People, Wildlife and Livestock in the Mara Ecosystem: the Mara Count 2002

The Mara count

the count that counts

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Acknowledgments

Well done!
The Mara count 2002 was truly a team effort in every sense of the word. The count owes its existence and success to the 22 vehicle counting teams, 3 aircraft counting teams, 20 organisations and 84 individuals who counted in the rain and mud and contributed vehicles, lodging, airplanes, communications equipment, food, t-shirts, writing and filming expertise, GIS and statistical analysis help, counting practice help and venue, fuel, website help, engineering expertise, and moral support. We were all overwhelmed with the support and good will given so freely by so many. We list the people here who contributed and we give this report to you: this is your hard work and your accomplishment! We say a very big 'thank you' to all involved. It was an honour and pleasure to work with you.

Mara Count 2002 supporters

Overall count sponsors: Rainy family, Campfire Conservation, Narok County Council, Mara Wildlife Trusts, Koyiaki Group Ranch, Olkinyei Group Ranch, and the International Livestock Research Institute (ILRI).

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1. Summary

Why count?
The great savannas of eastern Africa -- cradle of humankind, home to traditional nomadic pastoralists, and last refuge of some of the most spectacular wildlife populations on earth -- are in trouble. Notwithstanding 20 years of highly committed wildlife conservation, much of the wildlife in several regions of Kenya and Uganda (and to a lesser extent, Tanzania) has disappeared in just the last 20 years. The Mara part of the Serengeti-Mara ecosystem is of particular concern because nearly 70% of the wildlife has been lost between 1976 and 1996. Pastoral peoples living in the Mara ecosystem have less livestock per person than they did 20 years ago, and about half survive today on an income of less than Ksh 70 ($1) per day per person. If these trends continue, it is probable that the Mara will support very few wildlife and poorer pastoral peoples 20 years from now.

What is jeopardising work to conserve the Mara's priceless wildlife populations and improve returns to pastoralists from wildlife is a lack of a unified effort, by all concerned, to join together to seek solutions. The Mara count is one such effort: a joint venture by pastoral peoples, conservationists, private industry, land managers and researchers to create an unparalled set of information to form the foundation of future decisions to conserve wildlife and develop pastoral peoples. This count owes its existence and success to the Mara pastoral communities, the Mara reserve management and the 22 vehicle counting teams, 3 aircraft counting teams, 20 organisations and 84 individuals who completed the count.

How did we count?

- Counted and mapped 43 species of wildlife and livestock, land use, bomas, vegetation, burns, tsetse, infrastructure, and vehicles.
- Covered 2,212 km^2 in the Maasai Mara Reserve and surrounding group ranches in Narok and Transmara Districts.
- Completed two dry season counts in 1999 and 2002.

What did we find?

- **How many?** There were 373 bomas, 2000 huts, 400,000 wildlife and livestock, 10 schools, 4 football pitches, 13 airstrips, 72 tourist lodges and camps, 7 veterinary dips, 10 cattle crushes, and 69 shops, and 250 fresh animal carcasses in November, 2002.
- **Human population growth:** There has been above average population growth rates due to immigration and local growth; 0.8 people/km^2 in 1950 to 14.7 people/km^2 in 2002.
- **Land use:** Less than 1% of the land area was *farmed or fenced* in 1999 or 2002, but they are expanding by 60-200% per year.
- **Paper and plastic:** About 75% of the rubbish was in the group ranches, with 25% in the reserve.
- **Vehicles:** Twice as many vehicles in the reserve as the ranches.
- **Green grass available:** There was more than twice as much *green grass biomass* in the reserve than group ranches. Also, there was more than twice as much green grass biomass in 2002 than 1999.
- **Cattle in the reserve:** We counted a quarter (1999) to a third (2002) of the ranch cattle herd within the reserve.

