Chapter 17

Impact and Value of Wildlife in Pastoral Livestock Production Systems in Kenya: Possibilities for Healthy Ecosystem Conservation and Livestock Development for the Poor[1]

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Introduction

Despite decades of habitat loss, some parts of East Africa are still unrivalled in diversity and abundance of wildlife. The traditional pastoral approach to livestock husbandry has always been considered compatible with and complementary to wildlife. In Kenya, more than half of the wildlife habitat is outside protected areas in communal grazing lands and group ranches, where wildlife, people, and livestock all interact and compete for the same natural resources. As human population has increased, agriculture has expanded into more marginal areas and formerly open communal grazing lands have been transformed into high-density rural settlements of small-scale farmers engaged in cultivation and livestock grazing (Aligula *et al*. 1997, Reid *et al*. 1999). Pastoralists whose range has become too restricted for traditional livestock grazing practices have increasingly turned to agriculture (Thompson *et al*. 2002). As the pressure on land becomes more intense, there is considerable potential for conflict between wildlife and people over grazing land, predation of domestic livestock, and disease transmission. Wildlife populations have been adversely affected by these changes. In the Mara ecosystem, for example, populations of some herbivores have declined by nearly 60% over the last two decades (Ottichilo *et al*. 2000, Said 2003).

The situation is serious across East Africa and if solutions are not found, wildlife will disappear in the very near future. One way that wildlife can be conserved in shrinking pastoral areas is if socioeconomic benefits from wildlife can be realised by the pastoral communities, and negative wildlife-related impacts such as disease and predation minimised. Recent research (Nuding 1996, Homewood *et al*. 2001, Ashley and Elliott 2003, Barnes *et al*. 2003) has indicated that returns from integrated wildlife and livestock production can be higher than returns to either enterprise on its own. In order to maintain or, in most cases, restore a healthy ecosystem, economically attractive solutions must be developed and implemented.

We conducted in-depth socioeconomic surveys at the household level in two semi-arid areas in an attempt to quantify both positive and negative impacts of wildlife for pastoral households raising livestock. In Laikipia and Kajiado districts, wildlife numbers have been fairly stable over two decades, with some species increasing in number (Peden 1987, Rainy and Worden 1997, de Leeuw *et al*. 1998). Both communal and commercial ranches support wildlife in these districts and, although they cover relatively small areas, they are increasingly important for Kenyan wildlife conservation. The goal was to quantify wildlife-related costs and benefits to a range of communities where livestock are being raised in close proximity to wildlife.

Ideally, such a study would follow particular households over several years and average the costs and benefits over the period to "smoothen" within and across seasonal (e.g., rainfall) variability. However, we are particularly interested in the relationship between the different causes of losses (e.g., losses due to disease compared with losses due to predation), and thus a one-shot survey across different communities facing similar environments is appropriate for gathering this type of information. Communities we selected are from agro-ecologically similar zones, but there are more sociological and ecological differences between Laikipia and Amboseli than between individual Laikipia communities. Noting these limitations, it would nonetheless be interesting to quantify the relative costs and benefits attributable to similar factors. For example, there are four major limiting factors that pastoralists perceive: grazing competition, water competition, disease, and predation (Muthiani 2001). This paper will focus on quantifying the latter two factors in the livestock production systems studied.

Disease imposes a significant cost to both livestock ranching and pastoralism (Homewood and Rodgers 1991, Mizutani 1995, Karani *et al*. 1995, Maddox 2003). In a study spanning 23 years, losses to disease were found to be twice as high as the total annual losses due to carnivores (Mizutani 1995). If disease transmission can be minimised in a livestock/wildlife system, it is critical to explore whether the impact of the losses of livestock to carnivores, and of the competition

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between livestock and wild herbivores for feed and water, is manageable. The economic benefits of livestock production are self evident, but wildlife, too, is valued in the culture and economics of pastoral communities. The longer-term question that this research explores, but does not yet answer, is what the optimal ratio of livestock to wildlife density is where livestock and wildlife continue to coexist with people. Maintaining this optimal ratio would minimise costs due to disease and death, prevent degradation of land/range resources, and allow for sustainable utilisation of wildlife as an asset.

