	0	1	0	1	0	0	0	7	103	110
2014	March	Meibae	Cattle	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2014	March	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	March	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	March	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	2	0	2
2014	March	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	March	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	March	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	April	Namunyak	Shoats	0	0	0	3	1	4	0	3	3	1	0	1	2	0	2	6	4	10
2014	April	Namunyak	Cattle	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
2014	April	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	April	Namunyak	Camel	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2014	April	Westgate	Shoats	0	0	0	0	0	0	5	0	5	0	0	0	0	0	0	5	0	5
2014	April	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	April	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	April	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	April	Meibae	Shoats	0	0	0	4	1	5	0	0	0	0	0	0	10	0	10	14	1	15
2014	April	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	April	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	April	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	April	Ltungai	Shoats	1	0	1	11	0	11	0	20	20	0	0	0	1	0	1	13	20	33
2014	April	Ltungai	Cattle	1	0	1	2	0	2	0	0	0	0	0	0	0	0	0	3	0	3
2014	April	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	April	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	May	Namunyak	Shoats	0	0	0	6	0	6	0	0	0	4	0	4	3	0	3	13	0	13

2014	May	Namunyak	Cattle	1	0	1	2	0	2	0	0	0	0	0	0	0	0	0	3	0	3
2014	May	Namunyak	Donkey	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2014	May	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	May	Westgate	Shoats	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	2	2
2014	May	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	May	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	May	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	May	Meibae	Shoats	0	0	0	5	0	5	0	0	0	0	0	0	0	0	0	5	0	5
2014	May	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	May	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	May	Meibae	Camel	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2014	May	Ltungai	Shoats	2	0	2	0	7	7	0	7	7	0	0	0	4	0	4	6	14	20
2014	May	Ltungai	Cattle	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
2014	May	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	May	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	June	Namunyak	Shoats	0	0	0	8	0	8	0	0	0	2	0	2	0	0	0	10	0	10
2014	June	Namunyak	Cattle	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	2	0	2
2014	June	Namunyak	Donkey	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2014	June	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	June	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	June	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	June	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	June	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	June	Meibae	Shoats	0	0	0	1	1	2	0	0	0	9	0	9	22	0	22	32	1	33
2014	June	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	June	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	June	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	June	Ltungai	Shoats	0	0	0	1	4	5	0	0	0	0	0	0	0	0	0	1	4	5
2014	June	Ltungai	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2014	June	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2014	June	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	July	Namunyak	Shoats	0	0	0	1	0	1	0	27	27	1	0	1	0	0	0	2	27	29
2014	July	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	July	Namunyak	Donkey	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2014	July	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	July	Westgate	Shoats	0	0	0	4	0	4	2	2	4	0	0	0	0	0	0	6	2	8
2014	July	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	July	Westgate	Donkey	0	0	0	0	0	0	2	1	3	0	0	0	0	0	0	2	1	3
2014	July	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	July	Meibae	Shoats	0	0	0	1	14	15	0	3	3	0	0	0	0	0	0	1	17	18
2014	July	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	July	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	July	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	July	Ltungai	Shoats	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	3	3
2014	July	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	July	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	July	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	August	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	August	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	August	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	August	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	August	Westgate	Shoats	0	0	0	12	0	12	0	20	20	1	0	1	0	0	0	13	20	33
2014	August	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	August	Westgate	Donkey	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2014	August	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	August	Meibae	Shoats	0	0	0	5	0	5	0	5	5	6	0	6	29	0	29	40	5	45
2014	August	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	August	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	August	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	August	Ltungai	Shoats	0	0	0	1	0	1	0	27	27	0	0	0	0	0	0	1	27	28