- **More wildlife in the reserve:** About 60% of the wildlife species are more abundant in the reserve than the group ranches, probably because of competition with livestock for forage.
- **What tourist want to see:** Concentrations of many species of wildlife (MSA's) disappear when there are too many settlements.
- **Not enough livestock:** Mara Maasai have only 25-35% of the number of livestock needed to support a pastoral lifestyle. Other income alternatives include cultivation of crops, consumptive use of wildlife, cultivation leases, remittances from family members living in the cities, employment in lodges, revenues from 'cultural manyattas', and tourism 'dividends' from wildlife associations.
- **Narok vs. Transmara:** There was no appreciable difference in the abundance of wildlife comparing between the Transmara and Narok parts of the reserve.
- **Private vs communal ranching:** There were fewer wildlife on Ol Chorro Oirowua (private) than the group ranches (communal).
- **Negative impacts of pastoral people on wildlife.** Some species avoid people, making protection in parks critical for their survival.
- **Positive impacts of pastoral people on wildlife.** Wildlife seem to be both attracted to and repelled by pastoral people. Some species prefer to be near people around water points and bomas, perhaps because they feel 'safer' there, either because predators are scarce or predators avoid people.

What does this new information mean?

- **Pastoralists can enrich biodiversity.** Our data here imply that pastoral communities, contrary to traditional views, can sometimes enhance biodiversity. These findings support other evidence that integrated livestock-wildlife systems are more productive than either livestock or wildlife systems alone, at least in East Africa. Conservation policy that excludes low to moderate levels of traditional pastoral use may inadvertently impoverish the very lands it was instituted to protect.
- **But many species need to live without people.** On the other hand, some wildlife species are best conserved in places with no people and no livestock. Any positive effects of pastoralism on wildlife break down when the density of settlements passes a certain point, which has been reached around the small villages in the group ranches of the Mara. Thus, we expect that further growth in the number of settlements in the Mara will result in further negative consequences for wildlife.
- **Land privatisation may deplete wildlife.** In the last 3 years, communities outside the reserve have begun to privatise the land and some families have split up in anticipation of land parcel allocation. We anticipate that this has and will have strong negative impacts on wildlife. If all the lands outside the reserve are privatised, we estimate that 40% of the wildlife will be lost, or 45,000 animals, and perhaps all the elephants and most carnivores.
- **Pastoralism does not provide enough.** The recent losses of wildlife in the Mara are partially caused by the fact that it is increasing difficult for the Mara Maasai to make ends meet through pastoralism. Pastoralists today are constantly searching for other options to support their families, and some are compatible with wildlife (tourism) and others are not (leasing land for wheat farming, high density settlement).
- **What can be done?** Managing the number and location of pastoral settlements in the Mara is key to protecting the remaining wildlife populations. It is crucially important that we make protected areas more effective, and, improve incentives for pastoral communities to maintain lifestyles compatible with wildlife by increasing returns from wildlife to pastoral peoples.

Website: Please see http://www.maasaimaracount.org

2. Why count? (Introduction)

2.1 Wildlife are being lost and pastoral peoples are poorer
The great savannas of eastern Africa -- cradle of humankind, home to traditional nomadic and transhumanent pastoralists, and last refuge of some of the most spectacular wildlife populations on earth -- are in trouble. Notwithstanding 20 years of highly committed wildlife conservation, much of the wildlife in several regions of Kenya and Uganda (and to a lesser extent, Tanzania) has disappeared in just the last 20 years[1]. The Mara part of the Serengeti-Mara ecosystem is of particular concern because nearly 70% of the wildlife has been lost between 1976 and 1996[2]. Pastoral peoples living in the Mara ecosystem have less livestock per person than they did 20 years ago, and about half survive today on an income of less than Ksh 70 ($1) per day per person[3]. If these trends continue, it is probable that the Mara will support many fewer wildlife and many more and poorer pastoral peoples 20 years from now. What is jeopardising work to conserve the Mara's priceless wildlife populations and improve returns to pastoralists from wildlife is a lack of a unified effort, by all concerned, to join together to seek solutions. The Mara count is one such effort: a joint venture by pastoral peoples, conservationists, private industry, land managers and researchers to create an unparalled set of information to form the foundation of future decisions to conserve wildlife and develop pastoral peoples.