Wildlife is often regarded as a danger to livestock production by Western livestock producers, who are concerned with perceived increases in the risk of infectious diseases. Management usually involves controlling and eliminating disease "carriers" or "reservoirs" in wildlife populations. Evidence exists, however, that livestock may actually better tolerate pathogens in the presence of wildlife (Ford 1971, Waller and Homewood 1997, Barre *et al*. 2001), and that by adopting certain improved husbandry practices, it may be possible to limit disease outbreaks while managing the coexistence of livestock and wildlife. Western science sees "health" as normal and "disease" as abnormal (Waller 2004) and tries to fence the diseased areas out (van Sittert 2002), whereas African herders regard disease as natural and inevitable, and potentially as a stable part of the environment. Pastoralists are aware of the vulnerability of animals that lack acquired immunity, and use movement and controlled exposure to endemic diseases (Ford 1971) as protection against epidemic outbreaks. They may accept limited losses to safeguard their herds. Current research on disease control emphasises the importance of naturally acquired immunity and of accepting lower productivity as a price to pay for less expenditure on disease control and reducing risk of infection (Baker *et al*. 2003). Arguably, the best methods of disease prevention have thus arisen through indigenous knowledge of the causes of disease. Kenyan traditional herders appear to have evolved husbandry practices that can accommodate wildlife and disease (Waller and Homewood 1997). A primary strategy has been to move the animals across landscapes and to alternate grazing areas so as to avoid disease outbreaks and predation. Such use of pastures implies that there is sufficient available land to provide isolation of infected herds and to protect the remaining animals from the outbreak.

Regarding household income sources, the poorer the household, the higher is the importance of available natural resources (including wildlife) to rural incomes and livelihoods (Scoones *et al*. 1992, Cavendish 2000). This is especially true for the semi-arid areas, where farming is not a viable land-use option and more natural resources are available and used for multiple purposes. However, when a few individuals take the bulk of the income derived from natural resources (Swanson and Barbier 1992, Ribot 1998, Emerton 1999a, Emerton 1999c), and in cases in which transparency in managing communal benefits from those resources is missing, differences in wealth will only be accelerated by community-based enterprises (Emerton 1999b, Rutten 2002, Thompson and Homewood 2002).

Background

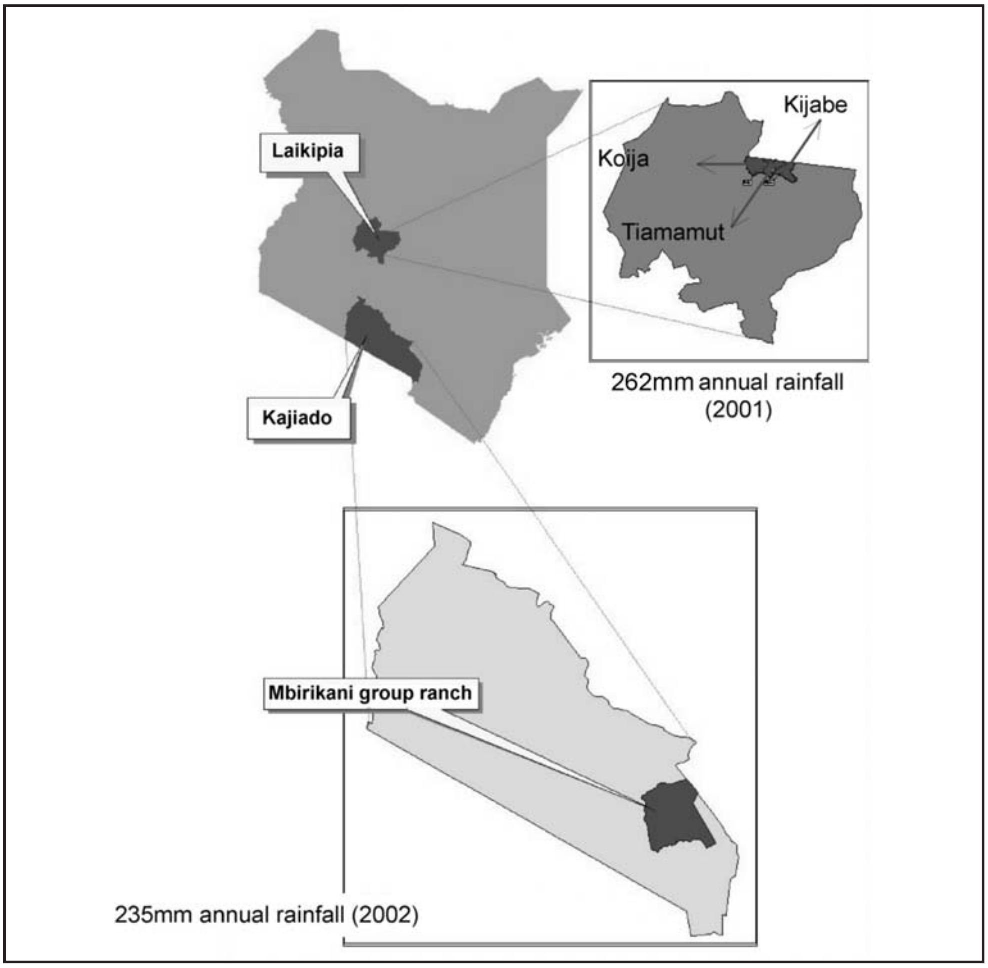
Agricultural development of East Africa in the 1970s was influenced by a paper published by Hardin in *Science* in 1968 called "The Tragedy of the Commons." Hardin proposed that land degradation was occurring due to the overstocking of livestock arising from a traditional system in which land was owned communally, leading to a lack of incentives to manage it properly in the long run. The Kenyan Government began encouraging private land ownership in pastoral systems, with the aim of intensifying and commercialising livestock production. The first major step towards privatisation came in 1968 with the introduction of the Group Land Representatives Act, which provided for the adjudication of group ranches (Bekure *et al*. 1991, Rutten 1992). Group ranches are organisational structures in which a group of people have a freehold title to land, although their livestock are owned and managed individually. Under the Kenya Livestock Development Project, the Mukogodo Reserve in northern Laikipia was divided and adjudicated into 13 group ranches in the late 1970s, while in Amboseli, this process had occurred during the 1960s.

