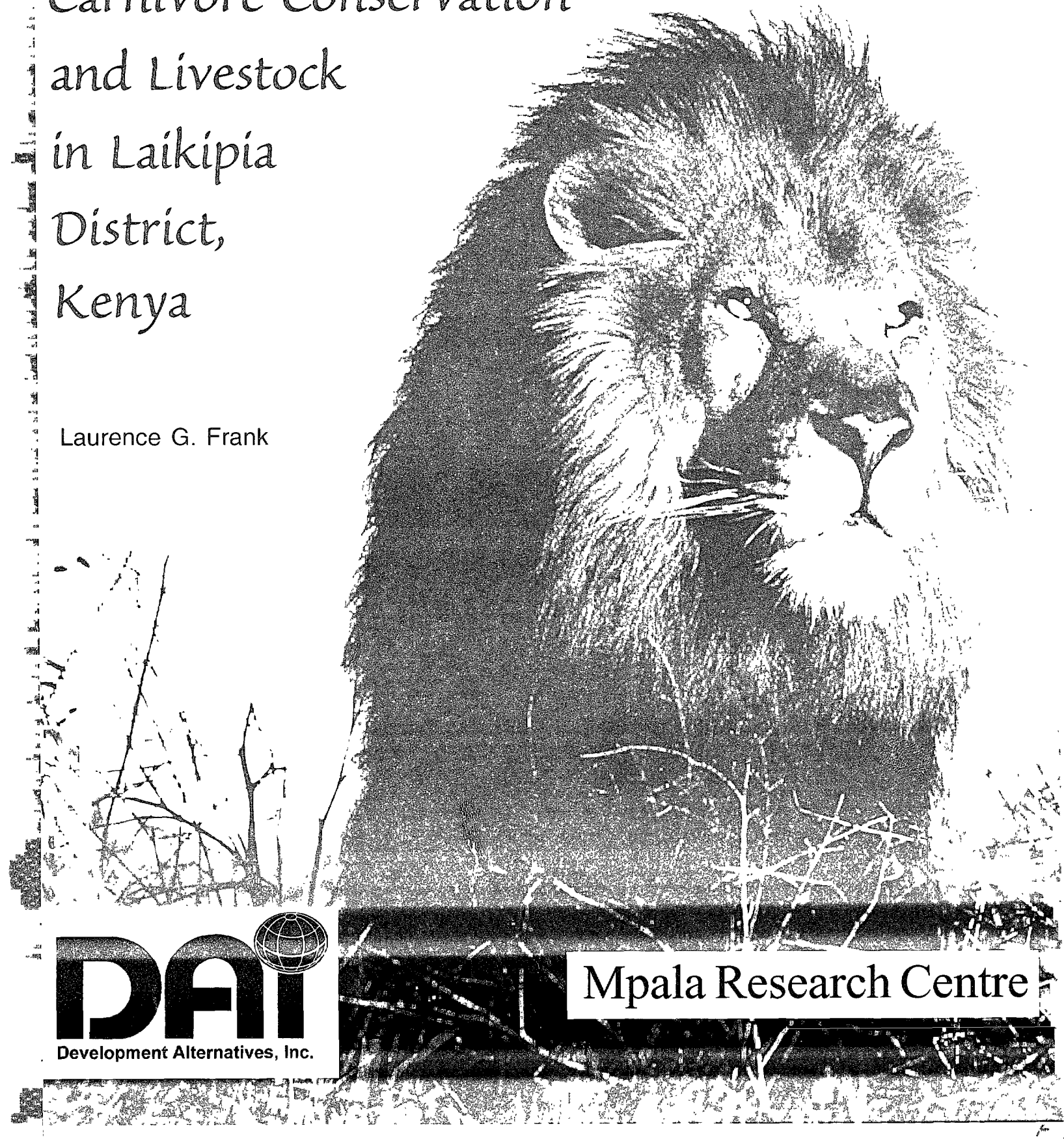
LIVING WITH LIONS

Carnivore Conservation and Livestock in Laikipia District, Kenya

Laurence G. Frank



DAI
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Mpala Research Centre

LIVING WITH LIONS:

CARNIVORE CONSERVATION AND LIVESTOCK IN LAIKIPIA DISTRICT, KENYA

Laurence G. Frank

February 1998

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This survey would have been impossible without the enthusiastic cooperation of Laikipia's residents, particularly the members of the Laikipia Wildlife Forum. Dozens of individuals spent many hours answering endless questions and offering their abundant knowledge of Laikipia, ranching, and carnivores. I am very grateful for their generous help.

This survey grew out of discussions between Mr. Paul DeLucco, chief of party of the Conservation of Biodiverse Resource Areas (COBRA) Project associated with the Kenya Wildlife Service (KWS), and Dr. Nicholas Georgiadis, director of the Mpala Research Centre in central Laikipia. They recognized the ecological, economic, and social importance of large predators in the district and the complete lack of information on them. Through Mr. DeLucco's efforts, Development Alternatives, Inc., hired the author to conduct this survey. Mr. DeLucco and the entire DAI staff were extremely helpful throughout.

Dr. Georgiadis made the author welcome at the Mpala Research Centre, and his extensive contacts throughout the district made conducting this work possible. He also contributed essential data on herbivore counts.

The United States Agency for International Development, which funds the COBRA project, paid the costs of this work.

Dr. Georgiadis, Mr. DeLucco, Dr. Dan Rubenstein, Dr. Joanna Elliot, and Dr. David Leonard made helpful comments on an earlier version of the manuscript.

FOREWORD

No landowner in Africa has a neutral attitude toward the roar of a lion, the whoop of a hyena, or the sawing cough of a leopard. These sounds can signal unaffordable losses from predation on livestock, or arouse a deep satisfaction that primal forces endure on the land. The balance of landowners' attitudes toward large wild carnivores determines the animals' fate in the world's unprotected areas, and history shows that the balance has been overwhelmingly against them. Where humans not only share the landscape with wildlife but must also make a living, the wolf, the tiger, the jaguar, and the wild dog have typically dwindled to extinction.

These are all species that require much more space than humans have been prepared to cede. Yet attitudes do change, with the result, for example, that wolves and jaguars are currently expanding their ranges into parts of the United States where they have not been seen for tens, even hundreds, of years.

Large carnivores persist in the Laikipia District of central Kenya, a vast and unprotected area that has historically been used for livestock production but is increasingly being used for tourism and other wildlife-related enterprises. Clearly, these land uses are fundamentally opposed.

What are the prevailing attitudes toward large carnivores in Laikipia? What is their status, their impact, and their future? These are some of the first issues concerning humans and wildlife to be addressed at the district level in Laikipia by the Mpala Research Centre. In seeking someone qualified to find answers to these questions, the Centre saw Dr. Laurence Frank as an obvious first choice. His extensive and distinguished research on wild carnivores in Africa speaks for itself.

At the time of the Centre's search, Dr. Frank was concluding a 20-year hyena project in the Masai Mara, and he was intrigued by the prospect of including humans and their livelihood in the equation of his research. His ultimate goal, to devise better methods for conserving and controlling large carnivores in unprotected areas, is far easier defined than achieved. With this report, Dr. Frank has taken an important first step toward achieving that goal by conducting a thorough appraisal of local landowners' attitudes about carnivores on their property, as well as a survey of their opinions about animal numbers, population trends, impact, and control.

In many ways, conservation is more demanding in unprotected areas than in parks and reserves; a laissez-faire management policy clearly is not an option. Rather, management must be active, interventional, based on accurate information, sensitive to changing conditions, and, above all, approved by the community. In this case, we need to know how best to conduct a census of lions and hyenas in Laikipia, monitor their numbers over time, and judge when populations are in danger. What are their space requirements? What are the most efficient trapping, darting, and, when necessary, killing methods? How can we minimize their predation on livestock?

With recent changes in Kenya's strategic approach to conservation that have devolved wildlife management authority to landowners, these are all issues with which landowners must not only become familiar, but well versed and actively engaged. For some of the above questions, answers are available from experience elsewhere, but many queries will be unique to the area, and all answers must be made available to landowners locally.

This report, combining results of a three-hour grilling that each survey respondent agreed to endure, is testimony to the depth of Laikipia landowners' commitment to, and knowledge of, carnivores in particular and wildlife in general. They know better than anyone that if carnivores are to maintain their role in the economy of nature, they must "pay their way" in the local economy. Such resolve among

landowners with a common interest in ecosystem conservation is exemplary and is the reason Laikipia offers the best opportunity in Kenya to learn these lessons. The ultimate products of this initiative, however, will not be confined to Laikipia, but will be relevant to vast areas of unprotected Africa where the persistence of wild carnivores is very much in question.

I would like to thank all who participated in this report, especially the Conservation of Biodiverse Resource Areas (COBRA) Project at the Kenya Wildlife Service (KWS), which paid for the study. Funded by USAID and implemented by Development Alternatives, Inc., COBRA is assisting KWS in developing strategies for conserving wildlife outside of protected areas. I would also like to extend special thanks to Paul DeLucco (COBRA chief of party) for such prompt action and good advice, and to Gilfrid Powys, chairman, and the directors of the Laikipia Wildlife Forum for their support and enthusiasm.

Nicholas Georgiadis, Director, Mpala Research Centre

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EXECUTIVE SUMMARY

Large carnivores are among the most fascinating of animals as well as being among the most problematic. They hold great appeal for many people, and their presence is virtually essential for ecotourism and sport hunting in Africa. However, they inevitably come into conflict with humans by killing livestock and occasionally people, as well. Outside of protected areas, large carnivores have been eliminated from most of the world inhabited by humans. In Africa, however, there still remains a real possibility of evolving "peaceful coexistence" between predators, livestock, and humans by refining the traditional methods of livestock management that African pastoralists have developed over millennia.

Laikipia District is one of the most important wildlife areas remaining in Kenya. This report summarizes current knowledge about large carnivores (lions, spotted and striped hyenas, leopards, cheetahs, and jackals) in Laikipia based on a survey of local residents undertaken in February and March 1997. The survey comprised nearly 800 questions about large-carnivore biology, predation upon livestock, and ranching economics.

Abundance

All the large carnivores still occur, and some species are of economic significance because of their depredation upon livestock. It is very difficult to count predators, because of their nocturnal habits and aversion to humans. Because only intensive research over time can produce accurate numbers, the estimates given here are very rough. Based on ranchers' estimates, currently there are approximately 175 lions, 580 spotted hyenas, 350 leopards, and 80 cheetahs in Laikipia. Striped hyenas are widespread but uncommon in the district, and wild dogs are effectively extinct. The lion and cheetah estimates are likely to be high, as these animals move very widely and are probably counted on more than one ranch.

Sustainability

These population estimates and data on the number of predators killed annually strongly suggest that human-caused mortality for both lions (at least 20 percent) and spotted hyenas (14 percent) is higher than these populations can tolerate. Leopards appear to be common and suffer little human-caused mortality. Ranchers tend to agree that most predator populations have been relatively stable in recent years; if population estimates are at all accurate, the known mortality rate suggests that the Laikipia lion population is maintained by immigration from outside the district. As female spotted hyenas essentially do not emigrate and 14-percent mortality would not be supportable, the actual population is probably higher than estimated.

Loss of Human Life

No cases of human death by carnivores in the past decade were reported on any of the properties or group ranches that supplied data. Although carnivores inspire fear and respect, they are not a significant threat to human life in Laikipia.

Costs of Predation upon Livestock

Predation accounts for about 17 percent of the total cost of keeping sheep and cattle on the large commercial ranches of the district, with lions being the most important predator. However, the costs of disease and stock theft are much higher. Further, much of the cost of predation is attributable to the labor

costs of herders and security men. Because these would still be needed even were large predators absent, the real cost of predation is only the actual value of stock killed. That figure amounts to about 6 percent of the cost of producing cattle and 10 percent of the cost of producing sheep.

If population estimates are accurate, each lion on a large ranch costs about US$360, each spotted hyena about US$35, each leopard about US$211, and each cheetah about US$108. Predation patterns vary widely, however; one ranch may suffer very little predation and rarely kill predators, whereas a neighbor may incur high losses despite regularly eliminating problem predators. To some extent, these discrepancies are probably the result of differences in behavior among individual predators or groups, but livestock husbandry methods appear to have a major impact on the severity of predation. Of course, were predator control nonexistent, depredation losses would rise significantly, as predators would eventually lose their fear of humans and livestock.

Pastoralists suffer predation rates similar to those of ranchers, but more data are needed before exact figures can be cited. The most striking difference between large-scale ranchers and pastoralists is that the latter suffer almost no losses to spotted hyenas. As hyenas take largely strays, this suggests that pastoralists are more diligent when herding their own stock than when working as herders on commercial ranches.

Small-scale farmers keep relatively few livestock, and there are few large predators in arable areas. Only leopard predation upon small stock is a significant problem for most small-scale farmers, although in some areas hyenas take both cattle and shoats.

Reducing Predation

Different predators have very different depredation behavior: lions typically stampede cattle from bomas at night, while hyenas largely take animals left out overnight. Ranchers are able to reduce losses significantly by building "lion-proof bomas" and by motivating herders to be more diligent about rounding up strays at night. Neither approach is expensive.

Sport Hunting

There is considerable interest in the possibility of sport hunting in Laikipia, an activity for which lions and leopards could be quite lucrative. In fact, both tourism and sport hunting would probably earn more money for Laikipia landowners than livestock production. Sport hunting could be combined with problem-animal control, resulting in no net increase in lions killed over current levels. However, we know little about managing either lions or leopards for sustained-yield sport hunting, and there are strong indications that trophy hunting of males may have potentially deleterious effects on reproduction at the population level. This concern is particularly acute in a relatively small area such as Laikipia. Hunting thus would have to be managed very carefully, but as yet there are no data upon which to base management decisions.

Recommendations

If large carnivores are to persist indefinitely, we need better methods to reduce livestock losses while minimizing the killing of problem predators. The most promising solutions lie in refining existing methods of livestock management. These would include building low-cost lion-proof bomas that would be practical and affordable for pastoralist communities as well as commercial ranches, and refining herding methods to reduce losses of strays to hyenas. Also worth testing would be the efficacy of using

herding dogs to decrease strays. Training wild carnivores to avoid livestock through proper application of conditioned taste aversion also needs to be tested.

If carnivores are to be managed in Laikipia, either for preservation, ecotourism, or sport hunting, a great deal of empirical data will be needed. Acquiring the data will require a multiyear study, starting with the basic population ecology of the major carnivore species in Laikipia. Such population data would be used to construct mathematical models of different management options. Equally important, different approaches to minimizing depredation must be rigorously tested. Because any long-term management must be dynamic in responding to ecological changes, we also need practical population assessment techniques that Kenya Wildlife Service technicians could use annually to monitor population trends.

CHAPTER ONE

INTRODUCTION

Large carnivores occupy a central position in the human psyche. They are among the most dramatic, interesting, and appealing of animals. They are also the most problematic. The great cats, the great bears, the wolf, and the hyena preyed on mankind long before we were human. The nameless terrors of a child's nightmares are the deep manifestations of the predators that were a constant threat until very recent history. As our ancestors emerged from the African forests, we became scavengers, competing with the predators for their kills. As we became hunters in our own right, we learned to protect our kills from the carnivores, which in turn scavenged from us. As we tamed wild game and became herders, the competition between predators and mankind took on a new form, as they found our livestock to be easy prey. Only other men rivaled the great carnivores as threats to our lives and livelihoods. For all of these excellent reasons, humans have a strong tendency to perceive the predators as evil and threatening. For millennia, there was little we could do about them, but with the development of efficient poison, traps, and firearms, we have eliminated large carnivores from most of the earth's surface.

These animals also hold great appeal and fascination for many people; witness the central role of carnivores in the folklore of most cultures. Their combination of grace, beauty, and power is unparalleled in nature. Several species share with us the characteristics of complex social systems and high intelligence; the wolf is so like us that we have made it "man's best friend." Millions of people readily spend large sums of money to see wild carnivores in nature: tourism is Kenya's primary source of income, and the opportunity of seeing lions, leopards, and cheetahs is the main attraction for most foreign visitors. For many people, the world would be an impoverished place without carnivores.

Only in eastern and southern Africa are there still significant numbers of large carnivores living in populated areas. We know very little about the conservation status of carnivores outside protected areas, but it is clear that ever-increasing numbers of humans and livestock are causing carnivore populations to shrink rapidly.

CONSERVATION EFFORTS IN AFRICA

Community conservation has become the central tenet for much of conservation in Africa. Wildlife can only persist if local human populations benefit economically by preserving both habitat and animal populations. Much of Africa is too dry to be arable, and in these areas tourism and commercial hunting will prove to be the most lucrative local enterprises compatible with nature preservation. An area's ability to attract tourists and hunters is greatly increased if large carnivores are present in reasonable numbers. However, residents of arid lands depend heavily on their livestock, and for them the presence of carnivores poses a constant liability. Thus, where carnivores are present, local people must be able to realize significant income from tourism or hunting to counterbalance livestock losses from depredation.

If wildlife conservation is to be compatible with livestock husbandry, we must develop techniques to minimize carnivore depredation upon livestock, especially from lions, leopards, and spotted hyenas. Over the millennia, pastoral peoples in Africa have developed sophisticated husbandry methods to reduce depredation from carnivores, but there has been remarkably little modern scientific research conducted that seeks to improve these time-honored practices (for an exception, see Kruuk, 1981). Firearms and poison have been the West's main solutions to the problem of large-carnivore depredation; we urgently need a more sophisticated approach.

Kenya's Laikipia District offers a remarkable opportunity in which to refine livestock husbandry methods in an effort to minimize livestock losses while conserving viable populations of large carnivores. Roughly a million acres (400,000 hectares) of semi-arid bush, Laikipia is a remarkably intact ecosystem, with nearly all native species of large mammals still occurring in good numbers. Livestock production is the foundation of the economy in most of the district. Only in the areas immediately north of Mount Kenya is there sufficient rain to allow productive agriculture. All of Laikipia is privately owned, with roughly 70 percent of the land in the form of large ranches and the rest divided between communally owned pastoral lands and settlement schemes of smallholders raising crops. In the latter areas, wildlife has become scarce, but most species are still found in good numbers in the pastoral and ranching areas.

LAIKIPIA DISTRICT

The Ecosystem

Because of its relatively low rainfall (600 to 800 millimeters annually), high daytime temperatures, and poor soils, most of Laikipia District is semi-arid bushland dominated by *Acacia* spp. interspersed with grassland dominated by *Themeda* and *Digitaria*. The montane areas, which are not included in this report, are covered by forest or moorland. Rivers and wetland margins support typical eastern African riverine vegetation dominated by *Acacia xanthophloea* and associated smaller trees.

Wildlife is diverse and abundant in Laikipia, and all native large mammals still occur in the district. Wild ungulates, including elephants and giraffes, are common, and black rhinos occur in several well-protected preserves. The most abundant ungulates are Burchell's and Grevy zebras, buffaloes, impalas, elands, kongoni, Thompson's and Grant's gazelles, and dik-diks.

The People

Prior to colonization, the district was inhabited primarily by Masai and Samburu pastoralists. After human and livestock numbers were decimated by warfare and the rinderpest epidemic of 1898, pastoralists were largely moved out of Laikipia to southern Narok District, making way for European-owned ranches. After Kenya's independence in 1963, some Europeans left, and their properties reverted either to communal group ranches owned by pastoralists or government-sponsored settlement schemes for small-scale agriculture.