2014	August	Ltungai	Cattle	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
2014	August	Ltungai	Donkey	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2014	August	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	September	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	September	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	September	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	September	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	September	Westgate	Shoats	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2014	September	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	September	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	September	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	September	Meibae	Shoats	0	0	0	0	16	16	0	7	7	0	0	0	25	0	25	25	23	48
2014	September	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	September	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	September	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	September	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
2014	September	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	September	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	September	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	October	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	October	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	October	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	October	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	October	Westgate	Shoats	0	0	0	2	2	4	0	1	1	0	0	0	0	0	0	2	3	5
2014	October	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	October	Westgate	Donkey	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2	2
2014	October	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	October	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	October	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	October	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2014	October	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2014	October	Ltungai	Shoats	0	0	0	3	12	15	0	58	58	0	0	0	0	0	0	3	70	73
2014	October	Ltungai	Cattle	0	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7
2014	October	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	October	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	November	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	November	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	November	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	November	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	November	Westgate	Shoats	0	0	0	5	8	13	0	0	0	2	0	2	0	0	0	7	8	15
2014	November	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	November	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	November	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	November	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	November	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	November	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	November	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	November	Ltungai	Shoats	0	0	0	5	6	11	0	7	7	0	0	0	0	0	0	5	13	18
2014	November	Ltungai	Cattle	0	3	3	0	0	0	0	3	3	0	0	0	0	0	0	0	6	6
2014	November	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	November	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	December	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	December	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	December	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	December	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	December	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	December	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	December	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	December	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	December	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2014	December	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	December	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	December	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	December	Ltungai	Shoats	0	0	0	0	22	22	0	10	10	0	0	0	0	0	0	0	32	32
2014	December	Ltungai	Cattle	2	1	3	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3
2014	December	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	December	Ltungai	Camel	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2015	January	Namunyak	Shoats	0	0	0	3	3	6	0	0	0	0	0	0	0	0	0	3	3	6
2015	January	Namunyak	Cattle	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2015	January	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	January	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	January	Westgate	Shoats	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	1	1	2
2015	January	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	January	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	January	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	January	Meibae	Shoats	0	0	0	1	0	1	0	0	0	2	0	2	9	0	9	12	0	12
2015	January	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	January	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	January	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	January	Ltungai	Shoats	0	0	0	0	7	7	0	3	3	0	0	0	0	0	0	0	10	10
2015	January	Ltungai	Cattle	2	0	2	4	0	4	0	7	7	0	0	0	0	0	0	6	7	13
2015	January	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	January	Ltungai	Camel	2	0	2	4	0	4	0	0	0	0	0	0	0	0	0	6	0	6
2015	February	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4	4	0	4
2015	February	Namunyak	Cattle	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	2	0	2
2015	February	Namunyak	Donkey	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	2	0	2
2015	February	Namunyak	Camel	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2	2
2015	February	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	February	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	February	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2015	February	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	February	Meibae	Shoats	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2015	February	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	February	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	February	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	February	Ltungai	Shoats	2	0	2	1	0	1	0	2	2	0	0	0	7	0	7	10	2	12
2015	February	Ltungai	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2015	February	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	February	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	March	Namunyak	Shoats	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	2	0	2
2015	March	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	March	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	March	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	March	Westgate	Shoats	0	0	0	7	0	7	1	0	1	0	0	0	0	0	0	8	0	8
2015	March	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	March	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	March	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	March	Meibae	Shoats	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
2015	March	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	March	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	March	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	March	Ltungai	Shoats	0	0	0	0	4	4	0	18	18	0	0	0	0	0	0	0	22	22
2015	March	Ltungai	Cattle	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
2015	March	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	March	Ltungai	Camel	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
2015	April	Namunyak	Shoats	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	2	0	2
2015	April	Namunyak	Cattle	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
2015	April	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	April	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	April	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	22	0	22	22	0	22