[1] Rainy and Worden 1997, Said and others submitted, Lamprey and Mitchelmore 1996, Mduma 2000?
[2] Broten and Said 1995, Ottichilo and others 2000, Serneels and Lambin 2001.
[3] Lamprey and Reid submitted, Thornton and others 2002

2.2 Recent changes in land use in the Serengeti-Mara Ecosystem
Our hominid ancestors walked side-by-side with wildlife in this ecosystem as many as 3.7 million years ago[4]. Archaeologists have found evidence of pastoral people living in the Mara part of the system from about 2500 years ago[5]. The Kenyan government started protecting part of the Mara for wildlife only 50 years ago.

Currently, the Serengeti - Mara Ecosystem supports the most diverse migration of grazing mammals on earth[6]. The Mara, although only a quarter of the total ecosystem area, is crucial to the survival of the entire system because it is the source of forage for wildlife migrating through the Serengeti during critical points in the dry season. Only 25% of the wildlife habitat in the Mara part of the ecosystem is protected (in the Mara Reserve); the rest lies within pastoral and agricultural areas north of the reserve. These lands outside the reserve are also under more pressure than the rest of the ecosystem, with recent unprecedented human population growth, expansion of wheat farming in wildebeest calving grounds and expansion of tourism facilities[7].

In the last 3 years, communities outside the reserve have begun to privatise the land and some families have split up in anticipation of land parcel allocation. We anticipate that this has and will have strong negative impacts on wildlife. If all the lands outside the reserve are privatised, we estimate that 40% of the wildlife will be lost, or 45,000 animals, and

[4] Leakey and Hay 1979
[5] Marshall 1990
[6] Sinclair and Arcese 1995
[7] Dublin 1995, Ottichilo and others 2000, Homewood and others 2001

perhaps all the elephants and most carnivores[8]. We think that it is critical to monitor people, livestock and wildlife in the system at this time so that we can mitigate these changes before they occur.

2.3 Why count people, livestock and wildlife?

It is clear that we must keep close track of the wildlife and land use in the Mara ecosystem if wildlife are to survive and people are to continue to benefit from wildlife. We have several reasons for counting wildlife in the Mara ecosystem:

1. **Better information to more people.** We want to put high quality scientific information into the hands of pastoral communities, land managers, tourism businesses, tourists, and policy makers in a form that is useful and promotes communication and discussion.

2. **Keeping track of changes as they occur.** We must know how many people, wildlife and livestock are in the system and where they are so that we will know when major changes are happening.

3. **When and where is pastoralism compatible with wildlife conservation and when and where is it not?** We know very little about the interactions between people, livestock and wildlife. Collecting fine resolution information across the ecosystem will help us understand when and where people, livestock and tourism are compatible with wildlife and when and where they are not. We will also understand which species are tolerant of different ways people use the ecosystem and which species are not.

4. **Better decisions.** With all this information in hand, we all can make better decisions on how to manage livestock and wildlife.

5. **Team building and communication.** We want to bring together most of the people who live and work in the ecosystem into one team, who collect this count information, discuss it and learn from it.

6. **Faster action.** We hope to accelerate efforts to improve the livelihoods of pastoral peoples and to conserve wildlife in the Mara ecosystem.

2.4 Send us your comments

In this report, we try to present the count information as clearly as we can. We also interpret the meaning of that data, when the patterns in the data are very clear. However, we acknowledge that there are different ways to interpret the same piece of data, so we welcome any and all comments on our accuracy, interpretation and form. Please contact r.reid@cgiar.org or k.kimani@cgiar.org with any comments. Also, please see our website at http://www.maasaimaracount.org for further information and updates on our counting efforts.