Materials and methods

Tiamamut, Kijabe, and Koija group ranches in Laikipia, and Mbirikani group ranch in Amboseli, Kajiado district, hereafter referred to as Laikipia 1, Laikipia 2, Laikipia 3, and Amboseli, were chosen as study sites (Fig. 1). The four study sites are in agro-ecological zone VI (semi-arid to arid land with rainfall less than 700mm, suitable for ranching). The Laikipia group ranches are on the border between Laikipia and Isiolo districts in northern Kenya. The Amboseli group ranch is northeast of Mt. Kilimanjaro, within the Amboseli National Park/Tsavo National Park wildlife corridor. The detailed ecologies of the study areas are described in reports by Mizutani (2002a, 2002b). According to the Farm Management Handbook of Kenya (Jaetzold and Schmidt 1983), the sites are characterised as upper midland ranching zone with moderate-to-low soil fertility (Laikipia 1 and Laikipia 3) or variable soil fertility (Laikipia 2), and lower midland ranching zone with moderate-to-low soil fertility (Amboseli). Ecotourism is a more recent development in Laikipia than in Amboseli.

Data were collected from March 2001 to March 2002 in Laikipia, and from April 2002 to March 2003 in Amboseli. In terms of animal health and livestock production, the year monitored was considered by the community as an average/good year for Laikipia and a bad year for Amboseli. Annual rainfall during the monitoring was 262mm in Mukogodo (LRP 2002), Laikipia, and 235mm in Mbirikani, Amboseli. The long-term mean annual rainfall, which is biomodal with temporal and spatial variation, is 446mm for Mukogodo (Mizutani 2002b), Laikipia, and 350mm (Altman *et al*. 2002) for Amboseli. The estimated wildlife biomass, excluding elephants, is estimated to be 11kg/ha in both Laikipia and Amboseli, using the air census data from Georgiadis and

Fig. 1. Koija, Tiamamut, and Kijabe group ranches of Laikipia district and Mbirikani group ranch in Amboseli district



Ojwang' (2001) and unpublished air census data from Bonham in 1999.

Community members were trained to conduct a questionnaire regarding household income and to undertake participatory monitoring of livestock production with 100 households at each group ranch. The households were selected randomly from each village within a ranch. The survey was structured in four sections. In the first section, general information was collected about the household, including information on schooling of children and on distribution of bomas and livestock. Socioeconomic variables such as sex, age, marital status of respondents, and family composition, all of which affect resource use, were also recorded. The second section dealt with the structure of herds, transfers, and parameters of livestock production; it covered all transfers seasonally, including births, losses due to stillbirths, abortion, slaughter, donation, and sale, and all deaths due to diseases, predation, accidents, lost animals, theft, and drought. Additionally, information on milk production and domestic consumption, and on other factors such as timing of weaning, price realised at sale, and weights of different types of animals, was collected. The third section dealt with other economic activities such as honey revenue, crops, and off-farm income. Crop production was recorded in terms of inputs and outputs, including domestic consumption of crops.

The final section of the questionnaire dealt with interventions aimed at reducing poverty in Laikipia and at reducing livestock losses due to wildlife in Amboseli. In addition, for the Amboseli community, ages of herders of different types of livestock were recorded, as were interventions that the households knew of or took to reduce predation losses. Questionnaires were open-ended and allowed for multiple entries.

Livestock productivity is difficult to measure. While the data are collected over a relatively short period, the longer-term breeding life cycles of the animals in the herd and the composition of the herd must be taken into account. The livestock off-take and related parameters of the livestock production systems were analysed using the Livestock Production Efficiency Calculator (LPEC) model (PAN Livestock Service 1991, Peeler and Omore 1997), and estimated production costs established in a recent survey of Maasai households in Kitengela, Kajiado District of Kenya (Kristjanson *et al*. 2002). The LPEC model calculates a value for the production of the herd over a certain period based on the nutrition of the animals (obtained from forage, including grazing and crop-based feed resources). Productivity is expressed in terms of the ratio of the *value of output per unit of time* to the *value of input per unit of time*. Because it is difficult to estimate the economic value of feed, it has been proposed that the economic margin per unit of forage is an appropriate index for many livestock production systems (James and Carles 1996). Thus, the productivity measure used for this analysis was refined, becoming the ratio of the *value of output less the value of inputs other than forage* to *quantity of forage input*. The LPEC model is a valuable tool to assess the sensitivity of productivity to various production parameters and to identify the most promising areas for improvement strategies.