2015	April	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	April	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	April	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	April	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	April	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	April	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	April	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	April	Ltungai	Shoats	0	0	0	13	0	13	11	0	11	0	0	0	0	0	0	24	0	24
2015	April	Ltungai	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2015	April	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	April	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	May	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	May	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	May	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	May	Namunyak	Camel	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2015	May	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	May	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	May	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	May	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	May	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	May	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	May	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	May	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	May	Ltungai	Shoats	0	0	0	0	0	0	0	37	37	0	0	0	4	0	4	4	37	41
2015	May	Ltungai	Cattle	2	4	6	0	0	0	0	0	0	0	0	0	0	0	0	2	4	6
2015	May	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	May	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	June	Namunyak	Shoats	0	0	0	0	1	1	0	0	0	0	0	0	1	0	1	1	1	2
2015	June	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	June	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2015	June	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	June	Westgate	Shoats	0	0	0	1	0	1	0	1	1	0	0	0	12	0	12	13	1	14
2015	June	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	June	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	June	Westgate	Camel	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2015	June	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	June	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	June	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	June	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	June	Ltungai	Shoats	0	0	0	0	5	5	5	0	5	0	0	0	0	0	0	5	5	10
2015	June	Ltungai	Cattle	2	1	3	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3
2015	June	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	June	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	July	Namunyak	Shoats	0	0	0	13	0	13	0	0	0	0	0	0	0	0	0	13	0	13
2015	July	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	July	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	July	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	July	Westgate	Shoats	0	0	0	2	11	13	0	4	4	4	0	4	0	0	0	6	15	21
2015	July	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	July	Westgate	Donkey	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	3	3
2015	July	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	July	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	July	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	July	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	July	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	July	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	July	Ltungai	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2015	July	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	July	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	August	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2015	August	Namunyak	Cattle	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	1	1	2
2015	August	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	August	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	August	Westgate	Shoats	0	0	0	2	5	7	0	0	0	0	0	0	8	0	8	10	5	15
2015	August	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	August	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	August	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	August	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	August	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	August	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	August	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	August	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	August	Ltungai	Cattle	1	3	4	0	0	0	0	0	0	0	0	0	0	0	0	1	3	4
2015	August	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	August	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	September	Namunyak	Shoats	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	3	0	3
2015	September	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	September	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	September	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	September	Westgate	Shoats	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	2	0	2
2015	September	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	September	Westgate	Donkey	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	1	1	2
2015	September	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	September	Meibae	Shoats	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
2015	September	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	September	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	September	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	September	Ltungai	Shoats	0	0	0	0	2	2	0	7	7	0	0	0	0	0	0	0	9	9
2015	September	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	September	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2015	September	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	October	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	3	0	3
2015	October	Namunyak	Cattle	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	3	0	3
2015	October	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	October	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	October	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	18	0	18	18	0	18
2015	October	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	October	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	October	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	October	Meibae	Shoats	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
2015	October	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	October	Meibae	Donkey	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2015	October	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	October	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	October	Ltungai	Cattle	3	2	5	0	0	0	0	0	0	0	0	0	0	0	0	3	2	5
2015	October	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	October	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	November	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	November	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	November	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	November	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	November	Westgate	Shoats	0	0	0	1	0	1	2	0	2	1	0	1	0	0	0	4	0	4
2015	November	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	November	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	November	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	November	Meibae	Shoats	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
2015	November	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	November	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	November	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	November	Ltungai	Shoats	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	4	4

2015	November	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	November	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	November	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	December	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	December	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	December	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	December	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	December	Westgate	Shoats	0	0	0	1	2	3	0	0	0	0	0	0	0	0	0	1	2	3
2015	December	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	December	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	December	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	December	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	December	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	December	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	December	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	December	Ltungai	Shoats	0	0	0	0	4	4	0	10	10	0	0	0	0	0	0	14	14	14
2015	December	Ltungai	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
2015	December	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	December	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	January	Namunyak	Shoats	0	0	0	2	3	5	0	0	0	0	0	0	0	0	2	3	5	5
2016	January	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	January	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	January	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	January	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	January	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	January	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	January	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	January	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	January	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	January	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2016	January	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	January	Ltungai	Shoats	0	0	0	0	0	0	13	28	41	0	0	0	0	0	0	13	28	41
2016	January	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	January	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	January	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Ltungai	Shoats	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	3	3
2016	February	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	February	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	March	Namunyak	Shoats	0	0	0	0	15	15	0	0	0	0	0	0	0	0	0	15	15	15
2016	March	Namunyak	Cattle	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2016	March	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	March	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	March	Westgate	Shoats	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
2016	March	Westgate	Cattle	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	2	2	2
2016	March	Westgate	Donkey	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
2016	March	Westgate	Camel	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1
2016	March	Meibae	Shoats	0	0	0	7	0	7	0	0	0	0	0	0	0	0	0	7	0	7