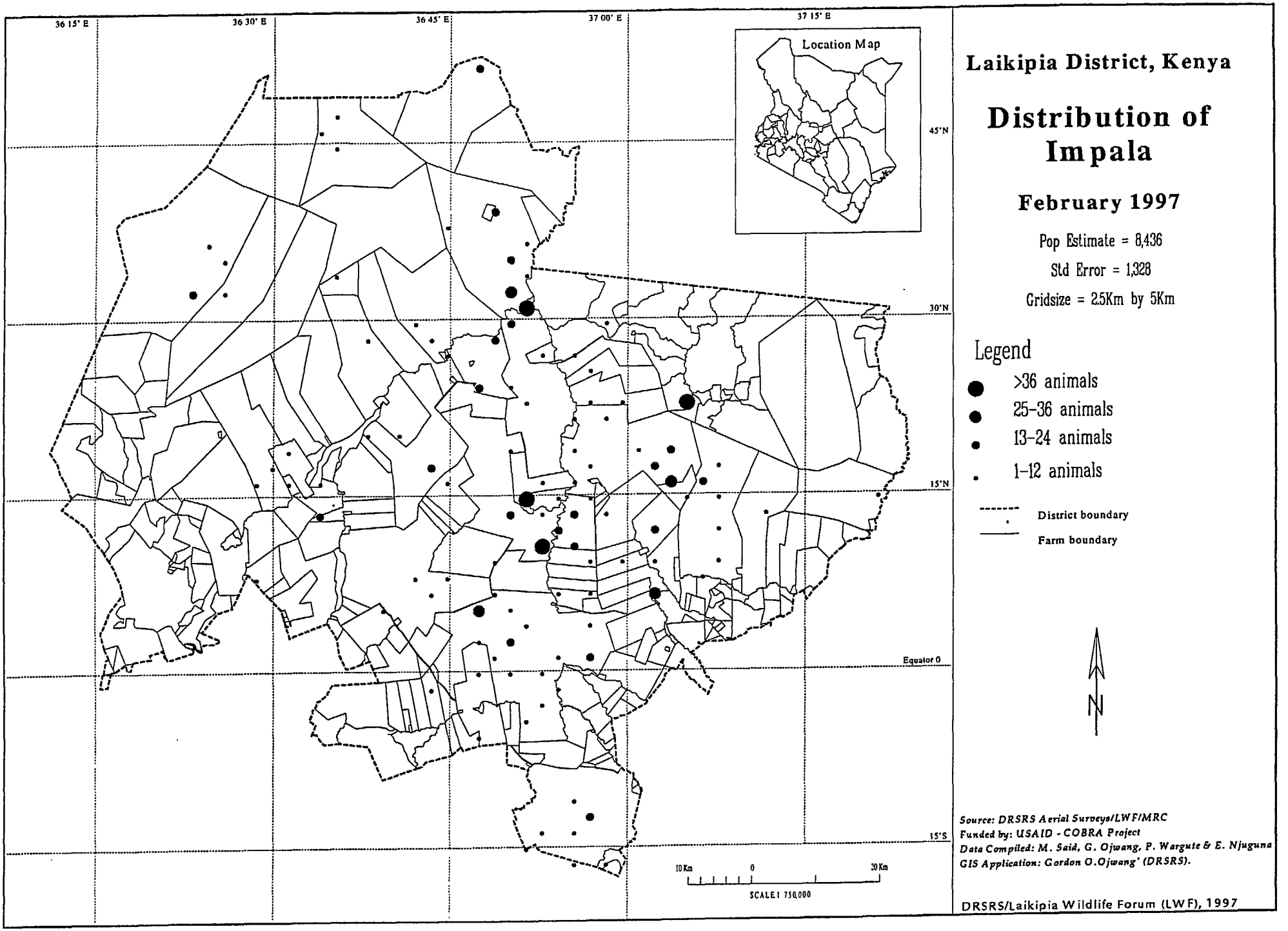
Today, Laikipia's population is very heterogeneous. The group ranches comprise native Wanderobo-Masai and Samburu people, while the settlement schemes are largely Bantu people who have immigrated into the district from elsewhere in Kenya. Some of the large private ranches are African owned, but most are owned either by descendants of the original settlers or by wealthy foreigners. Employees on these ranches comprise Masai, Samburu, Turkana, and Pokot people as well as members of other pastoral tribes of northern Kenya.

The Economy

Commercial agriculture and livestock, in the form of both commercial ranching and traditional pastoralism, constitute the economic bases of Laikipia, but ecotourism is becoming increasingly important. In the southern part of the district, commercial and subsistence cultivation have increased greatly in recent decades.

Types of Ranches

Most of Laikipia's ranches depend wholly or heavily on income from livestock operations. On some, however, tourism is challenging livestock in importance, and a few ranches are being devoted solely to wildlife and tourism. Several large properties are managed largely as wildlife preserves and are independent of livestock income. It is thus difficult to compare economic measures between ranches, as the preserve ranches receive large subsidies from their owners or donations for wildlife conservation. For example, security expenditures on rhino preserves may be much greater than on comparably sized areas used strictly for cattle. Similarly, these very well funded operations are able to spend more money than their cattle-ranch counterparts on every other management aspect as well, including veterinary care and infrastructure.


36 15' E
36 30' E
36 45' E
37 00' E
37 15' E
Location Map
45'N
30'N
15'N
Equator 0
15'S
10Km
0
30Km
SCALE1 750,000
Laikipia District, Kenya
Distribution of Impala
February 1997
Pop Estimate = 8,436
Std Error = 1,328
Gridsize = 2.5Km by 5Km
Legend
>36 animals
25-36 animals
13-24 animals
1-12 animals
District boundary
Farm boundary
N
Source: DRSRS Aerial Surveys/LWF/MRC
Funded by: USAID - COBRA Project
Data Compiled: M. Said, G. Ojwang, P. Wargute & E. Njuguna
GIS Application: Gordon O.Ojwang' (DRSRS).
DRSRS/Laikipia Wildlife Forum (LWF), 1997

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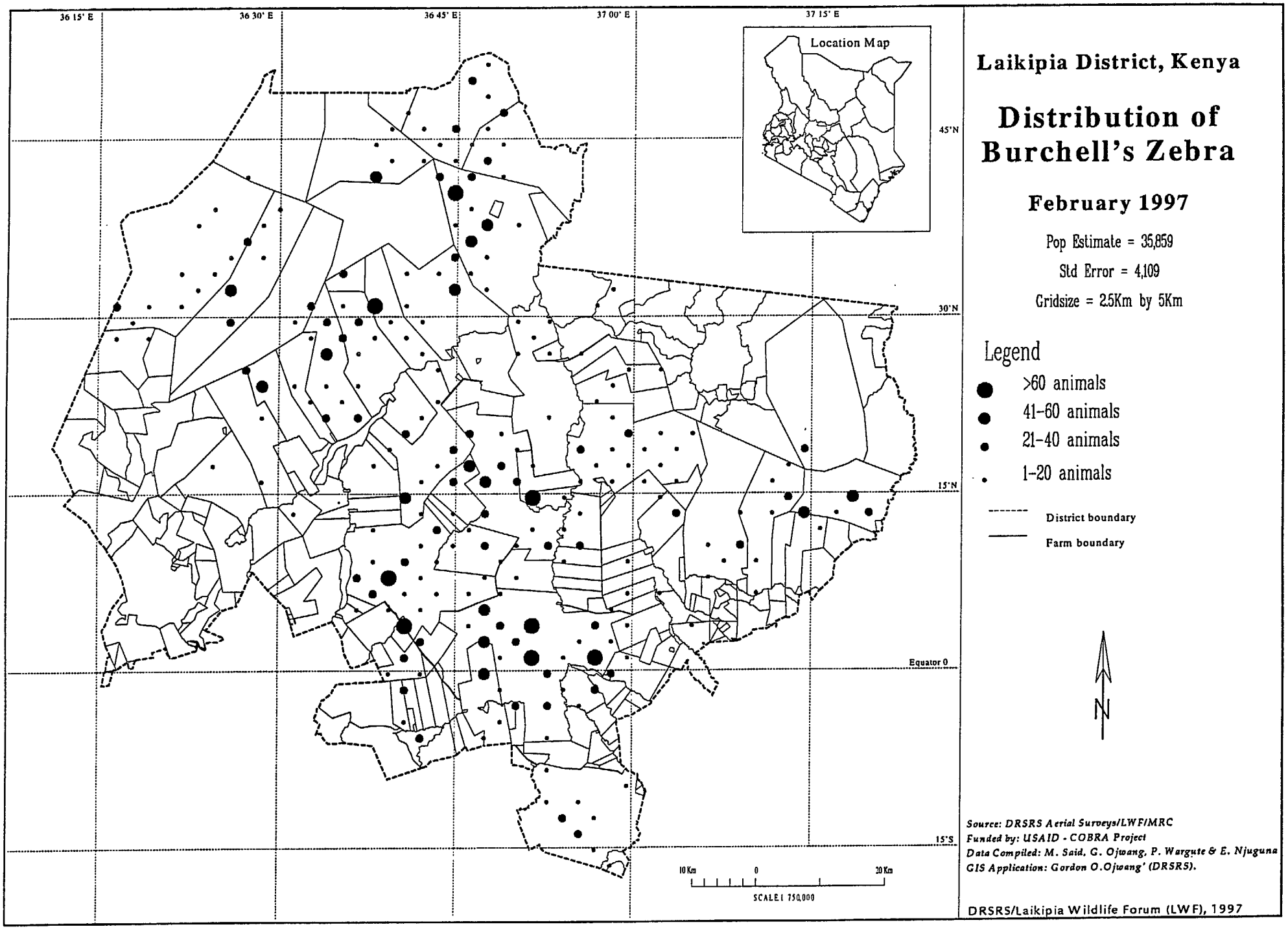

Laikipia District, Kenya

Distribution of Burchell's Zebra

February 1997

Pop Estimate = 35,859

Std Error = 4,109

Gridsize = 2.5Km by 5Km

Legend

- >60 animals
- 41-60 animals
- 21-40 animals
- 1-20 animals
- District boundary
- Farm boundary

N

Source: DRSRS Aerial Surveys/LWF/MRC
Funded by: USAID - COBRA Project
Data Compiled: M. Said, G. Ojwang, P. Wargute & E. Njuguna
GIS Application: Gordon O.Ojwang' (DRSRS).

DRSRS/Laikipia Wildlife Forum (LWF), 1997

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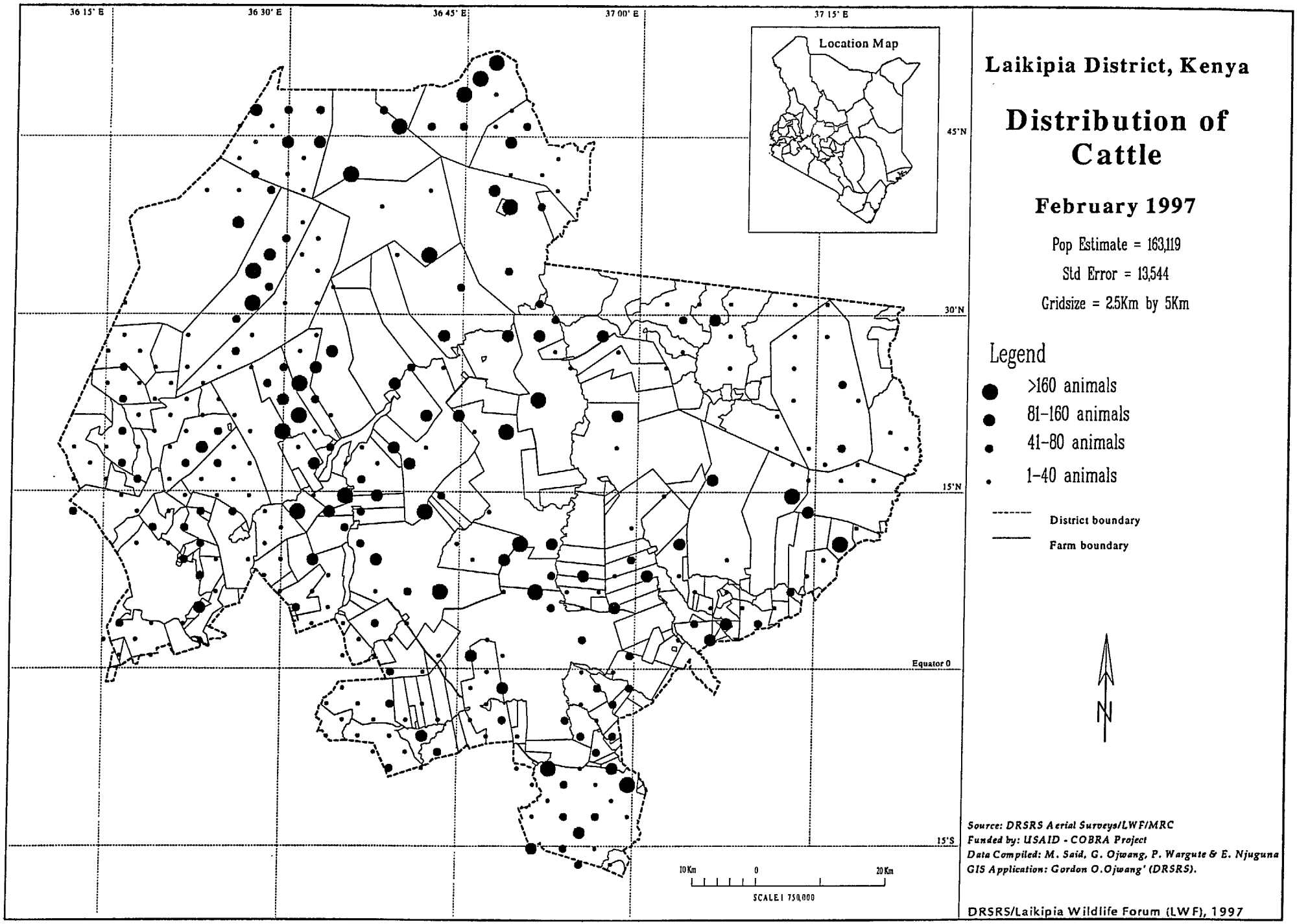

Laikipia District, Kenya

Distribution of Cattle

February 1997

Pop Estimate = 163,119

Std Error = 13,544

Gridsize = 2.5Km by 5Km

Legend

- >160 animals
- 81–160 animals
- 41–80 animals
- 1–40 animals
- District boundary
- Farm boundary

N

Source: DRSRS Aerial Surveys/LWF/MRC
Funded by: USAID - COBRA Project
Data Compiled: M. Said, G. Ojwang, P. Wargute & E. Njuguna
GIS Application: Gordon O.Ojwang' (DRSRS).

DRSRS/Laikipia Wildlife Forum (LWF), 1997

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CHAPTER TWO

SURVEY METHODOLOGY

The survey on which this report is based was undertaken in February and March 1997, during which the author spoke with as many district residents as possible, asking nearly 800 questions about carnivore biology, depredation upon livestock, and ranching economics (see annex for a copy of the questionnaire used). The survey concentrated on large landholders for three reasons:

(1) Because large ranches account for so much of the district's land area, most wildlife occurs on them.

(2) Wildlife generally and carnivores particularly are now uncommon in the intensively cultivated parts of the district. Given the small amount of time available, it seemed sensible to concentrate on those areas with the most wildlife.

(3) Because of stock theft, smallholders have few livestock.

Great distances and poor communications made it difficult to arrange interviews ahead of time, but the author was able to talk to the owner or manager of 14 large ranches as well as the Senior Chief of one group ranch and eight members of two group ranches. Additionally, a written questionnaire was mailed to 12 large ranches, the manager of an Agriculture Development Commission ranch, the chairmen of four settlement schemes, and the Senior Chiefs of three group ranches. Responses were received from seven of the large ranches, two of the group ranches, and two of the settlement schemes.

DATA COLLECTED

Research covered all carnivores that are of economic importance in Laikipia: lions, leopards, cheetahs, spotted hyenas, striped hyenas, and jackals. Wild dogs were essentially extirpated from Laikipia decades ago; although they are occasionally seen, virtually nothing is known about them. Small carnivores were not included in the study.

The author attempted to gather as much information as possible on both the biology of the carnivores and their role as problem animals. He also attempted to collect enough basic economic information on ranching in Laikipia to allow one to view the cost of carnivore predation in the overall context of the cost of raising livestock in this area.

The author promised complete anonymity to all respondents; names of individuals or ranches will not be made available. In each interview, the author gathered data covering eight species of carnivores (lions, leopards, cheetahs, spotted and striped hyenas, and three species of jackals) and six types of livestock (cattle, sheep, goats, camels, horses, and donkeys). Topics covered included:

- Estimates of current numbers and five-year populations trends of each species of carnivore;
- Wildlife prey of predators;
- Number of problem predators killed each year;
- Number of livestock preyed upon for each species of stock each year;

- Type of individual predator responsible (male or female, adult or juvenile);
- Type of stock attacked (juvenile or adult);
- Common circumstances of attacks (day or night, inside or outside of bomas, in the presence or absence of herdsmen, and so on);
- Predator control measures taken;
- Economic impact of depredation (value of livestock lost and cost of herdsmen, bomas, and veterinary care of injured stock);
- Attacks on humans in the past 10 years;
- Attitudes toward predators; and
- The effects of potential tourism or sport hunting income on attitudes.

In addition, the author collected the following ecological and economic information for each property:

- Acreage of properties;
- Habitat types on each property (proportion of grassland, bush, riverine forest, and so on);
- Water availability (number of dams and boreholes, kilometers of permanent rivers and streams);
- Numbers of each type of livestock;
- Human population of property;
- Economic costs of disease and stock theft;
- Proportion of annual income derived from livestock, farming, game cropping, tourism, and other activities; and
- Whether these sources of income were likely to change in the next five years.

Lastly, all respondents were asked whether they would be willing to allow research on large carnivores on their property.

At the time of this writing, the author had collected data representing about 70 percent (278,874 hectares, or 689,100 acres) of Laikipia and perhaps 90 percent of the area that supports most of the district's wildlife. In virtually all cases, the author was able to obtain complete data on estimated carnivore numbers, losses of each species of livestock to each species of carnivore over the past two years, and estimates of major costs (such as herders' wages and veterinary costs for each livestock type). Costs in Kenya shillings were converted to U.S. dollars using the exchange rate of KSh 52 = US$, which was current at the time of the survey. In some cases, the author was unable to obtain complete information from all property owners. For purposes of analysis, therefore, it was sometimes necessary to estimate certain parameters for a few ranches, based on the average for the other surveyed ranches. For instance, the first few ranchers interviewed were not asked to break down herding costs in terms of antipredator

activities, antitheft activities, and animal care duties. Because estimates of such figures were used in several economic analyses, the author used the mean values from all other ranches in order to estimate the total expenditure on these ranches. In statistical terms, this procedure reduces the number of degrees of freedom in each analysis, increasing the variance for the measure in question. Overall conclusions, however, are not affected. Each section of the report includes descriptions of the calculations used, as well as the rationale for the procedure and possible pitfalls resulting from the methods, assumptions, or simplifications.

STATISTICAL CONSIDERATIONS

"There are lies, damn lies, and statistics." This folk wisdom expresses the concern that a clever manipulator can reinforce any point he wishes by picking and choosing among "facts" to support his views. However, scientists use statistics in a very different way, in an effort to look at data as objectively as possible. Because of the great variation within the natural world, biological data in general and ecological data in particular are never "clean." Different areas might differ greatly in the number of species they support, for example, or the lions on one ranch might be far more likely to kill cattle than the lions on a neighboring property. Similarly, one rancher might spend more on veterinary care for his livestock than another. This natural variation often makes it difficult to discern clear trends in data. For instance, if one weighs 20 cattle on each of two ranches and finds they differ in average weight, is that apparent difference real or just chance variation because of random differences between the two samples?

We refer to a "real" difference as being significant. By measuring the amount of variation in each sample and comparing it with standardized tables that account for the size of each sample, one can estimate the probability that the difference is significant, as compared with random variation. Thus, in the example above, a p (probability) value of 0.1 says there is a 10-percent chance the difference in average cattle weight is the result of random chance and a 90-percent chance it represents a real difference in weight on the two ranches.

Typically, biologists use a probability of .05 (1 in 20) as a satisfactory criterion that a result is significant. That means that in 20 similar comparisons, we are likely to find one set that appears significant when in actuality it is the result of random variation in the underlying data (of course, we are unlikely to know which one is in fact spurious). A more conservative approach would use a p value of .01, giving only 1 chance in 100 of making a mistake.

For this report, the author frequently used an analysis of variance procedure to analyze differences in particular measures across the properties sampled. In the graphs presented in subsequent sections, the vertical lines within the data bars express a measure of variation called the standard error. This is a useful statistic, because it allows a simple visual comparison between sets of data: If the standard error bars overlap, the data are probably not significantly different at a probability of .05 (see Figure 2). If they do not overlap, they are probably different (see Figure 10). An additional advantage of the standard error is that it comes close to expressing the range of variation within a given sample, comparable to showing minimum and maximum values for all properties surveyed.

In many cases, the standard error bars are very wide, indicating great variability among ranches in that measure. For instance, ranches that have a large tourism operation need to be able to show visitors lions. They must also tolerate a high level of lion depredation upon livestock. Other ranches (with or without many lions) may incur very few livestock losses. This variability results in an average with very wide error bars. Even a single property with an extreme value can have a large effect on error bars.

CHAPTER THREE

CARNIVORE BIOLOGY IN LAIKIPIA

All the major carnivores are reported to occur throughout the district in most habitat types. They are much less common in areas of small-scale farming than in the large-scale ranching and pastoral areas. In the absence of better data, it seems likely that the relatively low wildlife densities in some pastoral areas would suggest that predators are fewer there as well.

For each predator studied, the author asked the respondents to estimate the total number of each on their property, how this number compares with that of five years ago, how many predators the respondents would ideally like to have five years from now, and how many they would like to have were sport hunting permitted. (These data are presented in subsequent graphs as percentages, with the 1996 population equal to 100 percent. Past levels and five-year target levels are displayed relative to current levels.)

The author asked the respondents to name the three most important wildlife prey species killed by each predator species on their ranch. As predation rates could not be quantified, they are indicated in the relative order of importance in which they were mentioned.

Also obtained were data on the number of each predator killed in the past two years. Because most of these species disperse widely and opportunistically, and because we know nothing of their home range, some of the animals undoubtedly occur on several ranches at different times. Thus, they could be counted twice or more, thereby inflating population estimates and minimizing mortality estimates. Dispersal of juveniles also makes it unrealistic to calculate mortality on a per-ranch basis. Thus, the mortality calculations presented in Figure 1 are based on the sample-wide population estimate and must be viewed as absolute minimums.