[8] Reid and others 2001

3. What did we do and how did we do it? (Methods)

3.1 Counting area

In the 1980's, Mike and Judy Rainy and their students began counting wildlife, people, and livestock over wide areas of the Mara ecosystem at a fine resolution. Previous scientific efforts to monitor this ecosystem either collected information at very broad resolutions (5-by-5-km grids) or focused on detailed studies of particular species. The Rainys' realised that there was something missing: a clear picture of how people, wildlife, livestock and tourism interact over most of the ecosystem. This required collection of detailed information on many species at once; on people, their bomas, livestock, and tourism; and on vegetation, farms, fences and burns. These earlier counts were done at a 1-km resolution. In 1999, a larger team joined together and decided to collect this information in even more detail. The team invented a new way to count livestock, wildlife and people at a very high resolution (333-by-333-m grids) to create this very clear picture of how wildlife interact with people and their livestock. We developed this new finer resolution technique so that we could collect information with enough detail to be useful to pastoralists and land managers on the ground.

In mid-November 1999, we counted about 1,500 km^2, including the western part of Koyiaki Group Ranch, a westernmost piece of Lemek Group Ranch, the southwestern half of Ol Chorro Oirowua, and central portion of the Mara Reserve (see Map 1). This area is a bit more than 25% of the 5,500 km^2 ecosystem.

We counted the Mara ecosystem again from 9-16 November 2002, but this time we counted 2,212 km^2, about 50% more area than in 1999 or about 40% of the Mara ecosystem. The new areas included the Mara Triangle, eastern Koyiaki, the western corner of Siana Group Ranch and a small part of southwestern Olkinyei Group Ranch. Teams counted almost all of Koyiaki, leaving out only the Bardamat Hills, Aitong Hill and a small piece in the southeastern corner of the group ranch. We counted 86% of the Mara Reserve (1,309 km^2 counted of a 1,525 km^2 reserve) leaving out the southeastern corner, where bushland and hills make total ground counting difficult.

At the same time we counted, we contracted the Dept. of Resource Surveys and Remote Sensing of Kenya (DRSRS) to make a broader count of wildlife over Narok District from aircraft. Their count took place one week after the ground count. DRSRS scientists counted a 180-m strip down the centre of each 2.5-by-2.5-km contiguous block over the whole district. This new count will be comparable to the counts they have completed in the district since the 1970's. The Kenya Wildlife Service also counted the larger wildlife (elephants, buffalo, giraffe and eland) at a 1-by-1-km grid over most of the 5,500 km^2 Mara ecosystem in November 2002.

3.2 Counting methods in 1999 and 2002

We counted animals at a spatial resolution of 333 -by-333 m (see illustration in Figure 1). Using global positioning systems (GPS), our sampling teams navigated vehicles down the centres of each 1-by-1-km **block** of territory while allocating all animals observed into one of the nine nearest 333-by-333-m **sub-blocks**. When we were not sure of the precise location of an animal or group of animals, we drove to the spot it occupied to obtain a definitive GPS reading. With practice, we allocated animals accurately within sub-blocks when they were located within 0.5 km of our sampling teams on flat, featureless ground or within 1 to 1.5 km

Map 1. Study area for the 1999 and 2002 counts showing Mara reserve and group ranches.

where we clearly saw gallery forests, roads, hilltops or other features on our paper and digital topographic maps. From the maps of animal locations, we are developing detectability corrections for each species based on the size of each animal group and the distance from the observers to the animal group. Without the detectability corrections, these still results give a reliable picture of the distribution of animals and their relative abundances. With the corrections, we will have a reliable picture of population sizes and trends within the areas counted. Here, we report changes in numbers of animals between 1999 and 2002; these should be treated with some caution because the data have not be corrected for detectability (although we have no reason to believe our ability to detect animals differed significantly in the same areas between 1999 and 2002).