2016	March	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	March	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	March	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	March	Ltungai	Shoats	0	0	0	0	0	0	12	41	53	1	0	1	0	0	0	13	41	54
2016	March	Ltungai	Cattle	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
2016	March	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	March	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	April	Namunyak	Shoats	0	0	0	2	2	4	0	0	0	0	0	0	0	0	0	2	2	4
2016	April	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	April	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	April	Namunyak	Camel	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2016	April	Westgate	Shoats	0	0	0	0	2	2	0	1	1	0	0	0	0	0	0	0	3	3
2016	April	Westgate	Cattle	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	2	2
2016	April	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	April	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	April	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	April	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	April	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	April	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	April	Ltungai	Shoats	0	0	0	0	3	3	0	9	9	1	0	1	0	0	0	1	12	13
2016	April	Ltungai	Cattle	3	0	3	0	1	1	0	0	0	0	0	0	0	0	0	3	1	4
2016	April	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	April	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	May	Namunyak	Shoats	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	2	2
2016	May	Namunyak	Cattle	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
2016	May	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	May	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	May	Westgate	Shoats	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2	2
2016	May	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	May	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2016	May	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	May	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	May	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	May	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	May	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	May	Ltungai	Shoats	0	0	0	0	0	0	11	24	35	0	0	0	0	0	0	11	24	35
2016	May	Ltungai	Cattle	1	1	2	0	0	0	0	1	1	0	0	0	0	0	0	1	2	3
2016	May	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	May	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Namunyak	Shoats	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
2016	June	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	June	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	July	Namunyak	Shoats	0	0	0	0	0	0	0	9	9	0	0	0	0	0	0	0	9	9
2016	July	Namunyak	Cattle	0	0	0	1	1	2	2	0	2	0	0	0	0	0	0	3	1	4
2016	July	Namunyak	Donkey	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
2016	July	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	July	Westgate	Shoats	0	0	0	5	1	6	0	0	0	3	0	3	0	0	0	8	1	9

2016	July	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	July	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	July	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	July	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	July	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	July	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	July	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	July	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	July	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	July	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	July	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	August	Namunyak	Shoats	0	0	0	6	0	6	19	2	21	0	0	0	3	0	3	28	2	30
2016	August	Namunyak	Cattle	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2016	August	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	August	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	August	Westgate	Shoats	0	0	0	5	3	8	0	2	2	2	0	2	18	0	18	25	5	30
2016	August	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	August	Westgate	Donkey	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2016	August	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	August	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	August	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	August	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	August	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	August	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	August	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	August	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	August	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	September	Namunyak	Shoats	0	0	0	5	0	5	0	0	0	0	0	0	0	0	0	5	0	5
2016	September	Namunyak	Cattle	4	2	6	0	0	0	0	0	0	0	0	0	0	0	0	4	2	6
2016	September	Namunyak	Donkey	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1

2016	September	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	September	Westgate	Shoats	0	0	0	6	0	6	10	2	12	0	0	0	0	0	0	16	2	18
2016	September	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	September	Westgate	Donkey	2	0	2	0	0	0	2	1	3	0	0	0	0	0	0	4	1	5
2016	September	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	September	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	September	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	September	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	September	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	September	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	September	Ltungai	Cattle	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
2016	September	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	September	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Westgate	Shoats	0	0	0	5	4	9	7	5	12	9	0	9	0	0	0	21	9	30
2016	October	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Ltungai	Cattle	1	2	3	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3
2016	October	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	October	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	November	Namunyak	Shoats	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	2	0	2