LIONS

Numbers and Trends

Responses to the preliminary survey results suggest a total lion population of 157 on the properties sampled, or about 0.06 animals per square kilometer. This figure, however, represents a maximum, because it is impossible to say how many predators have been counted twice or more on neighboring ranches. Extrapolating this figure to the entire area of the district that is likely to support lions would yield approximately 175 individuals.

Although it is not possible to compare directly predator densities between ecosystems that vary greatly in prey availability, the estimate of 0.06 lions per square kilometer is low compared with well-studied populations. For instance, Serengeti supports 0.08 to 0.14 adult lions per square kilometer (Packer, 1990), and Kruger supports 0.10 adults per square kilometer (Mills, M.G.L., cited in Creel and Creel, 1997). The Selous supports 0.08 adults per square kilometer in a hunted area and 0.14 adults in an unhunted area (Creel and Creel, 1997). (In the latter case, the difference in density was thought to be a result of differing prey densities rather than hunting pressure.)

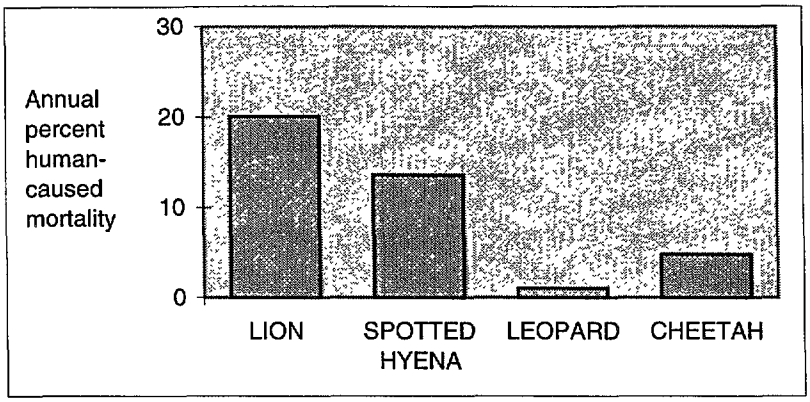

Figure 1. Estimated human-caused annual mortality rates of carnivores in Laikipia District, based on ranchers' population estimates and number reported as killed annually. Mortality rate estimates are based on very rough population estimates of unknown accuracy.

Overall, a slight reduction (12 percent) may have occurred in the district's lion population in the past five years, but the difference is not statistically significant; the population has probably been relatively stable (see Figure 2). Only one respondent would like to see a major decrease in lion numbers. All the rest are happy with the current levels or would like to see an increase, with the latter ranchers indicating they would like about 22 percent more lions in the district than currently exist. Interestingly, the prospect of income from sport hunting does not affect these figures.

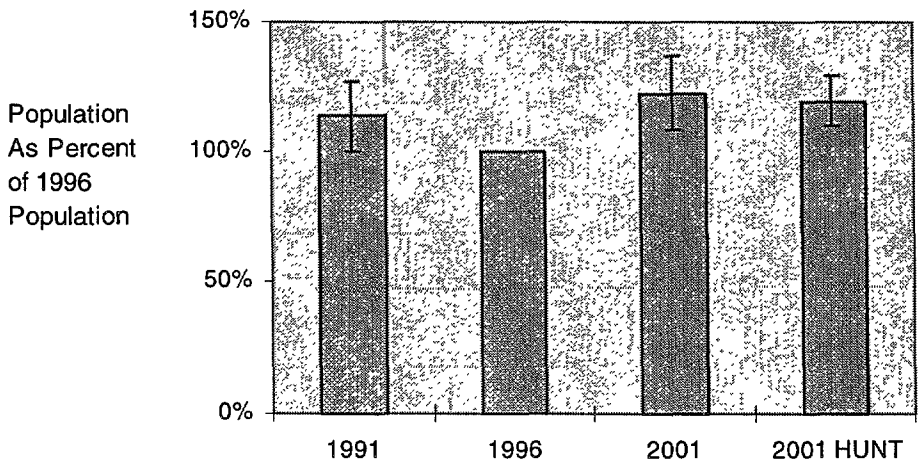

Figure 2. Population trends and target numbers for lions in Laikipia District, 1991-2001 (F =3.46, df = 3,52, p=.34).

Mortality

In 1995 and 1996, at least 63 lions were killed on the ranches surveyed, and the Kenya Wildlife Service (KWS) killed another 3 in 1996, for a mortality rate of 20 percent. This figure includes an average of at least 6.5 adult females and 12.5 adult males killed each year. Because the population estimate is probably high, this mortality rate should be taken as the minimum number killed; the actual rate is almost certainly higher. In the absence of disease epidemics, killing by humans is probably the only serious mortality factor among lions in this area.

Long-term Survival

Without data on lions' birth and survival rates in Laikipia and on their movements into the district from surrounding areas, it is currently not possible to assess the likelihood that this population will sustain its current rate of loss. However, data from a number of studies (Schaller, 1972; Smuts, 1978; and Packer and Pusey, 1983) suggest that young lions disperse widely from the prides in which they were born. As long as there are source populations outside the district, the Laikipia lion population is probably constantly being augmented from outside. However, severe mortality in neighboring areas would eliminate this source of replacement animals. Further, there is concern that a high mortality rate disrupts the lions' social system, with potentially serious effects on their reproductive rate.

In the unhunted Serengeti lion population, normal annual male mortality is 8 to 12 percent (Packer et al., 1988). The Selous lion population supports an annual hunting take of 2.7 to 4.3 percent of the adult male population plus natural mortality, a level that appears to be sustainable (Smuts, 1978; Starfield et al., 1981; and Venter and Hopkins, 1988). In contrast, the Laikipia mortality rate of at least 20 percent is clearly not sustainable. The fact that survey respondents consider the population to be stable strongly suggests that immigration from outside Laikipia compensates for high human-caused mortality within the district.

Prey

The most frequently mentioned prey for lions in the district were zebras and elands, followed distantly by buffaloes, warthogs, and kongoni. As zebras represent the greatest biomass of potential wild prey, lions appear to take wildlife prey more or less in relation to their abundance. Given that cattle and sheep represent by far the greatest number of available prey, most lions clearly avoid killing them.

Livestock Depredation

Male and female lions appear equally likely to attack livestock, with juveniles contributing only about 10 percent. About 86 percent of the lions that are killed are shot after livestock predation; the remainder are trapped. Virtually no one has a policy of shooting on sight, and very few respondents said they use poison. Many people said they had used poison previously but assured the author that although they themselves no longer use it, many other ranchers do. All in all, ranchers tolerate a certain amount of stock predation by lions before taking action (see sections on livestock).

SPOTTED HYENAS

Numbers and Trends

The survey yielded an estimated spotted hyena population of 521 animals; extrapolating to the entire district yields an estimate of about 580. However, it is extremely difficult to estimate hyena numbers, as the animals are nocturnal, secretive, and look alike.

All respondents emphasized that their hyena estimates were pure guesswork. (Interestingly, regardless of the size of the property or intensity of control efforts, most people tended to estimate a spotted hyena population of about 25.) Thus, because hyena numbers are so difficult to estimate, the figures presented can be given little credence. In the absence of intensive research and an extensive survey, then, the district's spotted hyena population will remain essentially unknown.

Laikipia residents feel that spotted hyena numbers have decreased 10 percent over the past five years (see Figure 3); however, respondents' estimates varied widely, and that figure is not statistically significant. Hence, the population has probably been quite stable. Nonetheless, the district still has 35 percent more spotted hyenas than most residents would like. No respondents want more spotted hyenas, and some would be happiest with none at all.

This latter point seems to reflect cultural attitudes rather than economics. Lions, for example, have a much greater impact on livestock and cost the rancher a great deal more than spotted hyenas. Moreover, it is clear that losses to hyenas are almost entirely preventable through diligent herding, as they take almost exclusively strays. Thus, the bias against hyenas appears to be based on emotional rather than economic factors; the widespread admiration of lions contrasts dramatically with the equally widespread dislike of hyenas.

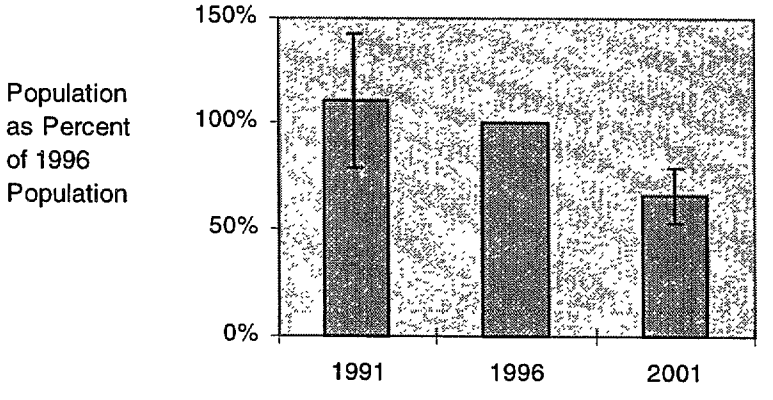

Figure 3. Population trends and target numbers for spotted hyenas in Laikipia District, 1991-2001 (F= 1.47, df = 2,31, p=.25).

Mortality

Spotted hyenas sustain human-caused mortality of at least 71 animals per year (13.6 percent) on the ranches surveyed in Laikipia. Because there can be no realistic estimate of actual population size, however, it is impossible to estimate an annual percentage take from control measures. In areas without human intervention, lions are the main cause of hyena deaths (Frank et al., 1995), and they are likely to be an important factor in Laikipia, as well. Additionally, based on personal observations, road kill mortality is probably considerable.

Long-term Survival

Given the lack of data on Laikipia's spotted hyena population, it is impossible to say whether the animals can sustain the current rate of killing. Nonetheless, there is reason for concern, because, unlike lions, spotted hyenas do not readily disperse from the area in which they were born. A hyena group only grows from births within its ranks, not from immigration. Both controlled studies (Smuts, 1978) and anecdotal accounts from many areas demonstrate that hyenas are very slow to recolonize areas from which they have been eradicated. Even when hyenas are wiped out of rather small areas (such as Nairobi National Park), with intact source populations nearby, the very conservative nature of females usually prevents them from recolonizing for many generations.

The aversion to recolonization is likely to be even more pronounced when the source populations themselves are suffering severe mortality. In one case in which hyenas were observed to recolonize rapidly a newly created habitat "vacuum," a previous group had been eradicated by poisoning, and the low-ranking members of the neighboring clan moved into the newly available area. This occurred because of a high density and the resulting intense feeding competition among the source clan (Holekamp et al., 1993). In contrast, in Laikipia, where widespread hyena control has resulted in a low population density, rapid recolonization after a clan depopulates is unlikely.

If total elimination of a local hyena population is the goal, the unlikelihood of recolonization could be an advantage, as wiping out a population once is likely to lead to very long-term absence of hyenas. Several ranchers interviewed mentioned this effect, alluding to drastic control measures taken decades ago that continue to result in low numbers of spotted hyenas.

Prey

Most respondents regard the spotted hyena as purely a scavenger, though others mentioned a variety of ungulate prey, particularly zebras. It is nearly certain that Laikipia spotted hyenas hunt more than residents realize. In fact, Kruuk (1972) found that spotted hyenas are primarily active predators, and no subsequent study anywhere in Africa has found scavenging to be a primary source of prey. There simply are very few carcasses lying around waiting to be scavenged.

The perception of spotted hyenas as scavengers seems to result from traditional "lore" and the fact that they hunt at night, when humans are unlikely to see them, and tend to eat an entire carcass without leaving remains. Additionally, lions frequently steal kills from hyenas at night; upon finding the carcasses in the morning, people assume lions made the kill.

Livestock Depredation

Only adult hyenas are thought to present a risk to livestock. About 49 percent of hyenas killed are shot in response to specific depredation events, and another 24 percent are trapped at bomas. About 14 percent die as a result of a "shoot on sight" policy or occasional hyena control campaigns, and another 13 percent are poisoned. Interestingly, there is little evidence that the presence of dogs at a boma helps deter hyena depredation of livestock.

LEOPARDS

Numbers and Trends

Laikipia ranchers estimate there are approximately 246 leopards on the properties sampled; if their estimates are accurate, this would convert to about 350 in the entire district (this estimate assumes that leopards are found on small-scale farms and in pastoral areas at similar densities as on large-scale ranches).

One of the world's best leopard studies has been conducted by Dr. Fumi Mizutani in recent years on Kenya's Lolldaiga Hills Ranch (Mizutani, 1997). From her meticulous research there, we know that there is about one leopard per 2,000 acres (809 hectares) on Lolldaiga. If that is representative for the entire region, we can extrapolate to about 510 animals in the district. Given the heterogeneity of habitat suitability and the imprecise nature of estimates, this figure is actually in reasonable agreement with the interviewed ranchers' estimates.

The above figures represent an increase of 9 percent over the past five years (see Figure 4). It is safe to conclude that the population has been stable. The leopard is the second most popular of the area's carnivores, after cheetahs; indeed, people would like to see the leopard population increase by 38 percent, or 53 percent, were sport hunting legal. Clearly, ranchers view leopards as a relatively minor threat to livestock and consider them to be aesthetically admirable animals, as well as a potential source of major income through hunting.

It seems likely that leopard habitat in Laikipia is saturated. In the absence of a large increase in the animal's prey base, the territorial nature of its social system probably would preclude a significant rise in the leopard population.

Mortality

Deaths resulting from predation control account for about 1 percent of the estimated leopard population annually, less if the population is actually higher than estimated.

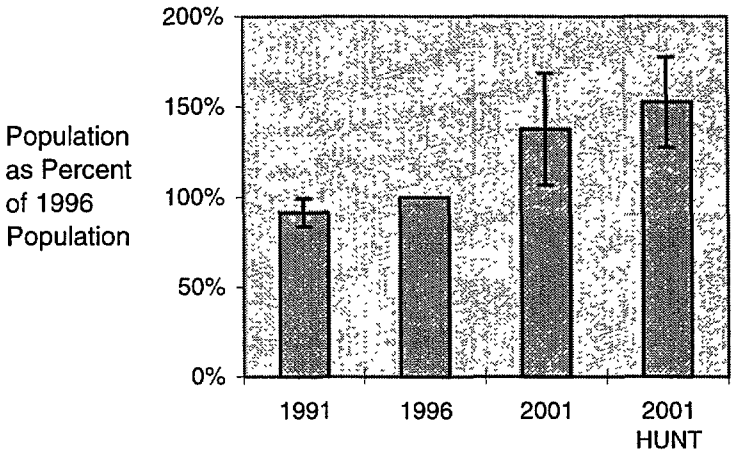

Figure 4. Population trends and target numbers for leopards in Laikipia District, 1991-2001 (F=1.89, df = 3,37, p=.15).

Prey

The leopard's ability to prey on a large variety of smaller animals gives it the ecological flexibility to live in many areas that do not have the larger game needed to support other large carnivores. Leopards reportedly feed primarily on impalas but also choose gazelles, dik-diks, warthogs, and baboons (one respondent emphasized that he would like an increased leopard population to better control baboons on his property).

Livestock Depredation

There is very widespread agreement that only specific leopards become livestock killers, and 80 percent of those are males. There is also widespread tolerance of leopards, as evidenced by the fact that many respondents said they would like to see an increase in their population. The most bitter complaints about leopards concern their habit of killing dogs.

CHEETAHS

Numbers and Trends

The ranchers interviewed estimate that they have 67 cheetahs on their property; extrapolating that figure yields about 75 animals for the district as a whole. However, most cheetahs probably are not resident on a single ranch and are thus being counted at least twice. In the absence of research, we can only say that there are probably no more than 80 cheetahs, and probably fewer, in Laikipia currently. Additionally, there seems to have been little change in the number of cheetahs in recent years (although one ranch did report a major increase, coincident with an increase in sheep losses). (See Figure 5.)

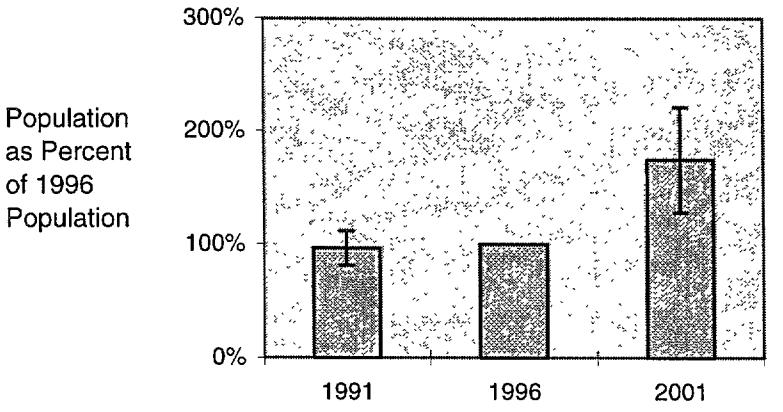

Figure 5. Population trends and target numbers for cheetahs in Laikipia District, 1991-2001 (F=1.32, df=3,41, p=.28).

According to the interviews, the cheetah is clearly the most popular carnivore in Laikipia. Respondents in general said they would like to see a population increase of 74 percent. (Note the large standard error in Figure 5, however; not everyone shares quite that degree of enthusiasm.)

Mortality

If the ranchers' estimate of cheetah numbers is accurate, the animals are suffering an annual mortality of 5 percent from problem-animal control measures. However, because the true population is probably lower, the real mortality rate is likely to be higher.

It should be noted that the rancher noted above who has suffered severe sheep losses to cheetahs has killed a number of the latter in response. On other reporting ranches, few cheetahs have been shot in recent years.

Prey

Cheetahs are reported to feed primarily on gazelles, followed closely by impalas, dik-diks, hares, and warthogs.

Livestock Depredation

Among livestock, cheetahs take only sheep. Males and females are equally likely to kill, but some ranchers said that a female with cubs is most likely to become a local problem: not only is she feeding many mouths, but she also has a much smaller home range than do males.

STRIPED HYENAS

Numbers and Trends

All respondents agree that striped hyenas occur everywhere at low densities and that their population has been stable. Only two ranchers dared to venture a guess at their numbers, the two estimates yielding a

density estimate of 1 striped hyena per 6,764 acres (2,737 hectares), or about 149 for the district as a whole. Despite this species' wide range throughout much of Africa and Asia, it has never been properly studied anywhere. Thus, no external basis exists for estimating striped hyena densities or numbers in Laikipia. Respondents widely agreed, however, that current striped hyena numbers are appropriate.

Mortality

Striped hyenas are occasionally killed, either by shooting or when caught in traps, because some ranchers regard them as predators of sheep. They are also killed by vehicles at night and, no doubt, by larger carnivores. Very little is known about this animal, but it appears to occur at comparably low densities throughout its range. Given the absence of a population estimate, we lack a mortality estimate for striped hyenas. Further clouding matters, some ranches tally striped and spotted hyenas together in reporting predators killed.

Prey

All respondents agreed that striped hyenas are strictly scavengers. Elsewhere, they are known to eat vegetation, insects, and small vertebrates.

Livestock Depredation

On a few sampled ranches, compelling evidence exists that striped hyenas sometimes kill sheep, as in Turkana, Kenya (Leakey et al., 1994). However, although many ranchers assume they are losing some sheep to striped hyenas, most said it would be impossible to distinguish their kills from those of spotted hyenas.

JACKALS

Numbers and Trends

The author did not attempt to differentiate between golden, black-backed, and striped jackals (*Canis aureus*, *C. mesomelas*, and *C. adustus*). A recent major epidemic has seriously reduced jackal numbers in some parts of the district, with many properties reporting a dramatic decline in the past few years. Overall, there seems to have been a drop of 80 percent, and on one property, jackals are estimated to have decreased 95 percent (see Figure 6).

Severe population declines among jackals and bat-eared foxes (*Otocyon megalotis*) occur regularly in the Serengeti ecosystem (Roelke-Parker et al., 1996), although the disease causing the losses has rarely been identified. The populations typically recover during the subsequent few years, and this will presumably happen in Laikipia as well. Given the recent epidemic of canine distemper virus among lions and spotted hyenas in the Serengeti ecosystem, a study of jackal disease ecology in Laikipia would be warranted.

Even though they cause relatively little damage to livestock (occasionally taking small lambs), jackals elicit little enthusiasm among Laikipia residents, who say they want the animals' population to increase only 23 percent above the current, very depressed level. Again, this seems to derive from jackals' poor "image" rather than from their impact on the local economy.

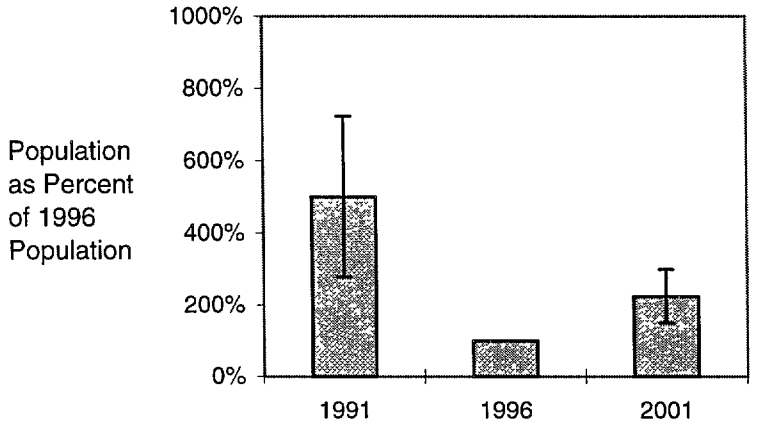

Figure 6. Population trends and target numbers for jackals in Laikipia District, 1991-2001 (F=2.9, df=2,24, p=.072).