Data were collected according to a number of classes or types of animals. In the case of cattle, breeding females are defined as cows that have successfully calved. Replacement females are heifers used to replace cows. Surplus females are heifers that are surplus to requirements for maintaining a given herd size. This category is not commonly recognised within the target communities and almost all female stock is considered replacement. Because no distinction is made between replacement females and surplus females, in our case the same production parameters were used. Breeding males are defined as bulls of commonly recognized breeding age. Replacement males are young bulls not yet used for breeding. Surplus males are bulls reared for purposes other than breeding. The LPEC parametres such as mortality and culling rates, parturition rate, stillborn rate, and 24-hour survival rate are calculated on an annual basis. Livestock holdings were converted into tropical livestock units (TLU) to allow for comparisons between communities, in which 1TLU equals 250kg live body mass as defined by the Food and Agriculture Organization of the United Nations. The average body masses of the different management groups from previous studies were used to estimate the TLUs. For instance, in cattle, a breeding female is equal to 1TLU; a breeding male, 1.29; a replacement suckling, 0.40; a replacement weaned female, 0.70; a weaned male, 0.68; and a surplus weaned male, 1.05TLUs. For sheep, a breeding female is equal to 0.11TLU and a breeding male, 0.15TLUs. For goats, a breeding female is the equivalent of 0.11TLU and a breeding male, 0.17TLUs.

Because natural resources such as grazing, water, wild plants, and fruits are communally owned, the outputs of the pastoral economic activities come from a shared ecosystem. Therefore, we aggregated the results from 100 households to calculate the total output from livestock production in one locality. The community members also found it easier to interpret the results with such an aggregation. The number of adult equivalent (AE) and TLUs were estimated at the level of 100 households to avoid taking means of different clusters of non-normally distributed samples.

Results

Livestock holdings and socioeconomic characteristics of households in Laikipia and Amboseli

Table 1 summarises the land and livestock resources for each of the communities. The communities in Laikipia own less than a quarter of the livestock kept by the Amboseli community, indicating that the Laikipia communities are relatively poorer, at least in terms of livestock assets, than the Amboseli community studied. The Laikipia communities had far fewer cattle, with less than one-eighth of the cattle holdings of the surveyed Amboseli community.

The results from the questionnaire on herd dynamics are summarised as the proportion of annual off-take due to mortalities and net culling in relation to herd size (Table 2). While cattle production in Laikipia 3 does not appear to be viable (with a mortality rate of 72% in 2001), the Laikipia 2 and Amboseli communities are keeping relatively stable herds. Cattle herd growth rates are 0% for Laikipia 1 and 3 while greater than 10% for Laikipia 2 and Amboseli (Table 3). Of the 37 households in Laikipia 3 that kept cattle, 38% purchased them recently or received them as gifts. However, no output from those animals had so far been recorded.

The pastoralists interviewed noted that crossbreeding local with exotic livestock improved the productivity of the livestock. Typically, crossbreeds make up close to half of the sheep herds, while goat herds are made up of almost totally indigenous breeds. Crossbred sheep suffer higher mortalities (Table 2) than indigenous goats, and the growth rates of goats are higher (Table 3). On the other hand, half of the cattle in Amboseli are crossbreeds, but cattle in the Laikipia communities are mainly indigenous (Table 4). The breakdown of the various causes of mortality (Table 5) indicates that cattle herds in Laikipia 1 and 3 and Amboseli suffered significant losses due to drought during the year of the survey. As the surveyed year was considered a bad year for Amboseli, these cattle spent half the time away from the homesteads (6 months) seeking water and grazing. In Laikipia 1 and 2, cattle stayed away for 7 and 9 months, respectively. In Laikipia 3, cattle hardly left the homestead within the ranch, and it was here that the highest milk off-take was recorded. For the four communities surveyed, the reduction of income due to drought was highest in Amboseli.

The estimated annual net income from livestock per adult equivalent (Table 6) was approximately US $147 for Laikipia 1, US $155 for Laikipia 2, and US $141 for the Amboseli community, while for Laikipia 3, it was negative (–US $9). Net annual livestock income per TLU ranged from –US $8 to US $61 in Laikipia communities and was US $21 in Amboseli. The breakdown of livestock production revenues and profits suggests that the current cattle production systems of these communities are relatively unprofitable, while more income is earned from sheep and goats, particularly amongst the poorer Laikipia communities.