2016	November	Namunyak	Cattle	0	3	3	0	1	1	0	0	0	0	0	0	0	0	0	0	4	4
2016	November	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	November	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	November	Westgate	Shoats	0	0	0	0	0	0	1	0	1	1	0	1	3	0	3	5	0	5
2016	November	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	November	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	November	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	November	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	November	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	November	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	November	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	November	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	November	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	November	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	November	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	December	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	December	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	December	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	December	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	December	Westgate	Shoats	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	1	1	2
2016	December	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	December	Westgate	Donkey	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	2	0	2
2016	December	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	December	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	December	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	December	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	December	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	December	Ltungai	Shoats	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2	2
2016	December	Ltungai	Cattle	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2016	December	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2016	December	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Westgate	Shoats	0	0	0	4	0	4	0	0	0	0	0	0	0	0	0	4	0	4
2017	January	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Meibae	Shoats	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
2017	January	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	January	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	February	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	10	0	10
2017	February	Namunyak	Cattle	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3
2017	February	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	February	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	February	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	February	Westgate	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2017	February	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	February	Westgate	Camel	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
2017	February	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	February	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	February	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	February	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	February	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2017	February	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	February	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	February	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Meibae	Shoats	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
2017	March	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Ltungai	Shoats	0	0	0	0	0	0	0	19	19	0	0	0	0	0	0	0	19	19
2017	March	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	March	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	April	Namunyak	Shoats	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2017	April	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	April	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	April	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	April	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	April	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	April	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	April	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	April	Meibae	Shoats	0	0	0	5	0	5	0	0	0	1	0	1	0	0	0	6	0	6
2017	April	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	April	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2017	April	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	April	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	April	Ltungai	Cattle	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2017	April	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	April	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Westgate	Shoats	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
2017	May	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Meibae	Shoats	0	0	0	3	0	3	0	0	0	1	0	1	0	0	0	4	0	4
2017	May	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	May	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	June	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	June	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	June	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	June	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	June	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	June	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	June	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	June	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	June	Meibae	Shoats	9	0	9	0	0	0	0	0	0	1	0	1	0	0	0	10	0	10

2017	June	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	June	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	June	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	June	Ltungai	Shoats	17	0	17	0	0	0	0	0	0	0	0	0	0	0	0	17	0	17
2017	June	Ltungai	Cattle	1	4	5	0	0	0	0	0	0	0	0	0	0	0	0	1	4	5
2017	June	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	June	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Westgate	Shoats	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	3	0	3
2017	July	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Meibae	Shoats	0	0	0	0	0	0	1	0	1	0	0	0	12	0	12	13	0	13
2017	July	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	July	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	August	Namunyak	Shoats	0	0	0	0	0	0	37	8	45	0	0	0	0	0	0	37	8	45
2017	August	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	August	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	August	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	August	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	August	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	August	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2017	August	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	August	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	9	0	9	9	0	9
2017	August	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	August	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	August	Meibae	Camel	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2017	August	Ltungai	Shoats	0	11	11	0	0	0	0	0	0	0	0	0	0	0	0	0	11	11
2017	August	Ltungai	Cattle	5	2	7	0	0	0	0	0	0	0	0	0	0	0	0	5	2	7
2017	August	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	August	Ltungai	Camel	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2017	September	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	September	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	September	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	September	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	September	Westgate	Shoats	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
2017	September	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	September	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	September	Westgate	Camel	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2017	September	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	September	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	September	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	September	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	September	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	September	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	September	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	September	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	October	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	October	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	October	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	October	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	October	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2017	October	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	October	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	October	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	October	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	October	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	October	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	October	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	October	Ltungai	Shoats	10	25	35	0	0	0	0	0	0	0	0	0	0	0	0	10	25	35
2017	October	Ltungai	Cattle	5	4	9	0	0	0	0	0	0	0	0	0	0	0	0	5	4	9
2017	October	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	October	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Westgate	Shoats	0	0	0	1	0	1	0	7	7	1	0	1	0	0	0	2	7	9
2017	November	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Meibae	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	November	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	December	Namunyak	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	December	Namunyak	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	December	Namunyak	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2017	December	Namunyak	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	December	Westgate	Shoats	0	0	0	0	0	0	0	2	2	1	0	1	0	0	0	1	2	3
2017	December	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	December	Westgate	Donkey	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1
2017	December	Westgate	Camel	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
2017	December	Meibae	Shoats	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
2017	December	Meibae	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	December	Meibae	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	December	Meibae	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	December	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	December	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	December	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	December	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	January	Namunyak	Shoats																		
2018	January	Namunyak	Cattle																		
2018	January	Namunyak	Donkey																		
2018	January	Namunyak	Camel																		
2018	January	Westgate	Shoats	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0	2	0	2
2018	January	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	January	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	January	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	January	Meibae	Shoats										1	0	1				1	0	1
2018	January	Meibae	Cattle																		
2018	January	Meibae	Donkey																		
2018	January	Meibae	Camel																		
2018	January	Ltungai	Shoats	5	12	17	0	0	0	0	0	0	0	0	0	0	0	0	5	12	17
2018	January	Ltungai	Cattle	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
2018	January	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	January	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	February	Namunyak	Shoats																		