Prey

Jackals reportedly feed on a wide assortment of small vertebrates, especially hares, dik-diks, and game birds. It is likely that rodents make up their single most important prey.

Livestock Depredation

As noted above and discussed later in this report, jackals often take very small lambs. However, because lambs are of little intrinsic value and many of those eaten are born dead, this form of predation is a small concern among most ranches sampled.

AFRICAN WILD DOGS

African wild dogs were once common in Laikipia but were so heavily persecuted that they now essentially have been extirpated from the district. They have occasionally been seen (and captured) in recent years, but this has occurred so rarely that we must assume there are no residents. Where they do occur, wild dog packs have enormous home ranges and undertake long movements. The few animals recently sighted were probably those that strayed from neighboring areas.

CHAPTER FOUR

ECONOMIC IMPACT OF LARGE CARNIVORES IN LAIKIPIA

THREAT TO HUMAN LIVES

The fact that large carnivores can kill humans is an ever-present concern in Laikipia. Consequently, the author asked all respondents whether a fatal animal attack on a human had occurred on their property in the past 10 years. Although elsewhere in Kenya people are occasionally attacked by animals, the ranchers surveyed said no animal-induced human fatalities had occurred on their property in the past decade. (One respondent cited a honey gatherer who was mauled by a lion after his dog had harassed it.) Although attacks by carnivores no doubt occur in Laikipia District, they appear to be very rare. Thus, carnivores do not present a significant threat to human lives in this area.

LIVESTOCK DEPREDATION

In a pastoral or ranching economy, large carnivores are at their most significant as killers of livestock. Depredation of livestock represents financial losses in terms of not only the loss of animals that can be sold or bred, but in the costs of preventing depredation, as well.

Identification of Livestock Killers

In any study of livestock depredation, there is always the question of how reliably people are able to recognize the kill of a particular species; that is, how often is a kill attributed to a lion when in fact it was killed by a leopard? Or how often does an animal die of disease before it is fed upon by a predator that is then blamed for the death?

For each carnivore species, the author asked all respondents about their degree of certainty in recognizing the predator responsible for a particular livestock kill. For all predators, the respondents were uniformly 100 percent certain that they correctly identified the killer. Typically, the predator is tracked after the kill is discovered, even if it is not shot. In other cases, the type of wounds and tracks at the site confirm the predator's identity. Of course, sometimes lions will displace hyenas from a kill the latter have made, or vice versa, so occasional mistakes can occur. On the whole, however, based on the survey results, most carnivore kills in Laikipia are probably correctly attributed.

Costs of Depredation

The author has used two basic approaches to estimating the costs of predation on Laikipia ranches: the first examines average costs; the second, marginal costs. The average cost of predators includes that part of herding and security costs devoted to predation prevention, as well as the value of the stock killed or injured. Using this approach, it is vital to consider one other factor as well: herders perform many functions other than guarding against predators, such as keeping track of stock, moving them back and forth between bomas and grazing and drinking areas, looking after pregnant and sick animals, and so on.

The author asked all respondents whether they would be able to reduce their number of herders if there were no predators. Almost all answered that they would not; on average, the ranchers said that even if carnivores posed no threat, they would still need to employ 97 percent as many herders as they currently do. Similarly, security personnel are employed to protect against cattle theft, even though such workers

also serve a secondary, antipredator function. Thus, in the absence of large carnivores, herding and security costs in Laikipia would not change materially. Therefore, the marginal, or incremental, cost represents that amount ranchers would save if no predators existed in Laikipia. This essentially amounts only to the value of stock killed. (By contrast, large herbivores such as elephants and buffaloes cost a significant amount in terms of the fencing and structures they destroy, the 24-hour vigilance they require, and the value of the crops they destroy.)

In all cost calculations, the author has used both average and marginal cost estimates. It seems clear, however, that the marginal cost is the more accurate reflection of predator costs. Note, however, that the marginal cost excludes such intangibles as decreased weight gain in a herd after it has been stressed by a predation event. Furthermore, the author did not attempt to include the cost of shotgun shells fired to deter predators. Even at the price of ammunition in Nairobi, this would constitute a very small factor.

It is important to keep in mind that the costs presented here reflect the current state of predator control measures and antipredator measures in Laikipia. One cannot assume that the number of stock lost would be similar if control were significantly relaxed, unless changes in livestock management methods made stock less vulnerable to predation.

To estimate average costs, the author obtained several measures for each species of carnivore and each type of stock:

(1) The average total value of each stock type lost to each predator annually over the past two years (V_l). A calf or lamb was valued less than an adult, a breeding bull more than a steer.

(2) The costs of herders' wages (W_h), security guards' wages (W_s), and security equipment costs (E = vehicles, radios, firearms, and ammunition) on each property. Because herders do many things besides protect against predation, and security personnel devote only limited attention to predators, ranchers were also asked to estimate (a) the proportion of effort (or time spent) by herders on antipredator vigilance (H_v) as compared with antitheft vigilance and animal husbandry duties; and (b) the proportion of the antipredator part of herders' duties attributable to each major predator (H_c). For the most part, this figure would be a function of the threat of each predator species on each property. However, two ranchers made the oversimplified assumption that antipredator duties could be equally divided among four or five predator species. Obviously, protection against jackals is trivial compared with protection against lions. While this oversimplification is unrealistic, the figures have been left as reported, as changing them would have made a very small difference in overall means.

(3) A similar proportional breakdown for security costs (antitheft = S_t versus antipredator = S_v duties) and the proportional breakdown for each species of predator (S_c). In attributing total personnel costs to each predator, the author multiplied total annual herding and security costs by the proportion of effort put into antipredator vigilance times the proportion of the latter allocable to each predator: $W_h \cdot H_v \cdot H_c + W_s \cdot S_v \cdot S_c$.

(4) The proportion of antipredator costs devoted to each type of livestock. Given that the estimates of proportional expenditures were difficult to obtain and are very rough anyway, it seemed excessive to ask people to make those estimates for each species of predator in relation to each species of livestock. Instead, the author multiplied the figure for each predator by the proportional value of each stock species on each property (P_l). Thus, if cattle represented 90 percent of the livestock capital on a property, cattle were allocated 90 percent of the cost of antipredation efforts.

In a few cases this procedure may have produced deceptive estimates. (For instance, because of the relatively high value of camels and the fact that some sampled ranches keep quite a few of them, the estimate of security costs for camels seems high compared with the likelihood of camel theft.)

Nonetheless, adding this figure to the value of stock killed ($V_{cattle} + V_{sheep} + V_{camel}$) gives an estimate of total costs devoted to each predator on each surveyed property (see Table 1). The resulting number could then be converted to a per-hectare or per-individual-predator figure.

Factor	Description
V_l	Average total value of each type of stock lost to each predator per year ($V_{cattle} + V_{sheep} + V_{camel}$)
E	Security equipment costs (vehicles, radios, firearms, and ammunition)
W_h	Herders' wages
W_s	Security personnel wages
H_v	Proportion of herders' duties devoted to (or time spent on) antipredator vigilance
H_c	Proportion of the antipredator part of herders' duties devoted to each major predator
S_t	Proportion of security guards' duties devoted to antitheft vigilance
S_v	Proportion of security guards' duties devoted to antipredator vigilance
S_c	Proportion of the antipredator part of security guards' duties devoted to each major predator
P_l	Proportional value of each livestock species
C_p	Average cost of each predator per property = $W_h H_v H_c + W_s S_v S_c + S_c E + V_{cattle} + V_{sheep} + V_{camel}$
$P_l C_p$	Average cost of each predator for each livestock species = $P_l(W_h H_v H_c + W_s S_v S_c + S_c E) + V_l$

Table 1. Factors used for calculating average (total) costs of carnivores on each surveyed property.

Total (average) costs for each predator species were calculated by adding the value of stock killed (the marginal cost) to the cost of the relevant proportion of herding and security costs. The cost of each individual predator on a property was then calculated by dividing the total cost of the species on a property with the estimated number of individuals. Obviously, this number is very sensitive to the population estimate. As that estimate is rarely likely to be accurate, the per- individual estimate is very rough indeed.

(5) For each property, the costs of predators versus the costs of animal health and theft prevention. Animal health costs comprise veterinary and dipping expenses, plus the value of stock that die. Antitheft costs are the proportion of herding and security costs allocable to theft prevention for each stock type, plus the value of animals stolen and not recovered.

The most critical economic question regarding predators in livestock areas is: How much does it cost to maintain them? In order to compare ranches, this question would typically be expressed in terms of costs per acre or hectare (see Figure 7). That would seem to be a reasonable measure for an area where land use is fairly homogeneous. As indicated above, however, the different ranches in Laikipia vary widely in philosophy, livestock and wildlife mix, management goals, and economic bases. They are thus very hard to compare.

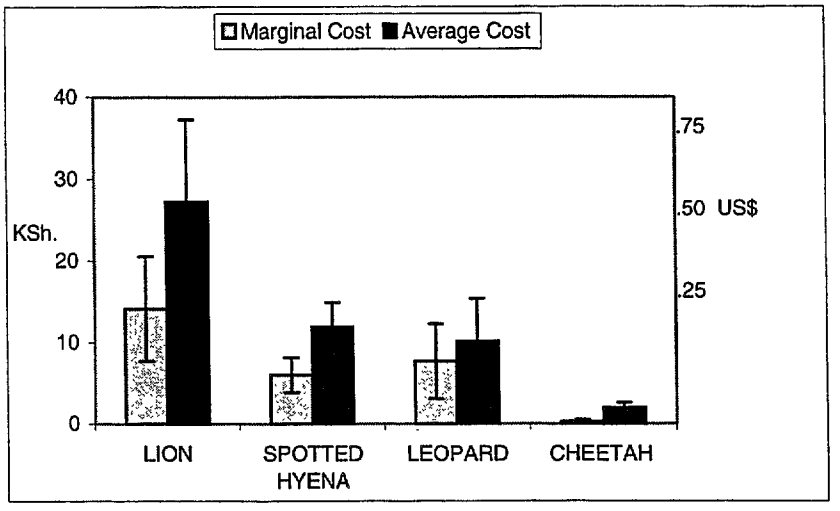

Figure 7. Relative costs per hectare of large carnivores on large-scale ranches in Laikipia District. (Marginal: F=1.93; df = 3,76; p=.13. Average: F=3.25; p=.026.)

Note that a single ranch that tolerates high depredation rates has a great effect on these figures. For instance, if that ranch were to be eliminated from the analysis, lion costs would be reduced by nearly half. It seems more useful, therefore, to compare the costs of the different carnivores in terms of their impact on each type of livestock. This approach allows more direct comparison between properties, based on the mix of stock on each.

Depredation Costs in Context

The marginal costs of depredation in terms of lost stock amount to about 6 percent of the cost of raising cattle, 10 percent of the cost of raising sheep, and 11 percent of the cost of raising camels in Laikipia (see Figure 8). Average costs, which add the costs of prevention, increase these amounts to about 16 percent for cattle, 18 percent for sheep, and perhaps 21 percent for camels. (The figure for camels is heavily influenced by one ranch that had lost quite a few camels to lions at the time of the survey, so a more representative figure would be similar to that of the other stock species.) The relative costs of security and disease prevention compared with those of depredation are presented below for each livestock species.

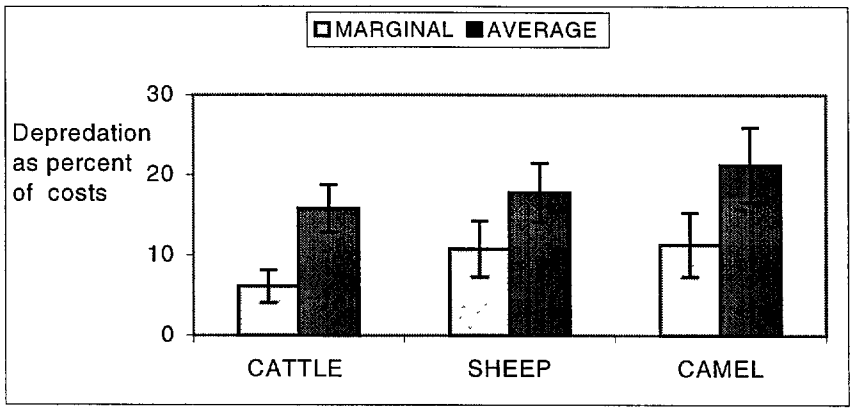

Figure 8. Depredation as a percentage of overall costs of raising cattle, sheep, and camels on Laikipia District ranches. (Marginal: F=1.03; df=2,40; p=.36. Average: F=.50; df=2,40; p=.61.)

Cattle

Depredation kills about 0.80 percent of cattle herds annually (see Figure 9), or 23 percent of total losses. By comparison, disease accounts for 73 percent and theft for 4 percent of total losses. This depredation rate is very similar to that reported on Galana Ranch in northeast Kenya, where roughly 1 percent of cattle have been killed by predators in recent years (personal communication with Brian Heath).

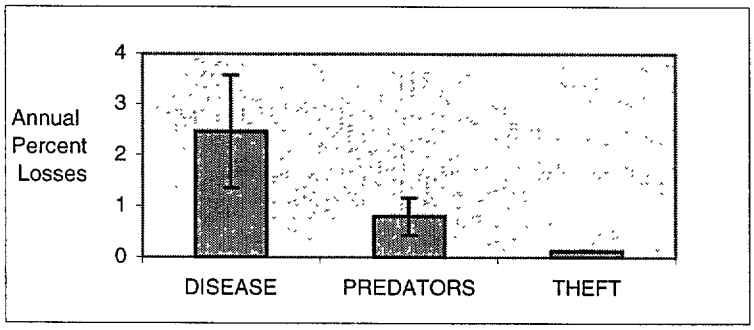

Figure 9. Percent of cattle herds lost annually to disease, depredation, and theft on large-scale Laikipia District ranches (F=7.85; df =2,37; p=.0014).

In terms of costs per head of cattle, however, theft is more important than depredation (see Figure 10). When factoring in veterinary costs and security costs, depredation and antidepredation measures account for 19 percent of total costs (about KSh. 310 per head), disease for 52 percent, and theft for 29 percent. The marginal costs of depredation on cattle amount to less than half the average depredation costs, or 8.4 percent of the total costs.

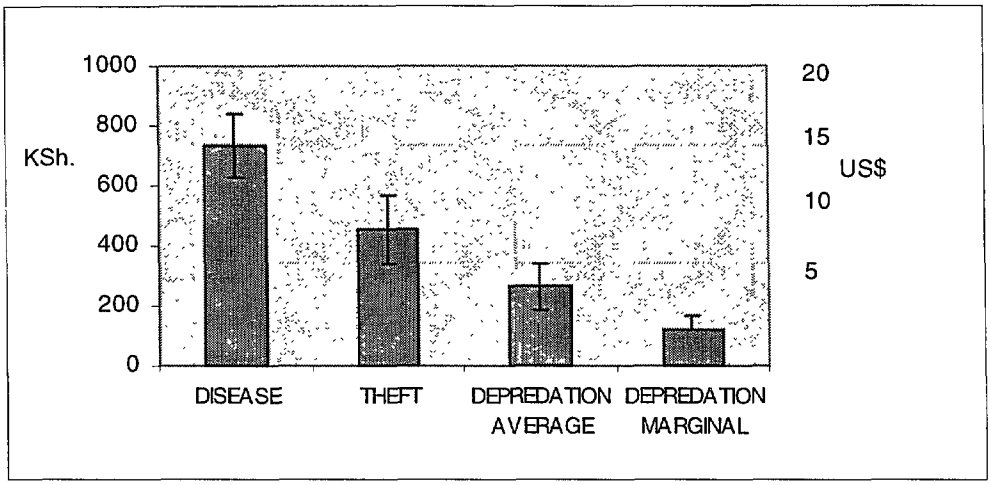

Figure 10. Annual costs of disease, theft, and depredation per head of cattle on large-scale ranches in Laikipia District (F=8.75; df=3,76; p=.00005).

Lions

Circumstances

All respondents agreed that only certain lions become stock killers. Males and females appear equally likely to attack stock, with juveniles contributing only about 10 percent. Eighty-six percent of the cattle killed are adults.

Twenty-eight percent of lion kills occur by day, the remainder at night. On only one sampled ranch do lions do most of their killing by day, when the cattle are being herded. This property has a large tourism operation and is thus forced to tolerate depredation; apparently the lions have learned that they can take stock by daylight with little fear of retribution. Overall, however, 68 percent of cattle are taken when lions approach a boma at night and panic the cattle, causing them to stampede and break out. About 16 percent of cattle losses occur when the animals are left out of bomas at night. Respondents estimated that a head of cattle left out overnight have a 22-percent chance of being killed by lions.

Costs

Lion depredation accounts for 64 percent of the average depredation costs for cattle, or about KSh. 171 per head of cattle annually (see Figure 11). Marginal costs, the amount that would be saved if there were no lion depredation, are KSh. 80 per head.

Response to lion depredation

About one-third of ranchers will move cattle out of an area to avoid lions. When depredation occurs, ranchers will typically ignore it 67 percent of the time. Most say they will give a lion several chances, reasoning that the first kill or two might have been simply "bad judgment" on the lion's part. If the lion starts to take stock repeatedly, respondents said they either hunt it or sit up for it at night. A few use traps set at bomas.

Prevention

Night guards and herders are frequently able to scare off lions by firing shotguns before any livestock are killed. Most respondents said this tactic is usually effective. Another tactic used is to scare lions off a kill before they have a chance to feed, in an attempt to teach them that stock killing will not result in a meal. Several ranchers also mentioned that lions are effectively discouraged by several paraffin lamps (Dietz lamps) left around a boma during the night.

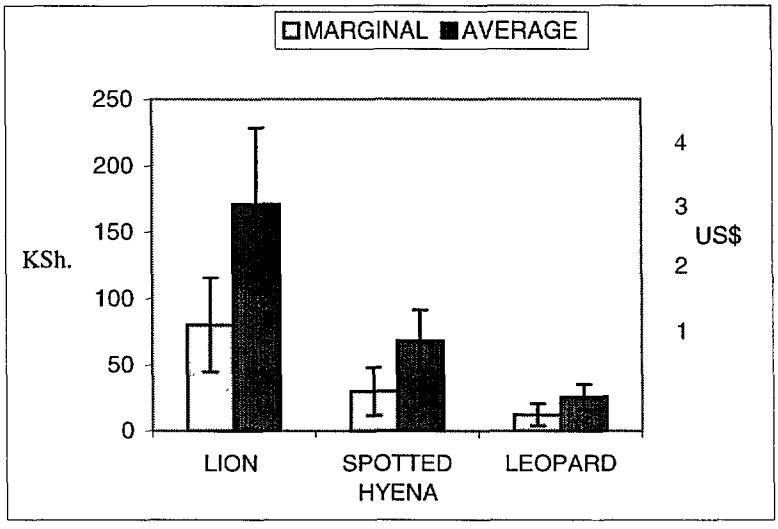

Figure 11. Annual cost of each major predator per head of cattle on large ranches in Laikipia District. (Marginal: F=2.25; df=2,57; p=.11. Average: F= 4.28; p=.018.)

Another major factor in preventing lion depredation on cattle is the effectiveness of night watchmen in both detecting and discouraging predators. Almost all respondents said the presence of dogs at a boma is highly effective in warding off lions, but some properties prohibit dogs to discourage poaching by employees.

Lion-proof bomas

The author asked the ranchers how frequently lions are able to stampede cattle from bomas, and the answers varied enormously. Some reported that lions are successful 100 percent of the time, others that they are never successful. The most effective anti-lion measure appears to be building "lion-proof" bomas, which are sufficiently high and strong to prevent cattle from breaking out of them. Some of these structures are simply thorn bomas with tightly packed walls.

Interestingly, no strong correlation appears between the boma wall dimensions and the lions' kill rate (kill rate and boma height, r =.52, p >.05 [n=10]; kill rate and boma width, r =.27, NS). Rather, the key seems to be the strength of the walls and the complexity of the bomas' inner construction: If there is only a single exit gate and internal fencing and gates separate the herds, the cattle have a much harder time escaping. Furthermore, the use of curved walls prevents livestock from piling up against fences.

According to the respondents, the costs of boma construction vary from KSh. 500 to KSh. 10,000 and average about KSh. 4,600. Ranchers varied widely in their assessment of the ecological impact of cutting thorn to build bomas. Most have so much thorn that they consider using it to be no problem, but a few said they prefer to avoid bush cutting.