Table 1. Land and livestock resources of the surveyed households (hh) (100 per site)

Site	Compensation or revenue from wildlife	Density of wildlife without elephants (kg/ha)[1]	Surveyed period and rainfall in % of long-term average rainfall	Agro-ecological zone	Total hhs in the surveyed sites	Total AE of 100 hh	Total TLU of 100 hh[2]	TLU per AE[3]	Size (ha)[4]	Grazing areas used (ha)[5]
Laikipia 1 Conservation trust established in 2002	**No**	**10.7 (+ 3.1)**	March 2001–March 2002 59%	Upper midland ranching zone	121	**391.9**	**Total 936** cattle 369 sheep 240 goats 327	2.4	5,215	115,000
Laikipia 2 Construction of a community-owned lodge in progress					136	**458.7**	**Total 1,166** cattle 539 sheep 243 goats 383	2.5	6,323	122,200
Laikipia 3 Community-owned lodge constructed and in operation since 2001	**Yes**				193	**456.2**	**Total 535** cattle 204 sheep 199 goats 408	1.1	7,641	113,800
Amboseli Lodge in operation since 1986; new community-owned lodge proposed		**11.0 (+0.2)**	April 2002–March 2003 67%	Lower midland ranching zone	490	**711.2**	**Total 4,754** cattle 4,152 sheep 302 goats 301	6.6	33,741	>381,250

[1] *Sources (Georgiadis and Ojwang' 2001; Bonham, unpublished data); figures in parentheses are density of elephants.*
[2] *The Laikipia communities hold some camels but they are excluded in this calculation.*
[3] *The concept of AE (adult equivalent) is based on the differences in nutrition requirements according to age and sometimes sex. It assumes that the life-cycle stages have an important influence on the needs of members or individuals of the same household. The study adopted the consumption weights used by the Ministry of Finance and Planning in Kenya, GOK (Government of Kenya 2000). Age 0–4 (years) = 0.24 AE, age 5–14 (years) = 0.65 AE, age 15+ (years) = 1.00 AE. TLU = tropical livestock unit.*
[4] *Total area covered by this survey was an entire group ranch in Laikipia, and three out of four villages, where the majority of the people reside in Amboseli.*
[5] *Laikipia communities utilise the areas that belong to absentee landlords as grazing lands, while 92% of the Amboseli community graze within the group ranch. The grazing area available outside the group ranch is currently being analysed using GIS.*

Table 2. Annual livestock off-take rates of four sites (aggregation of 100 hh)

	Annual off-take rates (%)			
	Laikipia 1	Laikipia 2	Laikipia 3	Amboseli
Cattle				
Net culling	9	16	6	9
Mortality	22	7	72	6
Sheep				
Net culling	18	24	28	9
Mortality	21	25	24	16
Goats				
Net culling	14	2	18	11
Mortality	12	12	19	13

Table 3. Annual livestock growth rates at four sites

Site	Growth rates (per year)		
	Cattle	Sheep	Goats
Laikipia 1	0%	7%	17%
Laikipia 2	15%	3%	11%
Laikipia 3	0%	2%	1%
Amboseli	12%	7%	7%

Table 4. Percentage of indigenous livestock kept by communities

Site	Indigenous livestock (%)		
	Cattle	Sheep	Goats
Laikipia 1	93%	53%	100%
Laikipia 2	86%	63%	100%
Laikipia 3	92%	43%	100%
Amboseli	47%	47%	72%

Table 5. Annual mortality of livestock by different causes

Causes of death	Total deaths per year (%)			
	Laikipia 1	Laikipia 2	Laikipia 3	Amboseli
Cattle				
Disease	81%	78%	7%	67%
Predation	9%	9%	3%	11%
Drought	5%	0%	84%	10%
Theft and gone missing	2%	0%	2%	10%
Snake bite	0%	0%	0%	0%
Other	3%	12%	4%	3%
Sheep				
Disease	59%	64%	48%	60%
Predation	22%	25%	15%	18%
Drought	7%	0%	0%	0%
Theft and gone missing	11%	7%	21%	12%
Snake bite	0%	3%	7%	0%
Other	1%	1%	8%	2%
Goats				
Disease	49%	66%	34%	59%
Predation	34%	20%	35%	18%
Drought	3%	0%	5%	10%
Theft and gone missing	9%	12%	12%	12%
Snake bite	0%	1%	7%	0%
Other	5%	1%	6%	1%

Table 6. Estimated net annual income from livestock

Source	Estimated net annual income (US$)			
	Laikipia 1	Laikipia 2	Laikipia 3	Amboseli
Cattle	3,837	19,663	-20,558	76,054
Sheep	19,288	13,754	2,064	11,690
Goats	34,430	37,875	14,260	12,344
Total net income per 100 hh	57,555	71,293	-4,234	100,088
Income/AE	147	155	-9	141
Income/TLU	61	61	-8	21