2018	February	Namunyak	Cattle																		
2018	February	Namunyak	Donkey																		
2018	February	Namunyak	Camel																		
2018	February	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	February	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	February	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	February	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	February	Meibae	Shoats																		
2018	February	Meibae	Cattle																		
2018	February	Meibae	Donkey																		
2018	February	Meibae	Camel																		
2018	February	Ltungai	Shoats	0	5	5	2	0	2	0	0	0	0	0	0	0	0	0	2	5	7
2018	February	Ltungai	Cattle	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
2018	February	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	February	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	March	Namunyak	Shoats																		
2018	March	Namunyak	Cattle																		
2018	March	Namunyak	Donkey																		
2018	March	Namunyak	Camel																		
2018	March	Westgate	Shoats	0	0	0	2	2	4	0	1	1	0	0	0	5	0	5	7	3	10
2018	March	Westgate	Cattle	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	4	4
2018	March	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	March	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	March	Meibae	Shoats																		
2018	March	Meibae	Cattle																		
2018	March	Meibae	Donkey																		
2018	March	Meibae	Camel																		
2018	March	Ltungai	Shoats	1	1	2	0	0	0	1	8	9	0	0	0	0	0	0	2	9	11
2018	March	Ltungai	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2018	March	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2018	March	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	April	Namunyak	Shoats																		
2018	April	Namunyak	Cattle																		
2018	April	Namunyak	Donkey																		
2018	April	Namunyak	Camel																		
2018	April	Westgate	Shoats	0	0	0	1	0	1	5	8	13	0	0	0	0	0	0	6	8	14
2018	April	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
2018	April	Westgate	Donkey	1	0	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	2
2018	April	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	April	Meibae	Shoats																		
2018	April	Meibae	Cattle																		
2018	April	Meibae	Donkey																		
2018	April	Meibae	Camel																		
2018	April	Ltungai	Shoats	0	1	1	0	0	0	2	0	2	0	0	0	0	0	0	2	1	3
2018	April	Ltungai	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2018	April	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	April	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	May	Namunyak	Shoats																		
2018	May	Namunyak	Cattle																		
2018	May	Namunyak	Donkey																		
2018	May	Namunyak	Camel																		
2018	May	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	May	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	May	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	May	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	May	Meibae	Shoats																		
2018	May	Meibae	Cattle																		
2018	May	Meibae	Donkey																		
2018	May	Meibae	Camel																		
2018	May	Ltungai	Shoats	4	20	24	0	0	0	1	0	1	0	0	0	0	0	0	5	20	25




2018	May	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	May	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	May	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	June	Namunyak	Shoats																		
2018	June	Namunyak	Cattle																		
2018	June	Namunyak	Donkey																		
2018	June	Namunyak	Camel																		
2018	June	Westgate	Shoats	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2018	June	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	June	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	June	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	June	Meibae	Shoats																		
2018	June	Meibae	Cattle																		
2018	June	Meibae	Donkey																		
2018	June	Meibae	Camel																		
2018	June	Ltungai	Shoats	7	0	7	0	1	1	0	1	1	0	0	0	0	0	0	7	2	9
2018	June	Ltungai	Cattle	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2018	June	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	June	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	July	Namunyak	Shoats																		
2018	July	Namunyak	Cattle																		
2018	July	Namunyak	Donkey																		
2018	July	Namunyak	Camel																		
2018	July	Westgate	Shoats	0	0	0	5	0	5	2	0	2	0	0	0	0	0	0	7	0	7
2018	July	Westgate	Cattle	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	1	1	2
2018	July	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	July	Westgate	Camel	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
2018	July	Meibae	Shoats																		
2018	July	Meibae	Cattle																		
2018	July	Meibae	Donkey																		