Additionally, several ranchers use other available materials for building permanent stockades that are very effective in containing panicked cattle. In one case, the stockades are built of surplus cedar fence posts, available because the ranch is removing its internal fencing. Walls are 5 to 10 feet high, with barbed wire at the top cantilevered outward. Because the materials cost nothing, the cost was KSh. 15,000 in labor and tractor time.

In another case, a rancher constructed a boma as a dry stone wall using local rock, with walls 3 feet wide and 7.5 feet high, at a cost of KSh. 25,000. In both cases, the cost of the boma approximates the value of a single head of cattle.

Unlike thorn bomas, the cedar and stone bomas require little maintenance. Of course, abundant stone is not always available, and free posts rarely so. As with thorn bomas, one would need a number of these alternative structures to allow cattle to move freely around a property.

Open boma systems

One ranch in Laikipia uses an "open boma" system at night (personal communication with Brian Heath). In reality, it is a "no boma" system and is based on a technique used by the Oromo people of the Tana region. Instead of confining the cattle within fencing at night, the herders herd them into an area roughly 100 by 100 meters and light several fires around the perimeter. In this setting, the cattle maintain a compact herd and do not wander. The rancher uses no night guard; rather, the herdsmen sleep among the cattle in small corrugated huts surrounded by tiny thorn bomas. Predators tend to avoid this concentration of cattle, men, and fires. Hyenas are not a problem using this system, but occasionally a lion threatens the cattle and must be shot.

According to Brian Heath, overall depredation is lower on his property now compared with when he used thorn or wire bomas. He estimated an annual depredation rate of about 2 percent, compared with the overall rate of 0.8 percent on cattle in Laikipia.

One advantage of the open system is that it permits herders to move cattle very easily and frequently, thereby avoiding the buildup of manure that can cause disease, particularly in calves. Further, when lions attack a thorn boma, several of the stampeding cattle can be killed by the pride. If lions attack an unenclosed herd, however, they will take a single animal, and the rest of the herd will move away. Shining a light on the lion is often enough to chase it off.

Spotted Hyenas

Circumstances

In the words of one longtime Laikipia rancher, "If hyenas get any of my stock, it is my own fault." Almost 100 percent of hyena depredation on cattle occurs when animals have been left outside the boma overnight. Ranchers estimated that a head of cattle left out overnight has a 31-percent chance of being killed by spotted hyenas. Cattle are occasionally killed in wire bomas that have been poorly staked down, allowing the hyenas to crawl underneath, or in thorn bomas with weak spots in their walls. In either case, human error allows the hyenas access to the cattle.

There is widespread opinion that any spotted hyena would kill cattle, although a few ranchers felt the opposite, that cattle depredation ceases after a specific hyena is killed. Spotted hyenas kill adult cattle and calves about equally (45 percent and 55 percent, respectively).

Costs

Spotted hyena depredation, on average, costs KSh. 68 per head of cattle annually, or 26 percent of depredation costs (see Figure 11). The marginal cost, the value of stock lost to hyenas, is KSh. 29 per head.

Response to predation

Only about 16 percent of ranchers move cattle to avoid hyenas in an area, possibly because they are so ubiquitous. Because hyena depredation is always a result of lapses in herding, few ranchers will attempt to kill hyenas after depredation, although a few will hunt them every time. Overall, 67 percent of respondents ignore a kill, 24 percent hunt for hyenas locally, and 11 percent put out a trap near the site. Trapped animals are killed.

Prevention

Because the large majority of hyena depredation affects strays, it seems that improvements in herding vigilance are the main antidote. One type of herding strategy seems to be highly effective in preventing strays: Ranches using the headman or gunman system have only 16 percent as many losses as those that do not use the system (because of high variance, however, this difference is not significant: $t=-.97$; $p=.17$).

On some ranches, each herder brings his own herd of 100 or more cattle back to its own boma, bearing full responsibility for the herd. On other ranches, several herds all return to a single boma, and a headman or gunman has overall responsibility for counting the animals from all herds as they arrive in the evening. If any are missing, he sends the herders to search. A night guard has responsibility during darkness and counts each herd out in the morning.

Among the watchmen, headmen receive the best pay and the status of carrying a shotgun. Respondents said that concentrating responsibility in one person motivates the individual to see that his subordinates do the best job possible.

Data from Laikipia pastoralists provide another perspective on hyena depredation as a function of herding diligence: There is virtually no loss of cattle to hyenas among the pastoralist communities studied. These areas have plenty of hyenas, but pastoralists seem able to avoid strays much more effectively than do large-scale ranchers. Although one can interpret this finding in various ways, the most likely explanation is that people are more conscientious about their own animals than they are about other peoples'. Again, herders' motivation seems to be key.

Leopards

Circumstances

Calves constitute 99 percent of the cattle taken by leopards. They are virtually always taken at night from bomas; only about 5 percent are taken as strays.

Costs

Leopard depredation on Laikipia cattle is a small problem, costing on average about KSh. 26 per head annually (10 percent of depredation losses) and marginally KSh. 12 (see Figure 11).

Response to depredation

Almost everyone ignores leopard depredation on calves, although offending animals are occasionally trapped and moved.

Prevention

Short of trapping repeat offenders, there appears to be little that can be done to prevent occasional leopard depredation.

Sheep

Annually, about 8.2 percent of the sheep population in Laikipia District die of disease, 2.1 percent are killed by predators, and only 0.4 percent are stolen (see Figure 12). These factors constitute 76 percent, 20 percent, and 4 percent, respectively, of annual sheep losses.

In terms of costs, disease and its prevention cost about KSh. 273 per head annually (68 percent), marginal predation costs KSh. 72 (12 percent), and theft/security costs KSh. 50 (12 percent). (See Figure 13.)

Lions

Circumstances

Lion depredation on sheep occurs only at night. About 75 percent of the sheep are taken from a boma, the rest are taken as strays left out at night. Still, respondents estimated that a sheep left out overnight has only a 9-percent chance of being killed by lions.

Costs

The average cost of lion depredation is KSh. 14.81 per head annually, or 18.4 percent of average depredation costs (see Figure 14). The marginal cost is KSh. 6.31 per head, or 12.6 percent of marginal depredation costs.

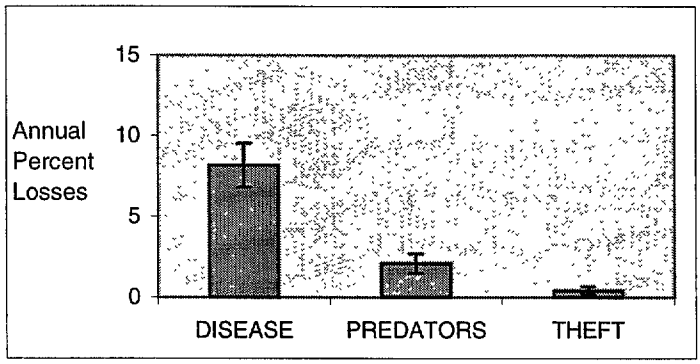

Figure 12. Percent of sheep herds lost annually to disease, depredation, and theft on large-scale Laikipia District ranches (F=21.55; df=2,39; p<.0001).

Prevention

Sheep are often kept in wire bomas at night, and it is difficult to prevent a determined lion from breaking into or leaping over these structures. Similarly, a lion can leap over most thorn bomas. Placing Dietz lamps around bomas and relying on quick action by night guards are probably the only ready solutions.

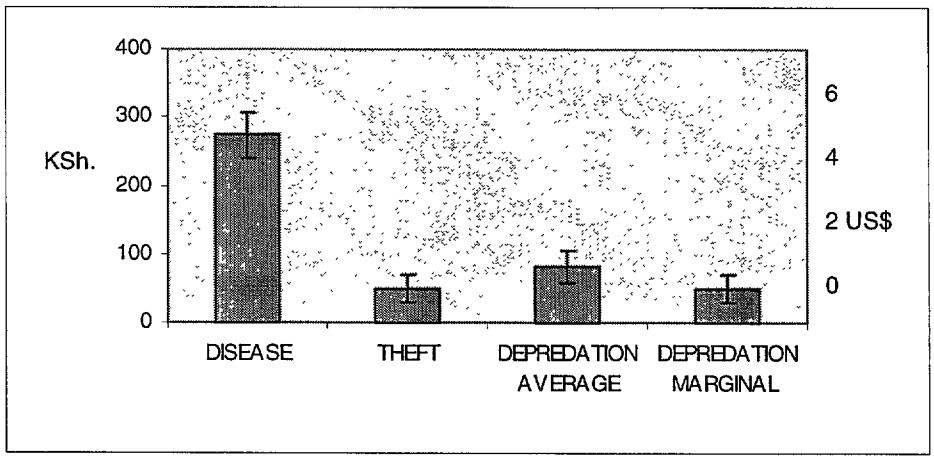

Figure 13. Annual cost of disease, theft, and depredation per head of sheep on large-scale Laikipia District ranches (F=19.14; df=3,52; p<.00001).

Spotted Hyenas

Circumstances

On most ranches, all sheep depredation by hyenas occurs when livestock have been left out at night. Ranchers estimated that a sheep left out overnight has a 71-percent chance of being killed by a spotted hyena. However, on a substantial minority of ranches, hyenas regularly take sheep from bomas (37 percent of losses overall). It is not clear whether this is the result of poor boma construction, lax night guards, or local hyenas having learned to break into wire bomas.

Costs

The average cost of spotted hyena depredation on sheep is KSh. 18.40 per head annually, or 23 percent of average depredation costs (see Figure 14). The marginal cost of hyena depredation is KSh. 13.80, or 28 percent of marginal depredation costs.

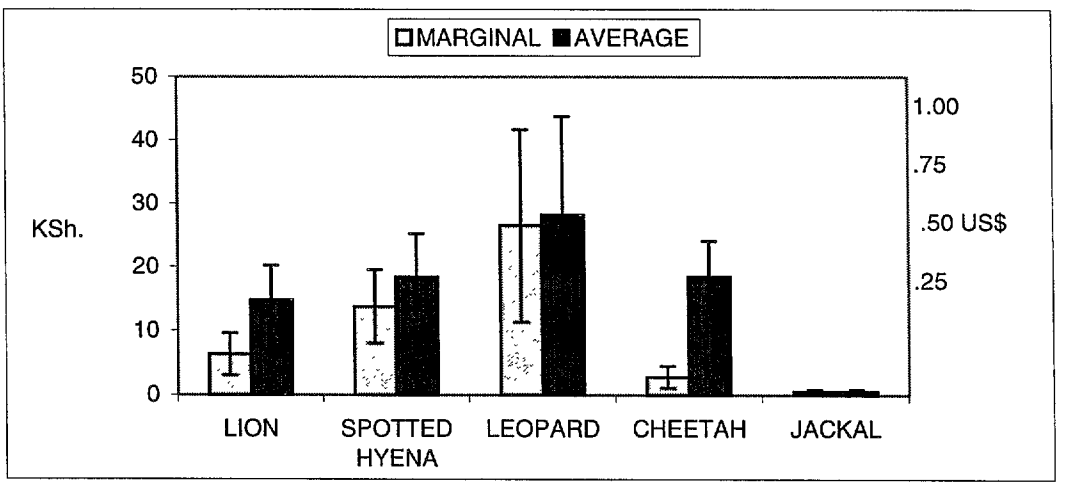

Figure 14. Annual cost of each major predator per head of sheep on large-scale Laikipia District ranches. (Marginal: F=1.99; df=4,65; p=.11. Average: F=1.43; p=.23.)

Prevention

Again, the primary factor in preventing hyena depredation is getting all animals into bomas at night.

Leopards

Circumstances

Leopards kill almost exclusively at night and nearly always by entering a boma: only 5 percent of the sheep killed by leopards in Laikipia are strays. Ranchers estimated that a sheep left out overnight has a

15-percent chance of being killed by a leopard. Leopard depredation rates vary greatly by ranch; some of this difference probably reflects the hunting habits of specific leopards that learn to specialize on sheep and goats.

Costs

Keeping in mind that leopard depredation on sheep varies highly across ranches, the mean average cost of the predation is KSh. 28.17 per head annually, or 35 percent of average depredation costs (see Figure 14). The marginal cost of leopard depredation on sheep is KSh. 26.50, or 53 percent of marginal depredation costs. These figures are very strongly influenced by high losses on two ranches in particular; costs are much lower on most of the surveyed ranches.

Prevention

All ranchers reported that their primary response to local depredation by leopards is to move their sheep. Other than that, most simply ignore sheep losses, but a few usually attempt to trap the offending leopard. On average, the likelihood of ignoring a specific loss is 82 percent; the likelihood of putting out a trap, 18 percent. Common practice is to relocate a trapped leopard, but ample evidence shows that this is an ineffective conservation strategy (KWS "Workshop on Problem Carnivores," March 3, 1997), because translocated leopards are very unlikely to find a social niche in habitats already containing a leopard population.

Cheetahs

Circumstances

Ranchers are divided as to whether individual cheetahs are likely to become sheep killers or whether all cheetahs are sheep killers. It is relatively uncommon for cheetahs to pose a serious problem, but a few ranches suffer heavy losses from them. Because other ranches report larger cheetah numbers but little predation, however, it may be that local populations of cheetahs vary in their tendency to kill stock.

Location might also be a factor: within the ranching area, cheetahs have largely learned to avoid stock, but ranches bordering large pastoral areas might be exposed to continued immigration of "naïve" cheetahs without experience of firearms.

Ninety-four percent of cheetah depredation occurs by day when sheep are being herded, and both sexes are equally likely to kill sheep.

Costs

Cheetah depredation on sheep is only important on a few farms, but those strongly affect the cost estimates. The average cost of cheetahs is KSh. 18.41 per head annually, or 23 percent of average depredation costs (see Figure 14). The marginal cost is only KSh. 2.80, or 6 percent of marginal depredation costs.

Response

Most ranchers ignore cheetah depredation, and about a third respond by moving their sheep. On a few ranches, however, every kill is followed up by hunting for the predator. Overall, 87 percent of sheep kills are ignored; the remaining 13 percent are followed by hunting.

Striped Hyenas

There is considerable disagreement over the role of the striped hyena as a livestock killer. For the most part, scientists consider it a predator of small vertebrates only, unlikely to kill shoat-sized animals. However, there has been only one brief behavioral study of the animal conducted in Serengeti National Park (Kruuk, 1976). Virtually nothing is known of them in livestock areas.

Despite scientific opinion, several Laikipia ranchers report that striped hyenas definitely kill sheep, and Turkana herdsmen also consider them to be a serious problem (Leakey et al., 1994). In Laikipia, as mentioned previously, it is likely that in some cases the striped hyena is falsely accused of killing livestock actually killed by spotted hyenas. In any event, sheep killing by the striped seems to occur only locally and occasionally in Laikipia, suggesting that the problem can be dealt with by trapping problem individuals.

Jackals

Jackals take a small number of newborn sheep, but the value of the lambs is trivial, and no respondent said jackals present a significant problem.

Camels

Laikipia camels seem to suffer little either from disease or depredation, although occasionally lions will take several from one ranch. As mentioned previously, the apparent high cost of antitheft security (see Figure 15) may be an artifact of the method used for calculating costs. The marginal cost of depredation on camels is KSh. 122 per head and is almost entirely attributable to lions (see Figure 16).

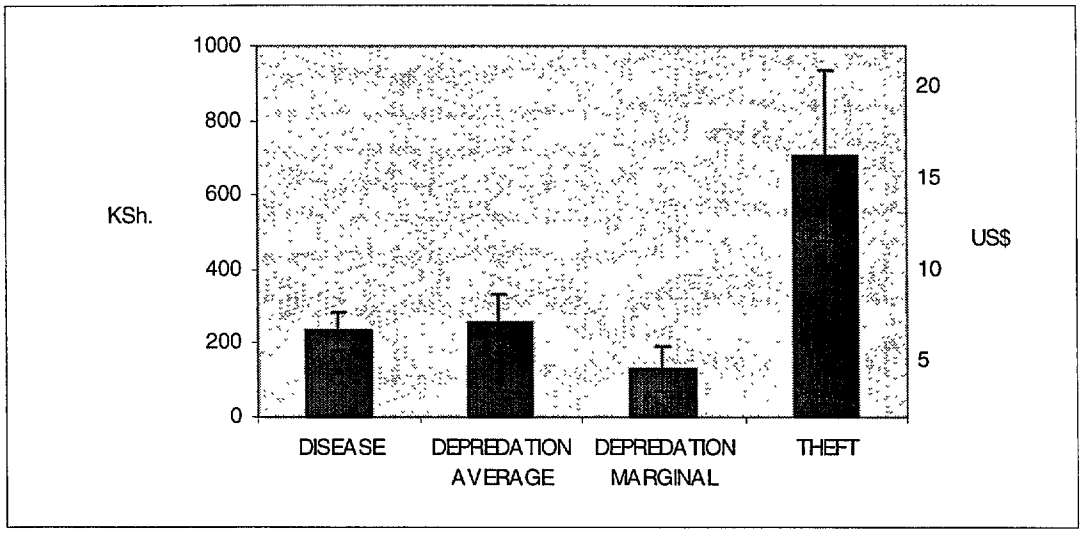

Figure 15. Annual cost of disease, theft, and depredation per camel on large-scale Laikipia District ranches (F=4.05; df=3,36; p=.014).

Lions

Lion depredation on camels is not common, but it can be locally important; one ranch reported losing nine camels to lions in one year. The camels are taken at night.

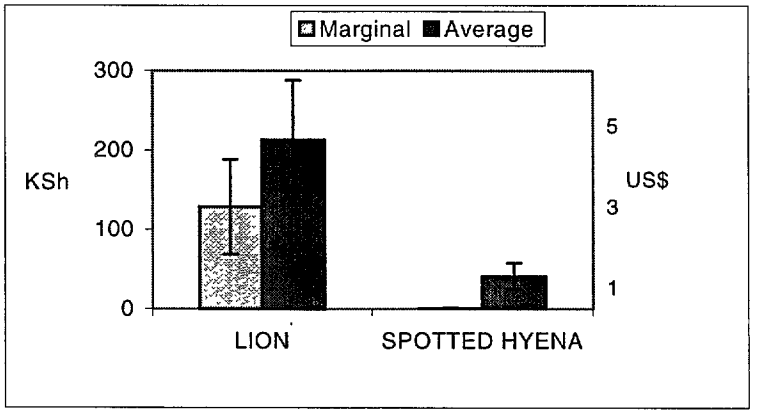

Figure 16. Annual cost of lion and hyena depredation per camel on large-scale Laikipia District ranches. (Marginal: F=5.07; df=1,18; p=.037. Average: F=4.59; p=.046.)

Spotted Hyenas

Respondents reported no camels being taken by spotted hyenas. Thus, the costs attributed to hyenas in Figure 16 are an artifact of the method used to apportion herding and security costs according to relative capital in each livestock type. However, it seems likely that camel calves would be potential targets for hyenas if left out at night.

Leopards

One ranch reported losing several camel calves to leopards annually. This may be attributable to a single animal.

Depredation on Livestock as a Function of Wildlife Numbers

In the Masai Mara, livestock depredation rates are highest when there is little wildlife available and lowest when the wildebeest migration occurs (I. Njumbi, KWS "Workshop on Problem Carnivores," March 3, 1997). Because the amount of wild prey on Laikipia ranches varies widely, depending in part on ranch policies, it is important to determine whether there is a relationship between wildlife numbers, livestock numbers, and depredation rates.

Data from aerial counts organized by Mpala Research Centre in September 1996 show the total number of ungulates counted on each surveyed property. These data were then converted to biomass per hectare using weight data from Kingdon, 1982. Livestock biomass data were derived from numbers from this survey. The relative importance of wild prey and livestock on each ranch is expressed as the ratio of the two biomass figures. The author left out the two ranches that tolerate high levels of lion predation because of tourist operations (but note that a third "tourist ranch" reports among the lowest predation rates of all).

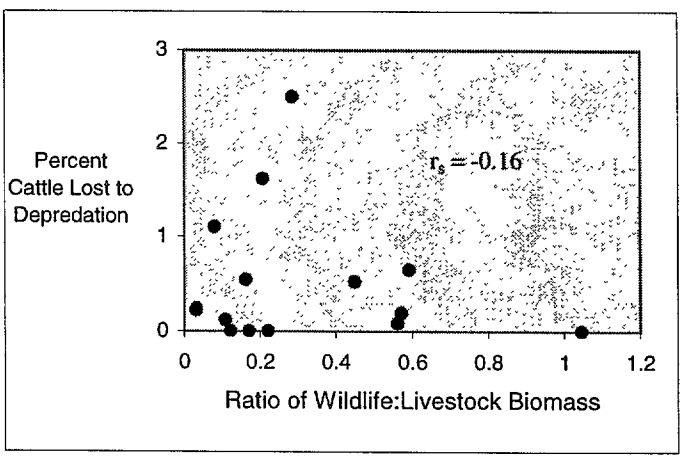

Figure 17. Relationship between annual depredation on cattle herds and relative abundance of wild prey versus livestock on large-scale Laikipia District ranches.