Table 7. Estimated net annual income from various sources

Source	Estimated net annual income (US$)			
	Laikipia 1	Laikipia 2	Laikipia 3	Amboseli
Livestock	57,555	71,293	-4,234	100,088
Off-farm	10,377	11,530	12,062	8,419
Honey related	6,829	0	11,175	187
Crops	0	0	0	5,986
Food relief	18,359	25,188	24,744	9,915
Wildlife related	0	0	16,053	1,964
Total net income per 100 hh	93,119	108,010	59,800	126,559
Net income per year per AE	238	235	131	178
Net income per day per AE	0.7	0.6	0.4	0.5

Total annual net income was calculated on the basis of 100 households for each group ranch. Estimated annual net income aggregated for the 100 households varied from US $59,800 to US $126,600 (Table 7). When these figures are calculated in terms of income per person per day, all four communities fall below the international poverty threshold of US $1 per person per day. Included in this figure is estimated off-farm income, which includes wage earnings from both informal and formal employment, remittances from relatives and families, and income from business revenues such as brewing beer or selling firewood. It also includes wildlife-related income, coming from warrior dancing, craft sales, sales from a cultural manyatta, and direct employment related to tourism, such as game guiding or employment at tourist lodges. In Laikipia 3, 99% of the households had some off-farm income, while in other communities about 50% of the households had off-farm income. Bee keeping was practised by the majority of the households in Laikipia 3, by 33% of households in Laikipia 1, and by 8% of households in Amboseli. Of the Amboseli households, 27% had planted crops.

Livestock products, such as meat and milk, contribute more to total income than do other sources for Laikipia 1 and 2 and Amboseli. However, off-farm income, food relief, and wildlife-related earnings are higher than livestock earnings (which are actually negative [Table 6]) in Laikipia 3 due to the recent restocking and poor livestock husbandry.

During the household survey, the respondents were asked to treat 10 beans as their total income and to allocate them towards five types of income (livestock, off-farm income, honey revenue, food relief, and wildlife), so as to represent the relative importance of their household's livelihood sources (Fig. 2). This was cross checked against the total annual income (Table 7) and found to be very similar. Laikipia 1 and 2 and Amboseli communities rely mainly on livestock for their livelihoods. The Laikipia 1 and 2 communities do not perceive any direct or indirect benefits from wildlife. Laikipia 3 shows greater diversification of income sources, with households on average receiving 13% of their total income from honey and 18% from wildlife (ecotourism). The survey also revealed that government food relief represents a substantial part of overall household income in all four communities. Off-farm sources of income are relatively small across the communities.

Fig. 2. Mean contribution of different income sources to total income as perceived by household members (n=100)

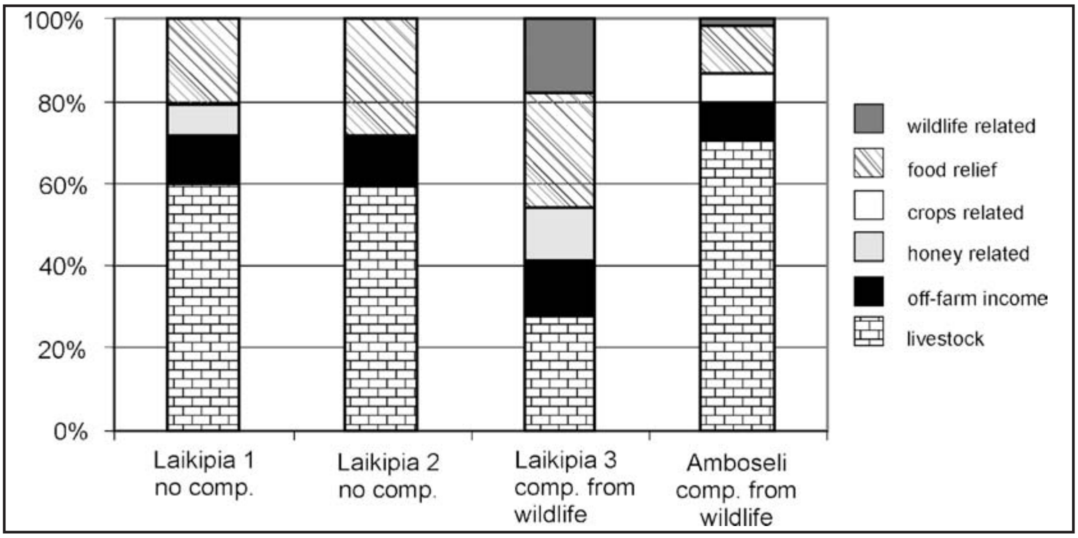
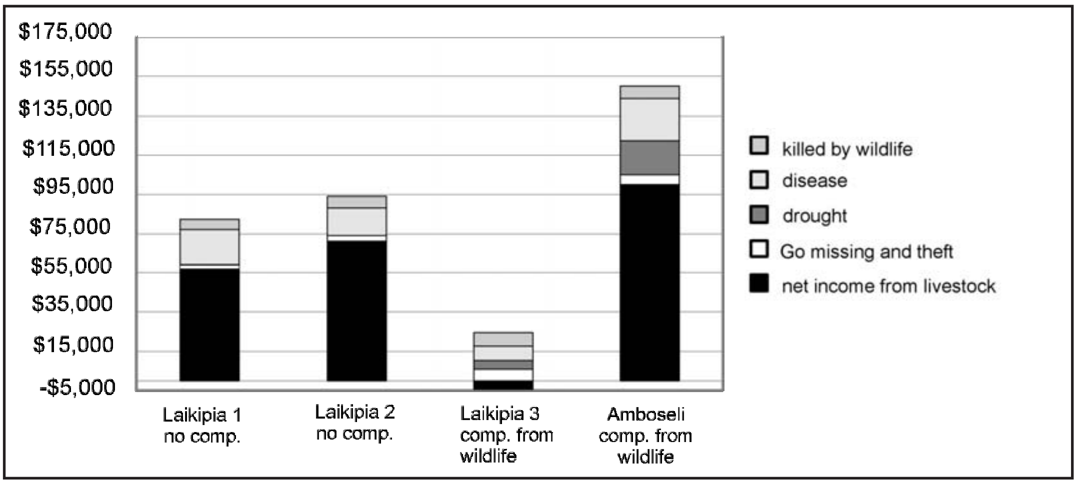