2018	July	Meibae	Camel																		
2018	July	Ltungai	Shoats	2	27	29	0	1	1	1	29	30	0	0	0	0	0	0	3	57	60
2018	July	Ltungai	Cattle	1	3	4	0	0	0	0	0	0	0	0	0	0	0	0	1	3	4
2018	July	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	July	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	August	Namunyak	Shoats																		
2018	August	Namunyak	Cattle																		
2018	August	Namunyak	Donkey																		
2018	August	Namunyak	Camel																		
2018	August	Westgate	Shoats	0	0	0	5	0	5	7	0	7	0	0	0	0	0	0	12	0	12
2018	August	Westgate	Cattle	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	1	1	2
2018	August	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	August	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	August	Meibae	Shoats																		
2018	August	Meibae	Cattle																		
2018	August	Meibae	Donkey																		
2018	August	Meibae	Camel																		
2018	August	Ltungai	Shoats	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
2018	August	Ltungai	Cattle	1	2	3	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3
2018	August	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	August	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	September	Namunyak	Shoats																		
2018	September	Namunyak	Cattle																		
2018	September	Namunyak	Donkey																		
2018	September	Namunyak	Camel																		
2018	September	Westgate	Shoats	0	0	0	8	0	8	5	2	7	3	0	3	0	0	0	16	2	18
2018	September	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	September	Westgate	Donkey	0	0	0	0	0	0	2	1	3	0	0	0	0	0	0	2	1	3
2018	September	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	September	Meibae	Shoats																		

2018	September	Meibae	Cattle																	
2018	September	Meibae	Donkey																	
2018	September	Meibae	Camel																	
2018	September	Ltungai	Shoats	3	3	6	0	0	0	0	0	0	0	0	0	0	0	3	3	6
2018	September	Ltungai	Cattle	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2018	September	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	September	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	October	Namunyak	Shoats																	
2018	October	Namunyak	Cattle																	
2018	October	Namunyak	Donkey																	
2018	October	Namunyak	Camel																	
2018	October	Westgate	Shoats	0	0	0	4	3	7	1	5	6	3	0	3	0	0	0	8	16
2018	October	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	October	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	October	Westgate	Camel	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1
2018	October	Meibae	Shoats																	
2018	October	Meibae	Cattle																	
2018	October	Meibae	Donkey																	
2018	October	Meibae	Camel																	
2018	October	Ltungai	Shoats	0	0	0	1	0	1	0	25	25	0	0	0	0	0	1	25	26
2018	October	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	October	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	October	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	November	Namunyak	Shoats																	
2018	November	Namunyak	Cattle																	
2018	November	Namunyak	Donkey																	
2018	November	Namunyak	Camel																	
2018	November	Westgate	Shoats	0	0	0	1	0	1	57	4	61	1	0	1	3	0	3	62	66
2018	November	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	November	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2018	November	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	November	Meibae	Shoats																		
2018	November	Meibae	Cattle																		
2018	November	Meibae	Donkey																		
2018	November	Meibae	Camel																		
2018	November	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	November	Ltungai	Cattle	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2018	November	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	November	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	December	Namunyak	Shoats																		
2018	December	Namunyak	Cattle																		
2018	December	Namunyak	Donkey																		
2018	December	Namunyak	Camel																		
2018	December	Westgate	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	December	Westgate	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	December	Westgate	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	December	Westgate	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	December	Meibae	Shoats																		
2018	December	Meibae	Cattle																		
2018	December	Meibae	Donkey																		
2018	December	Meibae	Camel																		
2018	December	Ltungai	Shoats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	December	Ltungai	Cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	December	Ltungai	Donkey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	December	Ltungai	Camel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

*Appendix XI. Comparative carnivore scat samples from the Samburu National Reserve showing the typical morphology types for each species.*

<b>carnivore species</b>	<b>scat sample</b>	<b>morphology</b>	<b>surface colour</b>	<b>content(s)</b>
lion		cylindrical	greenish black	fibrous with prey skeletal bone fragment(s)
leopard		cylindrical	greenish black	fibrous with prey skeletal bone fragment(s)
spotted hyaena		cylindrical	dirty white	fibrous with prey skeletal bone part(s) and fragment(s)

carnivore species	scat sample	morphology	surface colour	content(s)
lion		undefined	greenish black	fibrous
leopard		undefined	greenish black	fibrous
spotted hyaena		undefined	chalk white	fibrous with prey bone fragment(s)

Appendix XII. Carnivore species scat fragment height vs maximum scat fragment width.