For neither cattle (Figure 17) nor sheep (Figure 18) is there a correlation between wildlife numbers and depredation rates of all predators combined (r_s= -.16 and r_s= -.06, respectively). That is, we cannot say that the more wild prey a ranch supports, the lower the livestock depredation rate. The sample size is small, however, and this analysis is highly sensitive to sample size; one or two data points can have a strong effect on the correlation coefficient. For instance, omitting the one ranch with high wildlife numbers and high sheep predation would result in r_s= -.44.

Examination of the data in the figures suggests a trend toward lower depredation rates where there is plenty of alternative wild prey. This needs to be examined in much greater detail, looking at seasonal changes in stock depredation as a function of seasonal changes in wildlife numbers on particular properties. However, the effect does not appear to be strong enough to influence a rancher's willingness to encourage or discourage wildlife on a livestock ranch.

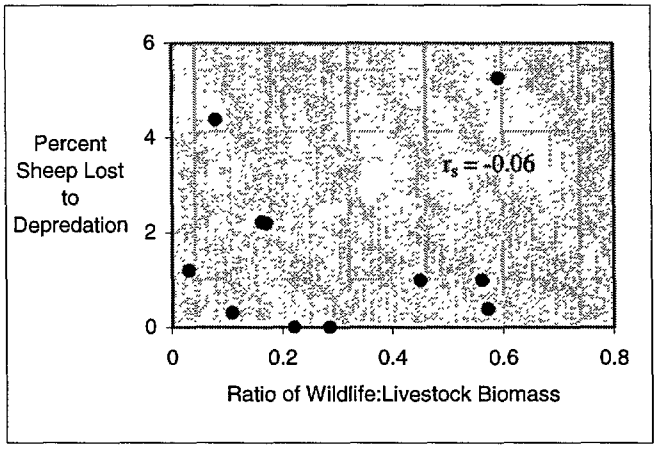

Figure 18. Relationship between annual depredation rates on sheep flocks and relative abundance of wild prey versus livestock on large-scale Laikipia District ranches.

COST OF MAINTAINING PREDATORS ON COMMERCIAL RANCHES

It seems most informative to calculate the cost of predators on a per individual basis: What does the average ranch spend in dealing with each of the major predators? These figures were derived by adding up all the relevant costs for each predator on each ranch (livestock losses and costs of preventing depredation) and dividing by the number of individuals of each species estimated on each ranch.

For all species except spotted hyenas, these figures are highly variable, largely because of the wide variation in numbers estimated on each property. On a ranch with few predators but a lot of livestock, expenditures on herding and security may be quite high, and thus each predator estimated on the property appears to cost a great deal. At the other extreme, a few properties report large numbers of predators but very few losses, because of boma construction and herding efficiency. These ranches incur a low cost per predator. On the other hand, spending a lot on herding and security probably results in lower livestock losses.

Despite the uncertainties with the above calculation, it is clear that the different species incur quite different costs. On the average ranch, the marginal cost of supporting each lion is KSh. 18,700 (US$360), with a range of zero to KSh. 108,000 (US$2,076). (See Figure 19.) Note that these figures include the one ranch that experiences extreme depredation problems; excluding that property from the data set reduces the mean cost per lion to KSh. 11,800, or US$226. Thus, each lion costs roughly the value of 1 cow or 9.3 sheep (see Figure 20). If it turns out that lions are being counted more than once, these figures would be higher.

Spotted hyenas are the least expensive predator to maintain, costing about KSh. 1,800 (US$35), and that varies little between properties. Thus, 10 hyenas can be tolerated for the price of a cow, or 1 for the value of a sheep. If the population estimate of spotted hyenas is indeed too low, as the author suspects, the actual cost of each animal would be reduced yet further.

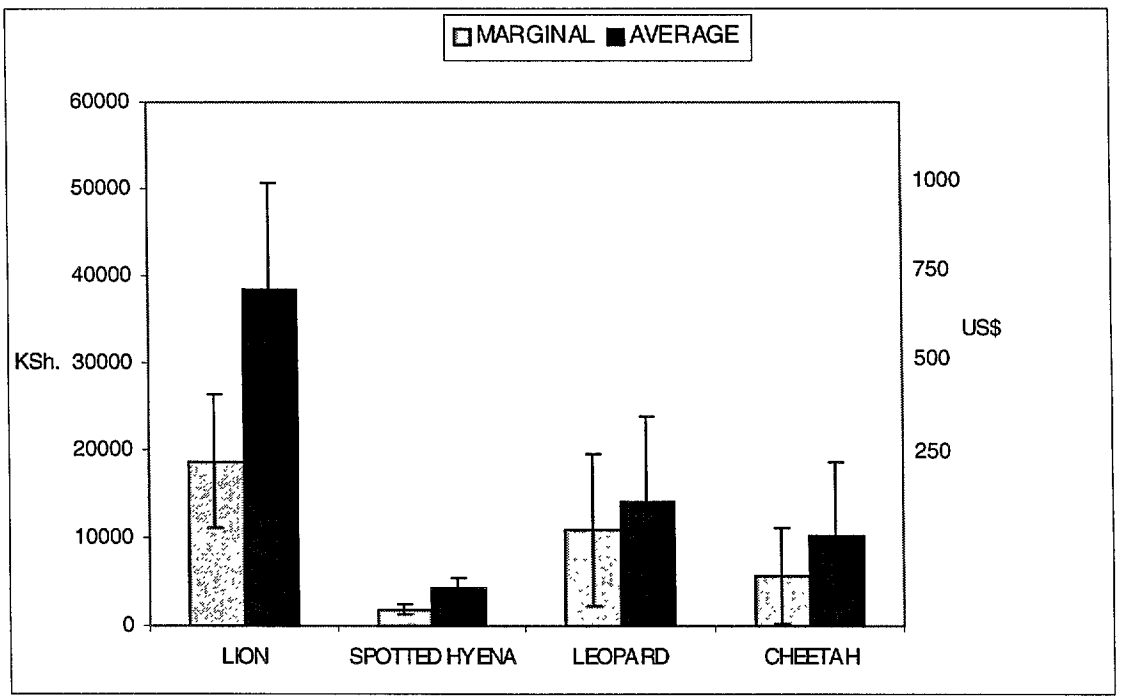

Figure 19. Relative costs of maintaining an individual large carnivore on large-scale ranches in Laikipia District (F=2.81; df=3,42; p=.05).

According to the estimated numbers, the marginal cost of a leopard is KSh. 11,000 (US$211), equivalent to half a cow or five sheep. This figure is highly variable because of differences in depredation rates on different properties, and probably because respondents likely underestimated the number of leopards they support. Based on Mizutani's work (1997), it is likely that Laikipia's actual leopard density is double or triple that estimated by ranchers. If true, this would effectively cut the marginal cost per leopard by roughly one-half or two-thirds, to KSh. 6,300 to KSh. 9,500 (US$115 to US$172). The latter figure is remarkably similar to Mizutani's; she estimates that it costs KSh. 9,888 to support each of 25 leopards on Lolldaiga Hills Ranch in Kenya.

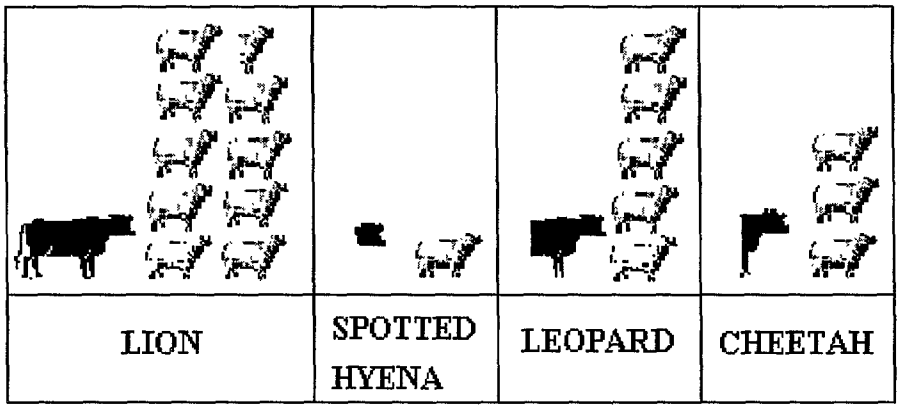

Figure 20. Cost in head of livestock of maintaining an individual predator annually on large-scale ranches in Laikipia District.

The average cheetah costs KSh. 5,600 (US$108), equivalent to one-quarter of a cow or three sheep, but that figure also varies widely between properties, largely because of unusually high losses on one particular farm. On many ranches, neither leopards nor cheetahs are problem predators.

PASTORALISTS

Although information on pastoralists in Laikipia is much less complete than for large-scale ranchers, the information from two available data sets is in general agreement. The author interviewed eight men from two group ranches in Laikipia: five from Il Polei in central Laikipia and three from Il Ngwesi in southeastern Laikipia (one of these interviews was cut short and could not be used). In both sets of interviews, the men were selected by the group ranch Senior Chief as representing different areas of the ranch.

In addition to obtaining data from individuals, the author reviewed depredation records for two group ranches as a whole, Ol Morani and Il Ngwesi, both of which are in areas supporting abundant wildlife. For Ol Morani, the author reviewed records for 1995 and 1996; for Il Ngwesi, the records available covered only September and November 1996. On the assumption that these months are relatively representative of the entire year, the author extrapolated the data to represent all of 1996.

As will be seen below, the data from the seven interviewees are generally similar to those from the group ranches as a whole. However, much more thorough study of pastoralists is needed.

Because the socioeconomic structure of pastoralism differs so from that of commercial ranching, the author has not attempted to analyze costs in detail. For instance, given that pastoralists do not generally pay others to look after their stock, it would be difficult to calculate average versus marginal costs of depredation. In addition, it proved difficult to get any accurate measure of how much individuals spend on veterinary costs, and much of the costs of dipping are not borne by individuals. Furthermore, data on disease losses were not available for the group ranches, and data on theft only from one. Therefore, comparative data on losses other than those resulting from depredation are more accurate for the individuals interviewed than for the two group ranches.

Generally, depredation loss rates are lower when measured by the whole pastoral community. Although there are a few marked differences between the two group ranches studied (such as in the loss of shoats to leopards), greater discrepancy occurs between measures for individuals and communities. This is presumably a factor of sample size: the individual measures are based on only seven men, who have experienced widely different rates of depredation. Conversely, the group ranch measures, if accurate, represent samples of several thousand households owning 12,600 cattle and 30,000 shoats, so these data sets should be a more representative reflection of overall depredation rates.

One caveat: Although commercial ranches keep meticulous records, there is no way to assess the accuracy of record keeping on the group ranches that provided data. A third group ranch returned a questionnaire, but its data were uninterpretable. Because no government compensation exists for losses to predators, one might predict underreporting of depredation.

Table 2 compares the rates of various sources of loss between large-scale commercial ranches and pastoralists. Figures for pastoralists are shown in two forms: those for the seven individuals interviewed and, where available, in parentheses, those for the two group ranches studied as a whole.

The data indicate that the individual pastoralists' cattle are 3.6 times more likely to die of disease and 3 times more likely to be killed by predators than are cattle on large-scale commercial ranches. However, if the depredation losses recorded on the ranches as a whole are generally more representative than the small sample of individuals, pastoralists lose only 10 percent more stock to predators than do commercial ranches. In terms of shoats, losses to disease are only 1.21 times greater for pastoralists. Depredation, however, is 1.74 times greater in the sample of individuals but only 1.17 times higher on the group ranches than on the commercial ranches.

Among predators, only lions pose a significant problem in the pastoralist sample. The individuals interviewed recorded no depredation by spotted hyenas on cattle. Similarly, hyenas took only 2.5 (.02 percent) of the group ranches' 12,600 cattle annually, even though hyenas are present on both properties.

Livestock	Loss	Large-Scale	Pastoralist	Multiple
Cattle	Disease	2.46%	8.87%	3.61
	Depredation	0.80%	2.52% (0.88%)	3.15 (1.10)
	Theft	0.13%	0 (1.57%)	NA (12.10)
Shoats	Disease	8.17%	9.89%	1.21
	Depredation	2.12%	3.69% (2.48%)	1.74 (1.17)
	Theft	0.43%	0.12% (1.02%)	0.27 (2.37)

Table 2. Comparison of annual livestock losses by three different factors on large-scale commercial ranches and pastoralist group ranches in Laikipia District. For pastoralists, figures are given for seven individuals on two group ranches, and, where available, in parentheses, for two group ranches as a whole (representing 12,600 cattle and 30,000 shoats).

Cattle

The individual pastoralists lose about 2.52 percent of their cattle herds to predators each year, compared with 0.88 percent on the group ranches (see Figure 21). Again, it should be remembered that the sample of seven individuals is quite small, while the ranch figures are based on a total herd of 12,600 cattle. Of course, predator numbers and wildlife ecology are not homogeneous. The sampled ranches and their neighboring properties support abundant wildlife, but livestock depredation may be substantially lower in pastoral areas where wildlife generally and predators in particular are less abundant.

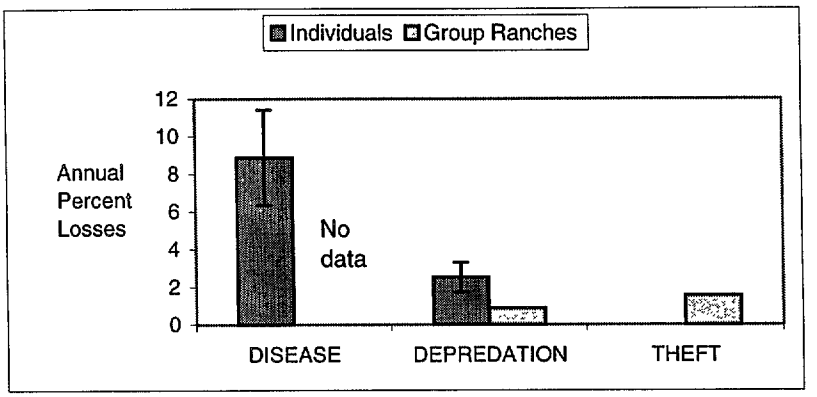

Figure 21. Percent of cattle herds lost annually to disease, depredation, and theft on pastoralist lands in Laikipia District.

Depredation costs the individual pastoralist about KSh. 324 (US$6.23) per head of cattle, compared with disease-related losses of KSh. 493 (US$9.48). Data for the group ranches indicate a much lower rate of predation, with losses costing KSh. 98 (US$1.88) per head (see Figure 22).

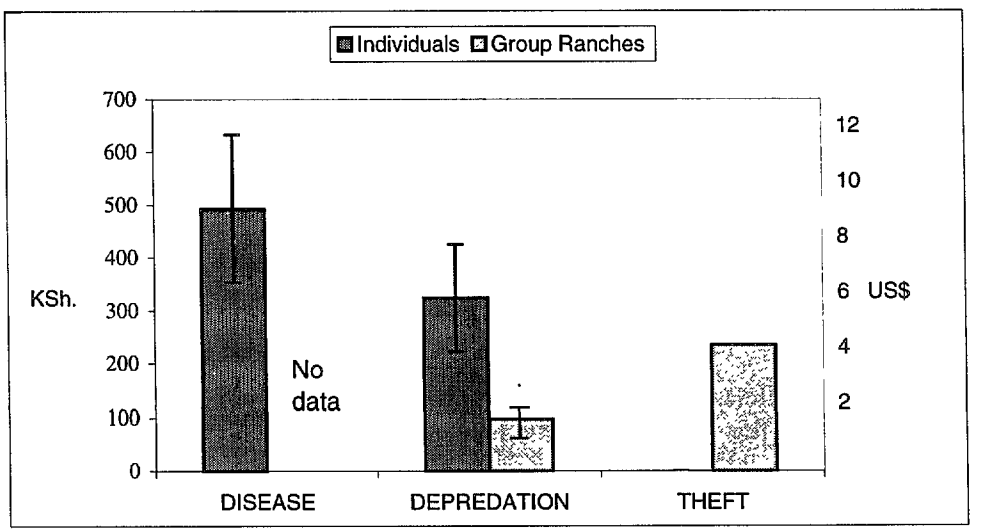

Figure 22. Annual cost of disease, theft, and depredation per head of cattle in pastoral areas of Laikipia District.

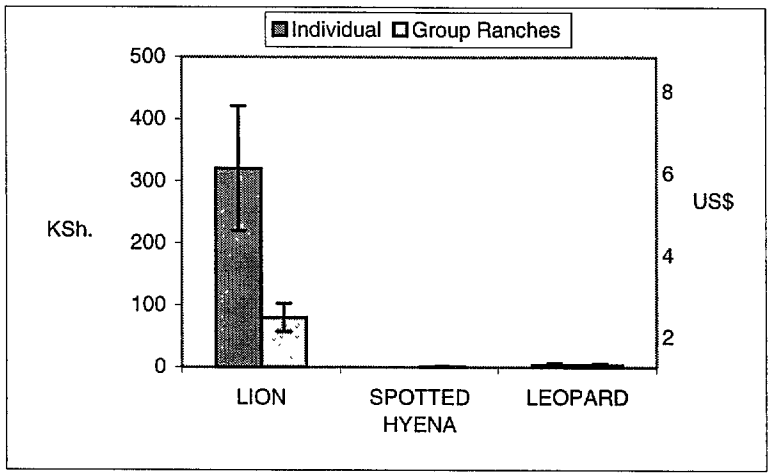

Figure 23. Annual marginal cost of each major predator per head of cattle on group ranches in Laikipia District.

Lions

Lions are the only serious threat to cattle on group ranches (see Figure 23), costing KSh. 321 per head in the individual data set and KSh. 80 per head for the group ranch data set. Only a small fraction of cattle are killed by day, but when lions attack a boma at night, they are virtually 100 percent successful in stampeding cattle. This strongly suggests that changes in boma construction would be very effective in reducing losses to lions. Note that Kruuk (1981) reached the same conclusion in his study of pastoralists in north Kenya. However, construction of stronger, thicker, and higher bomas is much more difficult for pastoralists than for large-scale ranchers, as the latter are able to use tractors to haul thorn bush.

At a typical boma, no one remains awake to guard stock at night; rather, the men say they wake up at any noise and attempt to chase off lions. It is possible lions could be detected earlier if a guard remained awake, but it is unclear whether they could be prevented from stampeding cattle unless the guard had a firearm or other noisemaker.

Leopards

Leopards take the occasional calf from bomas but are only a minor problem in pastoral areas.

Spotted Hyenas

Perhaps the most surprising difference between pastoralists and commercial ranches is that there seems to be virtually no loss to hyenas in pastoral areas, even though hyenas are said to be abundant there. The seven individual pastoralists interviewed reported no losses to hyenas in two years, and the Il Ngwesi group ranch reported none in the data from the two months provided. On Ol Morani, only five calves had been killed in two years at the time of the survey. Given that hyenas take almost exclusively strays, this suggests that pastoralists are more diligent when herding their own stock than they are when employed on ranches. Among pastoralists, much of the herding is done by boys and younger men, who may suffer greater consequences for lost stock than do herders on ranches. However, there are other possible reasons strays are more likely on commercial ranches:

- Bush cover may be generally denser than on pastoralist land;
- Commercial-ranch herders may move their animals greater distances than pastoralists do; and
- Higher-grade cattle on commercial ranches may form less cohesive herds, so that animals are more likely to wander.

The lack of hyena depredation is not reflected in a greater tolerance for hyenas, however: pastoralists generally agree that they would be happiest if both lions and hyenas were eliminated.

Shoats

Because pastoralists keep both goats and sheep, the author refers to small stock together as shoats. Disease accounts for nearly 10 percent of shoat losses annually for the individual pastoralists interviewed. In contrast, depredation accounts for 3.7 percent for the individual pastoralists and 0.65 percent for the group ranches (see Figure 24).

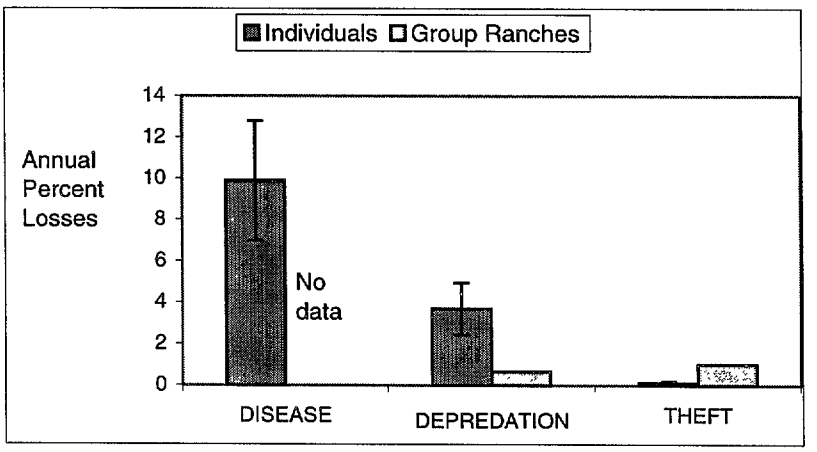

Figure 24. Percent of sheep lost annually to disease, depredation, and theft on pastoralist lands in Laikipia District.