Fig. 3. Estimated net income from livestock compared with costs of losing livestock (lost revenue in US$) by cause of loss



Impact of disease and predation on livestock production

Losses to disease result in the most significant costs associated with livestock production across all four communities (Table 8 and Fig. 3), although losses from predation (including livestock killed by buffalo and elephant) are regularly absorbed as well. Diseases had the highest impact on net revenue from livestock across all communities, and lost revenue due to predation was similar across the communities. The Amboseli survey respondents listed the following interventions to reduce or minimise predation losses: improved herding during the day (13 %), better and secure bomas (night kraal, 100%), keeping dogs (48%), fire at night (18%), and having a night guard at the boma (7%). One quarter of respondents reported taking some action to reduce the predator population, but less than half (44%) of them experienced satisfactory results. This seems to indicate that there is a threshold point beyond which losses due to predation become unacceptable to these households, and they then take action to reduce predators.

Regarding losses to predation, sheep and goats are more likely than cattle to be killed by predators (Table 5). One reason is that sheep and goats are more often herded by children younger than 16 years old who may be less capable of deterring predators (90% of herders for sheep, 86% for goats, 66% of herders for cattle).

We estimated losses due to disease and predation in terms of lost income (Table 8) and found that the diseases that the communities perceived to be caused by wildlife, such as tick-borne diseases and malignant catarrhal fever (MCF) do not present as high a cost as other diseases that are not associated with wildlife. The Amboseli community claimed during the feedback meetings that MCF was a wildlife hazard. However, the cost of the losses due to MCF turned out to be less than the costs due to anthrax or diarrhoea. Estimated lost revenues from livestock to tick-borne diseases

Table 8. Annual cost of major diseases and predation

Disease or predator	Lost income (US$)			
	Laikipia 1	Laikipia 2	Laikipia 3	Amboseli
Contagious bovine/caprine pleuropneumonia	3,425	5,780	3,551	22,351
Tick-borne diseases	6,172	6,323	2,749	-703
Anthrax and blackquarter	0	0	0	5,053
Diarrhoea and scouring	1,236	2,300	13	3,813
Lumpy skin disease and sheep pox	682	3,805	0	1,470
Lions	756	748	1,602	3,009
Hyaena	2,259	2,764	4,736	2,436
Leopards	906	2,979	1,563	501
Cheetahs	508	0	35	0
Wild dogs	829	0	16	0
Total	16,773	24,699	14,265	37,930

are not a problem in Amboseli but are significant in Laikipia. The highest losses experienced by all four communities are caused by two major diseases, contagious bovine and contagious caprine pleuropneumonia (CBPP and CCPP), found particularly in the Amboseli community.

Discussion

The total TLUs we found in Laikipia were similar to those reported by Herren (1990), and our findings for Amboseli are within the ranges of published literature showing TLUs for this area (Bekure *et al*. 1991, S. BurnSilver, personal communication). According to nutrition requirement estimates, 5TLUs are required to obtain the necessary food intake annually to sustain one adult in similar current pastoral systems (Lamprey 1983, Schwartz 1993, Aligula *et al*. 1997). Thus, livestock production in Laikipia communities (1.2–2.5TLUs per AE) alone cannot provide food security for the Laikipia communities, and diversified sources of food and income are necessary to maintain livelihoods. The total net income per person per day was also well below the commonly used international standard measure of poverty (US $1 per person per day). They are closer to the Kenyan poverty line of Ksh 1,239 per person per month, which is roughly US $198 per person per year (CBS 2003).