On a per-head basis, disease losses for the individual pastoralists are double their depredation losses, at KSh. 122 (US$2.34) versus KSh. 61 (US$1.17). (See Figure 25.) Note that, in this case, disease costs do not include an estimate of veterinary or dipping costs. The two group ranches vary greatly in shoat depredation costs but average KSh. 39 (US$0.75) per head. Theft accounts for KSh. 1.57 (US$0.03) per head on the two properties.

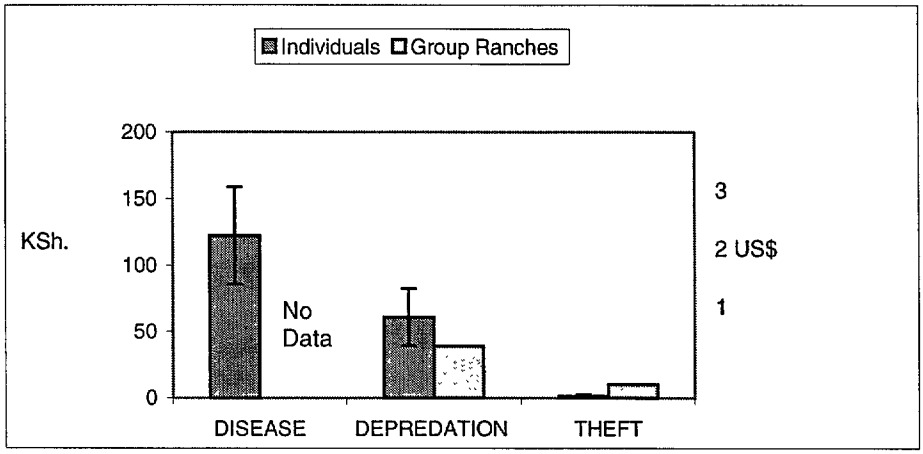

Figure 25. Annual cost of disease, theft, and depredation per head of sheep in pastoral areas of Laikipia District.

Predators

There is a great deal of variation in level of depredation on shoats reported for the different predators. On Il Ngwesi, there were no reports of shoat loss to hyenas, cheetahs, or jackals in the two-month period for which data were available. It is possible, however, that there was a reporting bias such that only losses to big cats were recorded. The four individual pastoralists from Il Polei lost shoats to all potential predators in roughly equal proportions, indicating a possible ecological or behavioral difference in the two areas (for example, perhaps Il Ngwesi supports more wild prey than Il Polei).

Figure 26 breaks down the annual marginal cost of predation by predator.

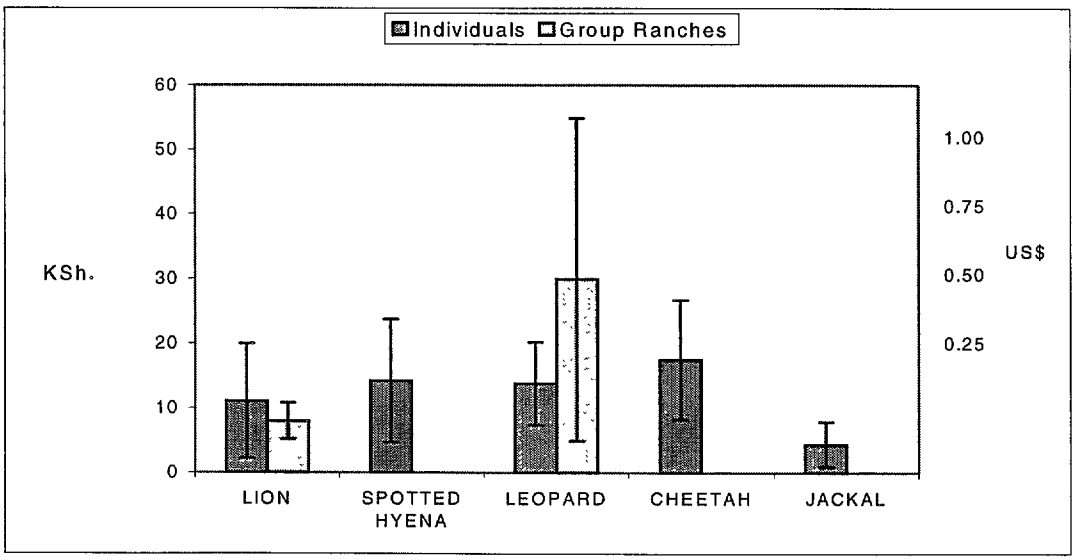

Figure 26. Annual marginal cost of each predator per head of sheep and goat in pastoral areas of Laikipia District.

SMALL-SCALE FARMERS

Large portions of Laikipia District have been taken over for small-scale and subsistence farming. In these areas, wildlife generally and carnivores in particular have been reduced or eliminated. Further, small-scale farmers typically own few cattle and shoats, in part because the problem of stock theft is severe.

Among small-scale farmers, the author received questionnaires from two settlement schemes and interviewed the representative of the southeastern part of the district on the Laikipia Wildlife Forum. According to all these sources, occasional leopard depredation on shoats is the only significant large carnivore problem in heavily settled areas, although lions and hyenas occasionally take stock. The loss rate appears small, although to a farmer who owns only a few head of livestock, the death of a single animal can be a serious economic setback.

ROLE OF THE KENYA WILDLIFE SERVICE

The Kenya Wildlife Service (KWS) is responsible for managing the country's wildlife, including "problem" carnivores. In 1996, the Laikipia office received eight reports of livestock damage by lions, three by leopards, and none by hyenas. In response, three lions were killed (J. Kagiri, KWS "Workshop on Problem Carnivores," March 3, 1997).

The author asked all respondents whether they ask for help from KWS in dealing with stock-killing carnivores. Large-scale ranchers said they handle problem carnivores themselves, filing annual reports with KWS in which they summarize livestock damage and predators killed. Virtually all said that when they have asked for help from KWS, their experience has not been encouraging. In most cases, KWS has not responded, the ranchers reported, and when rangers have come, they rarely have handled the problem appropriately.

Surveyed pastoralists tended to agree with their large-scale counterparts, although some said KWS's response to leopard depredation has been acceptable. In sum, neither large ranchers nor pastoralists feel that KWS is effective in dealing with stock depredation.

CHAPTER FIVE

SPORT HUNTING

At the time of this writing, the possibility of ending the ban on sport hunting in Kenya has received considerable discussion at all levels: privately, within the government and KWS, and in the press. Although the timetable is unclear, it appears likely that sport hunting will return to Kenya, and that Laikipia District will be one of the first areas where it will be reintroduced.

In this survey, the author asked several questions about sport hunting and also talked to a number of professional hunters about the possible organization and economic impact of hunting in Laikipia. Because the politics, economics, and ecology of sport hunting are extremely complex, a full discussion of the subject is well beyond the scope of this report, but some major points are summarized below.

ATTITUDES

Sixty-four percent of ranchers and 75 percent of pastoralists surveyed favor fee-based sport hunting on their land. Most ranchers would hope to earn about 10 to 15 percent of their annual net income from sport hunting of all species, but one optimist hoped for as much as 50 percent. If sport hunting were to become a significant economic factor, most ranchers said they would reduce the stocking rate for livestock by an average of 20 percent. This would have a clear benefit for wildlife, potentially increasing the amount that could be hunted or cropped commercially.

Some respondents said they would hope to run their own hunting operation were sport hunting reintroduced, while others said they would simply lease the rights to hunt on their land to a professional company. Because of the high fees that can be charged for lodging and professional hunting services, the former approach would be far more lucrative. Of course, it would also be a major distraction from the livestock business.

LION HUNTING

Sixty-four percent of landowners surveyed said they would encourage sport hunting of lions on their property, and most would favor an increased lion population if they could earn income from it. On average, they would seek to increase lion numbers 20 percent with the return of sport hunting. Nearly everyone, however, spoke in terms of restricting such hunting to the killing of stock-raiding animals, thus providing a double economic advantage: respondents would earn considerable income while getting rid of a liability. This type of lion hunting would not necessarily increase the number of lions killed annually.

Given the high potential productivity of lions, it seems likely that Laikipia could support a modest annual taking by sport hunters. Clearly, many lions are already being shot for depredation control, and most ranchers agree that the animals' population has remained stable during the past five years. Whether that stability is the result of replacement from within the district or of immigration from surrounding areas, an off-take of about 20 lions per year might be sustainable.

Because depredation cannot be scheduled, the primary practical obstacle associated with sport hunting of problem individuals is coordinating a hunter's safari to coincide with the time at which a stock-killing lion appears. It would be difficult to promise a hunter the opportunity of shooting a lion if only problem animals were permitted to be taken. One possibility would be to offer a Laikipia hunting safari with the understanding that there would be no guarantee that any lions would be available for hunting, with each hunter taking the luck of the draw.

A second, more flexible option would be for a professional hunter to line up several potential hunters who might be able to come to Kenya on short notice should a problem animal become available for hunting. One professional hunter with whom the author spoke said this might be a feasible option, but some other hunters disagreed. Another concern is that the high value of lion hunting could be a strong incentive for exaggerating lion depredation on livestock to produce additional shootable, "problem" animals.

Income from Lion Hunting

In neighboring Tanzania, the fees collected for hunting are about the same for lions, leopards, and buffaloes, each constituting about 12 percent of total license fees (Planning and Assessment for Wildlife Management, 1995). The professional's fee for shooting a lion in Tanzania is currently $2,500 to $3,000. However, lion hunts are generally offered only as part of safaris lasting a minimum of 21 days, and each member of the hunting party pays $1,000 to $2,000 per day for lodging, the services of the professional, and transportation. Thus, the actual income from the lion itself is only a fraction of the total brought in by the lion hunting opportunity.

In Kenya, Laikipia lions may not be highly sought after by the experienced hunter looking for a particularly good trophy. Today, excellent trophy lions in Botswana are bringing in fees of $20,000 and more (personal communication with Pieter Kat). However, Laikipia lions often have small manes, making them less desirable. Moreover, many stock killers are adult females or young males. For the client whose primary goal is a challenging lion hunt in difficult country, the characteristics of the target animal may be relatively unimportant. The client who demands a big mane, however, may be less willing to hunt in Laikipia. It is not clear whether this consideration is likely to affect the fees that could be charged.

The Problem of Infanticide

One aspect of lions' social biology potentially complicates the management and regulation of lion hunting: infanticide. It is well established that when new males enter a pride containing small cubs, they usually kill the youngsters (Packer and Pusey, 1983a, 1983b). This behavior has evolved because the tenure of a male in a pride is typically only two to four years, roughly the amount of time between a female's litters. If a female has small cubs when a male enters the pride, the male may be displaced by new males before he can inseminate her. It is thus to his strong evolutionary advantage to kill her cubs when he takes over a pride, bringing the female into estrus so that she can raise his own offspring during his period of tenure.

It has been suggested that if pride males were shot regularly, the resulting turnover of males would lead to litters being killed constantly as new males filled the vacancies, ultimately depressing cub production by the entire population. Should this prove to be true, it might become necessary to manage lion hunting so that young nomadic males rather than pride owners are targeted. This would call for detailed knowledge of local lion populations, because it is by no means simple to recognize pride males: they are frequently not with females. Thus, simple presence or absence of females is not sufficient evidence to identify resident males. Current studies by Whitman and Packer in Tanzania are addressing this problem.

Trophy Hunting, Social Instability, and Reproductive Rates

Several recent studies have examined the effect of trophy hunting on lion demography and social systems. Preliminary data suggest that the lion population's response to trophy hunting may be quite complex. In

the Luangwa Valley of Zambia, Yamazaki (1996) found that trophy hunting of males reduced the number of males associated with each pride. Thus, males tended to occur as singletons instead of male coalitions, and a singleton often had a home range smaller than the range of the local pride of females. These females might thus mate with several different males rather than only the "pride-owning" coalition. In a typical Serengeti pride, the male coalition effectively excludes other males from the territory. However, under Luangwa's circumstances, there may be greater opportunities for infanticide by nonfather males.

Two studies suggest that hunting of males may cause females to produce more male cubs than would normally be expected (Creel and Creel, 1997; Whitman, personal communication). In both studies, the overproduction of male cubs may be so great that the number of young females surviving to adulthood may be dropping. This obviously yields numerous shootable males in the short term but may cause severe population reduction in the long term.

The phenomenon of sex-ratio bias occurs in many mammals: Under certain ecological or social circumstances, females may produce more offspring of one gender than would normally be expected. Although we do not understand the physiological basis of this apparent sex selection, the evolutionary reasons are reasonably clear.

If further data show that constant shooting of adult males has significant deleterious effects on population reproduction, it may become necessary to focus hunting specifically on young males and nomads, and to take older, pride males only after long (two- to four-year) intervals. This would lead to the sort of intensive management typical of European stag hunting, in which the population is closely monitored and the gamekeeper determines each year which individual animals can be shot.

Laikipia lion prides almost certainly cover areas larger than a single ranch. Thus, lion hunting would need to be managed over large areas, demanding close cooperation among neighboring properties. Although some landowners say they will not allow sport hunting, they may well see "their" lions being killed on neighboring ranches, just as many lions resident in national parks are shot when they move into neighboring hunting blocks. Clearly, lion hunting in Laikipia would require sophisticated management, taking into account both the biological needs of lions and the sociological complexities of landownership.

LEOPARD HUNTING

Like lions, leopards are a much-sought-after trophy for sport hunters and offer income opportunities similar to those associated with lions. Safari fees and lengths, for example, are similar to those in lion hunting.

Leopard hunting could be a reliable source of income for many Laikipia ranches. About 50 percent of the landowners surveyed said they would allow such hunting on their property and would encourage an increase in leopard numbers of about 59 percent. Given the current low level of leopard control, however, the habitat may well be saturated, and such an increase might not be ecologically feasible.

As there appears to be a high density of leopards throughout Laikipia District, most ranchers could probably kill one or two males per year without significantly affecting the population. It has been suggested that incoming males are likely to kill cubs in the manner of lions, which might prove to be biologically important. Furthermore, Mizutani's 1997 study in one case showed a rise in livestock depredation following the loss of a longtime resident male. This presumably occurred because the resident was not a stock killer and was replaced by males that had not learned to avoid stock. Similar effects might occur when resident lions are replaced by newcomers.

CHAPTER SIX

RECOMMENDATIONS

In ecological terms, large predators are keystone species that, through their influence on grazers and browsers, affect vegetation patterns and thus the entire ecosystem. In a very real sense, the presence of large carnivores defines a healthy ecosystem: If an area can support them, it can also support healthy populations of other large mammals and the vegetation they require. In turn, these support myriad smaller vertebrates and invertebrates.

Large predators are central to all the wildlife-based enterprises that serve as viable economic alternatives to livestock raising in much of Africa. Tourism virtually requires lions, as does big game hunting. Cropping of zebras and other ungulates is becoming increasingly important, yet the impact of predation on these populations in Laikipia is completely unknown.

Large carnivores are extremely vulnerable because of their depredation on livestock and the ease with which they can be poisoned or shot. Direct human-caused mortality is the single most important problem in conserving all large carnivores; this has been very well documented in the case of grizzly bears and wolves in the northern hemisphere, and is clearly the case in Laikipia, as well. The mortality rates for lions and spotted hyenas documented in this report are so high that it is surprising that these species still occur in Laikipia.

Because respondents said that predator populations have generally been stable, it seems likely that the lion population is maintained by constant immigration from less populated parts of Kenya. Spotted hyenas reproduce slowly, and immigration is relatively unimportant (Frank, 1986). Thus, their 14-percent mortality rate can only be considered sustainable if there are many more spotted hyenas than people believe.

Reduction of human-caused mortality is the single most important factor that can ensure the continued survival of these species in Laikipia. It would be naïve and counterproductive, however, simply to exhort landowners to tolerate depredation losses in order to save the predators. Reduction in predator killing will only result from reducing depredation losses to tolerable levels. As summarized below, strong indications exist that many Laikipia ranchers have already found ways to do this.

LION-PROOF BOMAS

Cattle losses to lions can be significantly reduced by building bomas high and strong enough to prevent cattle from breaking out when they become panicked. Such structures can be made from thorn or other locally available materials, such as stone or posts. These options may be unrealistic for pastoralists, however, because of the equipment required to haul such materials. Consequently, a very productive use of conservation dollars might be to assist group ranches in building lion-proof bomas, perhaps by supplying a tractor and a driver for collecting stone. In some areas, it may be feasible to build bomas of timber offcuts or other inexpensive materials.

HYENAS: THE HEADMAN SYSTEM

Losses to hyenas are almost entirely avoidable through diligent herding. The fact that pastoralists rarely lose their own stock to hyenas seems to indicate that there is potential for considerable improvement on commercial ranches. Of course, strays will always occur in rugged and densely covered country, but some ranchers appear to be quite successful in motivating herders to minimize straying. By adopting a system

in which one person is given overall responsibility for several herds and is rewarded through better pay and the responsibility of carrying a shotgun, all herders studied seemed motivated to perform better. In fact, ranches using this system sustain one-sixth the hyena-induced cattle losses compared with ranches on which each herder has sole responsibility for his herd alone.

Rewarding individual herders for reliably returning the entire herd in the evening would probably also help. An extra hundred shillings now and then to reward good herding costs much less than losing stock to sloppy herding.

THE USE OF HERDING DOGS

Because so much of livestock loss occurs when animals stray, the author asked a number of sheep farmers whether anyone had tried to use trained herding dogs such as Australian shepherds, border collies, or Australian blue heelers. It would seem that dogs would be more effective than humans at finding lost stock and returning them to the herd. The author did hear of one European farmer who used dogs himself, but no respondent knew of African herders being trained in their use.

Some respondents seemed skeptical about the feasibility of using trained dogs in East Africa, because properly training and working with a herding dog is a complex matter. The pastoralists who constitute the herders on Laikipia ranches do not normally train animals, so it might be difficult to find people who could work with dogs effectively.

Respondents also expressed doubt about being able to persuade herders to feed and care for dogs properly. Additionally, of course, the dogs themselves would be vulnerable to predation and disease in the bush.

Despite these misgivings, effective herding is so important in avoiding livestock predation that it may be worthwhile experimenting with the use of livestock dogs. This would be a major undertaking but might have the potential of being very useful in Africa.

CONDITIONED TASTE AVERSION

Conditioned taste aversion is the phenomenon that occurs when an animal feeds on food that has been treated with a chemical (typically lithium chloride) that causes severe nausea (Revusky and Bedarf, 1967). In a laboratory setting, it is quite easy to make an animal permanently reject a formerly favorite food. This technique has been used with varying success both in North America and Africa to discourage individual carnivores from preying on livestock. For instance, Dr. Fumi Mizutani tried it with leopards on Lolldaiga Hills Ranch.

The technique appears to succeed when applied according to established principles of animal learning but fails if applied less rigorously (Gustavson, et al., 1982). This approach should be thoroughly tested with African carnivores, as it has the potential for being inexpensive and easily applied.

PREDATOR CONTROL

For a variety of reasons, some degree of predator control will no doubt be necessary for the immediate future. Although improvements in bomas and herding can clearly make a major difference in loss rates, ranchers and pastoralists cannot be expected to tolerate significant losses that inevitably occur. In the absence of a properly administered compensation program, some predators will be shot.

Most depredation by large cats is attributable to specific individuals; consequently, the need to eliminate such problem animals, as well as the occasional hyena that learns to invade bomas, will continue. Because the great majority of hyena-induced losses are strays that improved herding can largely eliminate, there is no justification for general hyena shooting campaigns or a shoot-on-sight policy. Similarly, depredation by jackals is such a small issue that there is no reason to control these predators.

If all predator control were to cease, depredation would soon grow rapidly, because all individuals would learn that they could raid stock with impunity. For instance, when lion culling ceased on Galana Ranch in northeast Kenya, livestock losses soon tripled (personal communication with Brian Heath). Some level of "continuing education" of the entire predator population is necessary to ensure that most individuals maintain their fear of humans and their livestock. In the absence of a human threat, predators would have no reason to avoid such easy prey. It is possible, however, that conditioned taste aversion would accomplish the same purpose.

SPORT HUNTING

If property owners could profit from lion and leopard hunting, it would be well worth their effort to conserve the predators. As noted earlier, some ranches already tolerate high depredation losses because they need to be able to show lions to tourists. However, in terms of a lion population, Laikipia is a small area, and demand for hunting here is likely to be high.

Detailed data on many aspects of lion ecology will be required if hunting is to be managed on a sustained-yield basis. Of particular concern will be take rates, lion dispersal into the district from other areas, and the population's reproductive response to frequent removal of males.

Large carnivore populations are subject to fluctuations caused by various factors, including changes in prey availability, mortality from hunting or disease, and social variables. It will thus be necessary to monitor regularly the status of individual prides, as well as the population as a whole. A major goal of intensive lion research should be to produce a monitoring system that can be applied at least annually on a district-wide basis.

ESSENTIAL RESEARCH

It should be abundantly clear from this survey that, excepting leopards, we have very little hard data on carnivore biology in Laikipia. We can learn a great deal from studies done in other ecosystems, but carnivore ecology is very flexible. What holds true for lions in the prey-rich Serengeti or for spotted hyenas in the Mara may be very different among the lower-density populations of Laikipia. We can make educated guesses based on other studies, but only intensive research in Laikipia will provide the needed answers if carnivores here are to be managed intelligently.

This report forms the basis for a proposal to conduct an intensive and extensive study of carnivores in Laikipia, focusing initially on lions and spotted hyenas. Such research should continue for three to five years in order to obtain adequate data to cover seasonal and annual variation. In conducting the current study, the author asked all responding landowners whether they would permit such research on their property. The great majority were very positive about the idea, and more than 700,000 acres of the district would be available for this research.

Future field research on lions and hyenas should primarily emphasize the following:

(1) Population numbers and trends;

(2) Distribution within the district;

(3) Mortality and recruitment rates;

(4) Sources of mortality, including disease and humans;

(5) Movement, dispersal, and home range patterns;

(6) Social group sizes and territoriality;

(7) Genetic substructuring of populations;

(8) Food habits;

(9) Livestock depredation patterns;

(10) Economic costs of depredation; and

(11) Extensive experimentation with methods for reducing livestock losses, including:

- improvements in boma construction,
- improvements in herding,
- testing of conditioned taste aversion, and
- testing of the use of herding dogs.

These data will allow us to design alternative management plans and mathematical models tailored to different goals. In every case, the governing principle would be to maintain viable populations of predators, while attempting to maintain natural age-sex distributions. Alternative goals might include maximizing lion populations in areas where tourism or commercial hunting are of primary interest; designing livestock management systems to minimize both depredation on livestock and the need to kill problem lions and hyenas; and designing culling recommendations to minimize predator incursions into limited areas of intensive livestock production.

BIBLIOGRAPHY

Creel, S., and N. M. Creel. 1997. Lion density and population structure in the Selous Game Reserve: evaluation of hunting quotas and offtake. *Afr. J. Ecol.* 35. In press.

Estes, R. D. 1991. *The Behavior Guide to African Mammals.* Berkeley, Calif.: University of California Press.

Frank, L. G. 1986. Social organisation of the spotted hyaena (*Crocuta crocuta*). I: demography. *Anim. Behav.* 34:1,500-1,509.

------. 1995. Female masculinization in the spotted hyena: endocrinology, behavioral ecology, and evolution. In John Gittleman, ed. *Carnivore Behavior, Ecology and Evolution (Vol. II).* Ithaca, N.Y.: Cornell University Press.

Frank, L. G., K. E. Holekamp, and L. Smale. 1995. Dominance, demographics and reproductive success in female spotted hyenas: a long term study. In A. R. E. Sinclair and P. Arcese, eds. *Serengeti II: Research, Management, and Conservation of an Ecosystem.* Chicago: University of Chicago Press.

Gustavson, C. R., J. R. Jowsey, and D. N. Milligan. 1982. A 3-year evaluation of taste aversion for coyote control in Saskatchewan. *Jour. Range Manage.* 35:57-59.

Holekamp, K. E., J. O. Ogutu, L. G. Frank, H. T. Dublin, and L. Smale. 1993. Fission of a spotted hyena clan: consequences of prolonged female absenteeism and causes of female emigration. *Ethology* 93:285-299.

Kingdon, J. 1982. *East African Mammals: An Atlas of Evolution in Africa.* London; New York: Academic Press.

Kruuk, H. 1972. "The Spotted Hyena." University of Chicago Press.

Kruuk, H. 1976. Feeding and social behaviour of the striped hyaena (*Hyaena vulgaris* Desmarest). *E. Afr. Wildl. J.* 14:91-111.

------. 1981. "The Effects of Large Carnivores on Livestock and Animal Husbandry in Marsabit District, Kenya." IPAL Technical Report E-4. UNEP-MAB Integrated Project in Arid Lands.

Leakey, L., et al. 1994. "Expedition Ebu Nagira: Study of the Diet of the Striped Hyaena (*Hyaena hyaena*) in Lothagam, Northern Kenya." Unpublished report.

Mizutani, F. 1997. Can livestock ranches and leopards coexist? A case study in Kenya. *J. Wildl. Cons.* In press.

Packer, C. 1990. "Serengeti Lion Survey: Report to TANAPA, SWRI, Mweka, and the Game Department." Unpublished report.

Packer, C., and A. E. Pusey. 1983a. Adaptations of female lions to infanticide by incoming males. *Amer. Nat.* 121:716-728.

------. 1983b. Male takeovers and female reproductive parameters: a simulation of oestrous synchrony in lions (*Panthera leo). Anim. Behav.* 31:334-340.

Planning and Assessment for Wildlife Management. 1995. Returns from tourist hunting in Tanzania. In N. Leader-Williams, J. A. Kayera, and G. L. Overton, eds. *Tourist Hunting in Tanzania.* Dar es Salaam, Tanzania: Tanzania Department of Wildlife.

Pusey, A. E., and C. Packer. 1987. The evolution of sex-biased dispersal in lions. *Behaviour* 101:275-310.

Revusky, S., and E. Bedarf. 1967. Association of illness with prior ingestion of novel foods. *Science* 155:219-220.

Roelke-Parker, M. E., L. Munson, C. Packer, R. Kock, S. Cleaveland, M. Carpenter, S. J. O'Brien, A. Pospischil, R. Hofmann-Lehmann, H. Lutz, et al. 1996. A canine distemper virus epidemic in Serengeti lions (*Panthera leo*). *Nature* (London) 379: 441-445.

Schaller, G. 1972. *The Serengeti Lion.* Chicago: University of Chicago Press.

Smuts, G. L. 1978. Effects of population reduction on the travels and reproduction of lions in Kruger National Park. *Carnivore* 1:61-71.

Starfield, A. M., J. D. Sheill, and G. L. Smuts. 1981. Simulation of lion control strategies in a large game reserve. *Ecol. Model* 13:17-28.

Venter, J., and M. E. Hopkins. 1988. Use of a simulation model in the management of a lion population. *S. Afr. J. Wildl. Res.* 18:126-130.

Yamazaki, K. 1996. Social variation of lions in a male-depopulated area in Zambia. *J. Wildl. Manage.* 60:490-497.

ANNEX: THE LAIKIPIA CARNIVORE SURVEY QUESTIONNAIRE

In conducting his research, the author surveyed Laikipia residents using the following questionnaire.

Laikipia Carnivore Survey

Please answer all questions for your property and experience only. When asked about depredation habits and wildlife prey of different carnivores, for instance, rely on your own experience rather than what you have heard from others.

For the sake of brevity, most of the questions are in tabular form. This yields many unanswerable or spurious questions for some species: I don't expect anyone to distinguish sex of hyenas or jackals, and no one is likely to have accurate figures for cubs produced, except possibly for lions on some properties. Other spurious questions would include number of groups of leopards, jackals, or striped hyenas.

For the purposes of analysis, it is much easier to deal with numbers or percentages rather than simple verbal description. Thus, when I ask about population or depredation trends since 1990, or your desired population five years from now, please answer in percentages or numbers, even when those are very broad estimates. Thus, it is far more useful if you guess that the cheetah population, for instance, has increased by 200 percent or decreased by 75 percent rather than say it has increased or decreased "a lot." I have no way of knowing if "a lot" means 10 percent or 1,000 percent.

So that I can better estimate the costs of protecting livestock against predators, several difficult questions ask you to apportion certain costs among several different functions. Thus, herders have a variety of simultaneous duties: They prevent animals from straying, watch for sick or pregnant animals, and watch for predators and thieves. I ask you to estimate how much of your herding effort (or costs) can be attributed to each function. Similarly, I ask you to estimate the importance of each predator in the anti-predation portion of those overall costs or efforts.

Another way I try to get at the same question is by asking if you could reduce your herding staff or use bomas under hypothetical situations of either no predators, no stock theft, or neither, keeping in mind that the animal care problems still exist. There are similar questions about security staff costs (not including livestock staff) and boma use.

Some specifics:

Carnivore questions:

Questions 3-4: How often in YOUR daily experience on your property do you see and hear the various species?

Questions 26-29: Of those individuals culled, what proportion were taken under each circumstance?

Question 30: If you are presented with dead livestock, how certain can you be that a given predator was responsible for killing it?

Questions 40-44, 60-64: Of those cattle and sheep killed by predators, what proportion were killed under each circumstance?

Question 45: How often do lions approach or circle your bomas WITHOUT successfully stampeding cattle out of them? If your bomas are particularly good or bad at keeping cattle from stampeding, please explain at the bottom of one of the sheets.

Questions 52-55, 71-74: For any given depredation event, how likely are you to take each action? Equivalently, out of 10 events, in how many would you take each action?

Questions 58, 77: Has your response to depredations by each predator changed over the last six years?

Questions 91-93: Do you ever keep herds out of a specific area, or move them to another boma, because certain predators are active in that area?

Questions 95-97: If an animal is left out of a boma at night, what is the likelihood of its being killed by each predator on a given night? Equivalently, if a head of stock is out on 10 different nights, on how many nights would you estimate that it might be killed by each predator?

Headman or gunman system: Some ranches bring several herds of cattle together in one large divided boma each night and have a senior herdsman who has overall responsibility for counting all those herds coming in at dusk and going out in the morning. On other properties, each herder is solely responsible for his own herd. If your own system is particularly effective (or ineffective) at preventing strays, please describe and comment on one of the pages.

CARNIVORES AND LIVESTOCK

	A	B	C	D	E	F	G
1		LION	SPOTTED HYENA	LEOPARD	CHEETAH	STRIPED HYENA	JACKAL
2	Estimated Population, 1997						
3	Seen (daily, weekly, monthly, yearly)						
4	Heard (daily, weekly, monthly, yearly)						
5	Population trend since 1990 (%)						
6	Desired Population in 2005						
7	Livestock Depredation Trend since 1990 (percent change)						
8	Number of Groups on Property						
9	Cubs Produced in 1996						
10	Favoured Habitat #1						
11	Favoured Habitat #2						
12	Favoured Habitat #3						
13	Favoured Wildlife Prey #1						
14	Favoured Wildlife Prey #2						
15	Favoured Wildlife Prey #3						
16	Total Number Culled in 1996						
17	Adult Males Culled in 1996						
18	Adult Females Culled in 1996						
19	Juvenile Males Culled in 1996						
20	Juvenile Females Culled in 1996						
21	Total Number Culled in 1995						
22	Adult Males Culled in 1995						
23	Adult Females Culled in 1995						
24	Juvenile Males Culled in 1995						
25	Juvenile Females Culled in 1995						
26	Percent Shot Following Stock Depredation						
27	Percent Trapped Following Stock Depredation						
28	Percent Poisoned Following Stock Depredation						
29	Percent Shot on Sight						
30	Percent Certainty of Identifying this Species as Killer When Stock are Killed						
31	Percent Stock Killers that are Adult Males						
32	Percent Stock Killers that are Adult Females						
33	Percent Stock Killers that are Juvenile Males						
34	Percent Stock Killers that are Juvenile Females						

CARNIVORES AND LIVESTOCK

	A	B	C	D	E	F	G
35		**LION**	**SPOTTED HYENA**	**LEOPARD**	**CHEETAH**	**STRIPED HYENA**	**JACKAL**
36	Would you Sport Hunt on your Property (Lions and Leopards only)?						
37	If Sport Hunting, your Desired Population in 2005?						
38	Humans Killed in Last Ten Years						
39	Humans Injured in Last Ten Years						
40	Percent Cattle Taken at Night						
41	Percent Cattle taken by Day						
42	Percent Cattle taken from Bomas						
43	Percent Cattle Taken from Herd by Day						
44	Percent Cattle Taken as Strays at night						
45	Percent of Attacks on Bomas that are Unsuccessful (Lions Only)						
46	Number Cattle Killed in 1996 (including calves)						
47	Value of Cattle Killed in 1996'(including calves)						
48	Number of Cattle Killed in 1995 (including calves)						
49	Value of Cattle Killed in 1995 (including calves)						
50	Percent of Cattle Killed that Were Adults						
51	Percent of Cattle Killed that were Calves						
52	Percent of Cattle Kills that you Follow up by Hunting						
53	Percent of Cattle Kills that you Follow up by Trapping						
54	Percent of Cattle Kills that you Follow up by Poisoning						
55	Percent of Cattle Kills that you do not Take Action						
56	Percent of Cattle Kills that you Report to KWS for Action						
57	Adequacy of KWS Response (none, acceptable, excellent)						
58	How Does Your Current Response to Cattle Killing Differ from 1990?						

CARNIVORES AND LIVESTOCK

	A	B	C	D	E	F	G
59		**LION**	**SPOTTED HYENA**	**LEOPARD**	**CHEETAH**	**STRIPED HYENA**	**JACKAL**
60	Percent Shoats Taken at Night						
61	Percent Shoats taken by Day						
62	Percent Shoats taken from Boma						
63	Percent Shoats Taken from Herd by Day						
64	Percent Shoats Taken as Strays at Night						
65	Number Shoats Killed in 1996 (including lambs/kids)						
66	Value of Shoats Killed in 1996 (including lambs/kids)						
67	Number of Shoats Killed in 1995 (including lambs/kids)						
68	Value of Shoats Killed in 1995 (including lambs/kids)						
69	Percent of Shoats Killed that Were Adults						
70	Percent of Shoats Killed that were Lambs/Kids						
71	Percent of Shoat Kills that you Follow up by Hunting						
72	Percent of Shoat Kills that you Follow up by Trapping						
73	Percent of Shoat Kills that you Follow up by Poisoning						
74	Percent of Shoat Kills that you do not Take Action						
75	Percent of Shoat Kills that you Reported to KWS for Action						
76	Adequacy of KWS Response (none, acceptable, excellent)						
77	How Does Your Current Response to Shoat Killing Differ from 1990?						
78	Number Camels Killed in 1996						
79	Value of Camels Killed in 1996						
80	Number of Camels Killed in 1995						
81	Value of Camels Killed in 1995						

CARNIVORES AND LIVESTOCK

	A	B	C	D	E	F	G
82		**LION**	**SPOTTED HYENA**	**LEOPARD**	**CHEETAH**	**STRIPED HYENA**	**JACKAL**
83	Number Horses and Donkeys Killed in 1996						
84	Value of Horses and Donkeys Killed in 1996						
85	Number of Horses and Donkeys Killed in 1995						
86	Value of Horses and Donkeys Killed in 1995						
87	Do you Ever Keep Cattle out of Certain Areas to Avoid this Species						
88	Do you Ever Keep Shoats out of Certain Areas to Avoid this Species						
89	Do you Keep Camels from Certain Areas to Avoid this Species						
90	Percent of Cattle Strays at Night that Would be Killed by this Species						
91	Percent of Shoat Strays at Night that Would be Killed by this Species						
92	Percent of Camel Strays at Night that Would be Killed by this Species						
93	**COMMENTS**						

LIVESTOCK

	A	B	C	D	E
1		**CATTLE**	**SHOATS**	**CAMELS**	**HORSE/ DONKEY**
2	Typical Number of Stock in a Normal Year				
3	Average Value of One Head				
4	Stock Stolen and not Recovered in 1996 (number)				
5	Value of Stock Stolen in 1996				
6	Stock Stolen and Not Recovered in 1995 (number)				
7	Value of Stock Stolen in 1995				
8	Risk of Stock Theft Compared to 1990 (percent change)				
9	Stock that Died of Disease in 1996 (total number, including young)				
10	Value of Stock that Died of Disease in 1996 (including young)				
11	Stock that Died of Disease in 1995 (total number)				
12	Value of Stock that Died of Disease in 1995				
13	Total Annual Veterinary Costs (Dawa, Dipping, etc.) for Stock (KShs.)				
14					
15	Head Per Herd (average)				
16	Herders per Herd (by day)				
17	Percent Day Herders Armed with Shotgun				
18	Shot Size				
19	Do you Use a Headman or Gunman System whereby one Man has Overall Responsibility for several Herdsmen (yes or no). Please Describe Below				
20	Number of Dogs with Herd by Day				
21	Are Dogs Effective at Warning Against Predators (no, somewhat, very)				
22	Head per Boma at Night				
23	Do You Graze This Stock at Night (percent of nights)?				
24					
25	COMMENTS OR SUGGESTIONS (use back if necessary)				

RANCH CHARACTERISTICS AND ECONOMICS, HERDING PRACTICES AND BOMA CONSTRUCTION

	A
1	
2	Area of Property (acres)
3	Percent that is Thick Bush
4	Percent that is Open Grassland
5	Percent that is Broken Bush and Grassland (e.g. Whistling Thorn)
6	Percent that is Forest
7	Percent that is Escarpment/Rocky Hills
8	Kilometers of River (semi-permanent water)
9	Number of Boreholes
10	Number of Dams
11	Villages and Herders' Camps
12	Total Human Population (incl. families)
13	Area under Cultivation (acres)
14	Wildlife Preserve (acres)
15	Percent Gross Income From Cattle
16	Percent Net Income from Cattle
17	Desired Percent Net Income from Cattle in five years
18	Percent Gross Income from Shoats
19	Percent Net Income from Shoats
20	Desired Percent Net Income from Shoats in five years
21	Percent Gross Income from Camels
22	Percent Net Income from Camels
23	Desired Percent Net Income from Camels in five years
24	Percent Gross Income from Horses/Donkeys
25	Percent Net Income from Horses/Donkeys
26	Desired Net Income from Horses/Donkeys in five years
27	Percent Gross Income from Wildlife Cropping
28	Percent Net Income from Wildlife Cropping
29	Desired Percent Net Income from Wildlife Cropping in five years
30	Percent Gross Income from Tourism
31	Percent Net Income from Tourism
32	Desired Percent Net Income from Tourism in five years
33	
34	Would Increased Tourist Income Cause you to Decrease Livestock (by what percent?)
35	When Possible, would you Offer Sport Hunting on your Property?
36	What Percent of Your Net Income Would You Like to Earn from Sport Hunting?
37	If You Offered Sport Hunting, Would You Reduce your Livestock (percent of current level)?
38	
39	Total Number of Herders and Boma Nigh Guards
40	Total Herders Wages (KSh./year)
41	Can You Apportion Herding Costs between Predator Protection / Theft Security/ and Stock Care? (%/%/%)
42	Can You Apportion Predator Protection Among Lion/Hyena/Leopard/Cheetah/Jackal ? (%/%/%/%/%)
43	
44	
45	If There Were No Predators, by How Much Could you Reduce the Number of Herdsmen (percent)
46	If There Were No Theft, by How Much Could you Reduce the Number of Herdsmen (percent)
47	If There Were Neither Predators Nor Theft, by How Much Could you Reduce the Number of Herdsmen (percent)
48	
49	
50	Total Number of Security Personnel (Not Herders or Boma Night Guards)

RANCH CHARACTERISTICS AND ECONOMICS, HERDING PRACTICES AND BOMA CONSTRUCTION

	A
51	Total Security Wages (KSh./year)
52	Security Vehicle Costs (KSh./year)
53	Security Radio Costs (KSh./year)
54	Firearms (Ammunition, permits, replacement KSh./year))
55	Other Security Costs KSh./year)
56	Total Security Costs per Year
57	Can You Apportion Security Costs Between Predators and Theft (%/%)
58	Can You Apportion Predator Security Costs Among Lion, Hyena. Leopard, Cheetah. Jackal (%/%/%/%/%/%)
59	
60	
61	Number of Bomas (Total)
62	Thorn Bomas (percent of total)
63	Cost of Thorn Boma (KSh.)
64	Height of Thorn Bomas (feet)
65	Thickness of Walls of Thorn Bomas (feet)
66	How Many Years Is a Thorn Boma Usable
67	Does Building a Thorn Boma Degrade the Habitat Locally (no, somewhat, severely)
68	Wire Bomas (percent)
69	Cost of Wire Boma (KSh.)
70	Height of Wire Boma
71	Other Boma Construction (Type, percent of total, height)
72	
73	Number of Night Guards on duty per Boma
74	Percentage of Night Guards Armed with Firearm
75	Are Night Guards Effective against Predators (no. somewhat, very)
76	Number of Dogs per Boma at Night
77	Are Dogs Effective for Warning (no, somewhat, very)
78	
79	Can You Apportion the Function of a Boma between Keeping Stock Inside, and Keeping Predators Out (%/%)
80	
81	Would You Still Use Bomas if There Were Theft but No Predators (yes, no)
82	What Type of Boma Would You Use if there were No Predators
83	Would You Still Use Bomas if there were Predators but No Theft
84	What Type of Boma Would You Use if there were No Theft
85	Would You Still Use Bomas if There Were No Predators and No Theft (yes, no)
86	What Type of Boma Would You Use if there were No Predators and No Theft
87	
88	
89	If we initiate a major study of livestock and predators in the District, would you be willing to participate in any way. eg.:
90	Would you be willing to let us radio collar predators on your property?
91	Would you be willing to allow us to radio track animals on your property, after prior notification?
92	
93	
94	IS THERE IMPORTANT INFORMATION THAT WE HAVE NOT ASKED FOR?? WE WOULD BE GRATEFUL FOR ANY ADDITIONAL COMMENTS OF ANY LENGTH. COMMENTS ON EFFICACY OF DIFFERENT HERDING SYSTEMS OR BOMA