Findings from a large-scale livestock/wildlife ranch with an extensive livestock production system using mobile bomas and herders in Laikipia (Mizutani 1995, 1999a, 1999b) are consistent with the results of this study. First, the percentage of deaths due to predation across all four communities studied is similar. Second, the different causes of mortality in Laikipia and Amboseli communities concur with observations made on the ranch (Mizutani 1995, 2002c). However, the traditional strategy of using space to isolate infected herds and to outrun the outbreak of disease seems to have been lost within the pastoral communities. Smaller stock are also more vulnerable to predators due to their body size. Across all four communities, animals were lost to theft and had gone missing.

Considering the loss of livestock to theft, missing animals, and predation, herders are more likely to blame predators than other causes particularly if losses might be due to their own negligence. Opportunistically, predators often kill livestock that has gone missing. If not, livestock may succumb to diseases out of the sight of the herder, and then be scavenged by predators.

Our findings suggest that husbandry interventions (diagnosis and treatment of diseases, and improved hygiene, herding, and security) and management efforts aimed at sustainability of the habitat of natural prey species are essential in the effort to contain livestock losses in mixed systems.

Crossbreeding of livestock with exotic types is likely to result in an increase in types and prevalence of diseases and thus an increased requirement for animal health care (Ayalew *et al*. 2003, Baker *et al*. 2003). The Amboseli community members had more crossbred cattle than the Laikipia communities, and this may explain the lower net output of the cattle production system in Amboseli during a year of relatively low rainfall (crossbreeds require more forage than do indigenous cattle). Mastitis was also reported to be a major problem in the crossbred Amboseli cattle, reducing milk production significantly during this poor year.

The idea that natural prey might act as a buffer against livestock losses to predators (Mizutani 1999a) was not a concept recognized by community members interviewed. Instead, the increasing number of wild herbivores is perceived as increasing the competition with livestock for scarce forage. This contrasts with the experience in the Marsabit area (northern Kenya), which is currently being studied, where depletion of natural prey is coinciding with increasing livestock losses to hyaena. The Kitengela area, located adjacent to Nairobi National Park is also experiencing high losses of livestock to lions during a period of declining wild herbivore populations. Investigations of losses of livestock to predators at different wildlife biomass densities are ongoing to try to identify a threshold wild herbivore density that correlates with contained livestock losses (Serneels *et al*. 2002).

Conclusions

We confirmed that there are certainly wildlife-associated losses in pastoral livestock production areas (outside protected areas) where wildlife numbers have been maintained or have increased in recent years. We found, however, that the estimated losses due to wildlife, both by disease and predation, are in fact negligible.

Losses to disease are much higher than losses to predation, and diseases that are not transmitted by wildlife impose much higher costs than do those most likely transmitted by wildlife. These findings are from a 1-year survey only, and ideally one needs to capture the stochastic nature of the sub-Saharan ecosystems. However, similar findings are reported from a long-term study of a mixed livestock/wildlife system in Laikipia (Mizutani 2002c).

Our findings show that these communities face a poverty challenge, with most households earning far less than US $1 per person per day. But we have also found evidence that healthy ecosystems and conservation of wildlife can contribute to improved incomes for poorer livestock keepers. Within such mixed systems, there is ample room for improvement of livestock husbandry on the basis of the identified major problems in the livestock production systems (Bekure *et al*. 1991, Grandin *et al*. 1991, IDL Group 2003). Such improvements include prevention of diseases, limiting losses due to drought, better security, improvements in basic hygiene for young stock, and prevention as well as treatment of mastitis to increase milk yield. Implementing basic vaccination schemes against such diseases as anthrax or limiting zoonotic diseases such as coenurosis are potential strategies for improved productivity within these poor communities. (Maasai people in these areas were reportedly once resistant to anthrax and therefore consumed carcasses after the animals died. However, the Amboseli community claims that today an increasing number of people suffer from this disease.)

Other possibilities include improved herding practices during the day and guarding the animals at night, as well as more tolerance for natural prey species populations that will act as "buffer zones" for predators and thus avoid or minimise livestock predation losses. Such developments will increase the likelihood of stemming the loss in biodiversity in East Africa while providing sustainable livelihoods for its people. Longitudinal and cross-sectional monitoring and evaluations (Bayer and Waters-Bayer 2002, Catley and Mariner 2001) will assist communities to better evaluate their productivity levels and to develop collective community-based action plans. Above all, benefits from wildlife likely offer the most important opportunity for these poor pastoralists in terms of income diversification possibilities. National natural resource and wildlife management policies urgently require attention if impoverished pastoralists are to benefit directly from natural resources such as wildlife. Better use of existing livestock and interventions to improve livestock productivity (e.g., increased use and sale of milk, appropriate crossbreeding practices for cattle and sheep) also offer opportunities for enhanced livelihoods. Promoting ecosystem health and livestock development for the poor can substantially contribute to the maintenance of biodiversity in an area where so many of the world's large mammals can still be found.

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