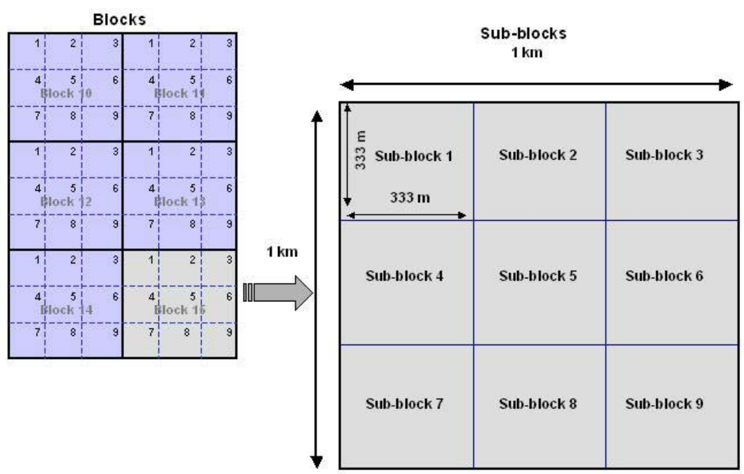

Figure 1. Illustration of counting blocks and sub-blocks for Mara ground counts in November 1999 and November 2002.

Months before the count, we contacted counting experts around the world to find a way to be able to create very accurate maps instantaneously in the field, as we collected the data. Many groups of researchers were thinking of developing a piece of equipment like this, but we could not find anyone who had done so yet. Our GIS team leader, Russ Kruska, decided to invent a new piece of equipment for the 2002 count to solve this problem, so that we could produce results more quickly and accurately than we ever have before. This new piece of equipment is made up of a Compaq Ipaq PocketPC (handheld computer) linked to a GPS, both running off power from a car cigarette lighter adaptor or car battery. We built a special fiber board and canvas holder for the handheld computers to protect from dust and breakage of the power and data plugs and sockets. The PocketPC contained maps of the area to be counted in the ESRI mapping software, ArcPad, which allowed the counting team to 'see' the landscape they were counting. We connected this to the GPS, so that the teams could see their precise location (within 4 meters) on the map (a moving red dot) throughout the count. For those teams without a handheld PC, we loaded the grid of blocks and sub-blocks into the GPS. Both of these tools allowed the teams to navigate very accurately through each block and sub-block within their counting areas. It also allowed us to locate and map all animal groups and other data more accurately than ever before. The ILRI team also created electronic data collection forms for the handheld computers that were connected directly to each sub-block on the map, so that the data could be recorded directly into the handheld computer in mapped form as it was collected. For the teams using the handheld computers, this allowed us to create maps of all the 155 data types we were collecting instantaneously. At the end of each day, all data in the handheld computers was transferred to a laptop so that we did not lose any information and the paper data served as a second copy of all data we collected. This method was a huge improvement over the previous methods of collecting this kind of data, which required entry of the data from paper data sheets into computer format after the count and then creation of maps from this data. The new method cut the time for map production from 6 months in 1999 to 1 month in 2002. For the remaining 8 teams that collected data only on paper, we assembled a team of our 6 best technicians to enter this data in 3 weeks after the count was finished. All teams collected all data on paper and about half of the counting teams also collected information on the handheld computers.

We had 22 vehicle teams, 3 aircraft teams and 84 people counting at the same time. Twenty-five Maasai pastoralists were part of the counting teams. Nearly all the counters were volunteers and all the vehicles and accommodation for the teams were donated for the count. Twenty organizations and 15 individuals waived use fees or donated their time, vehicles, and accommodation (see Acknowledgements above). More than 90% of the cost of this count and its analysis and publication have been contributed through volunteer efforts and in-kind contributions of all organizations and individuals concerned.

3.3 Animal species we counted

We counted 38 wild and 5 domestic animal species that were active during the day (see Table A1 in the Appendix for a complete list at the end of this report). We counted Kirk's dik-dik (*Rhynchotragus kirkii),* olive baboon (*Papio anubis*), vervet monkey (*Cercopithecus aethiops*), warthog (*Phacochoerus aethiopicus*), Thomson's gazelle (*Gazella thomsoni*), Grant's gazelle (*Gazella granti*), impala (*Aepyceros melampus*), topi (*Damaliscus korrigum*), Coke's hartebeest (*Alcelaphus buselaphus cokei*), wildebeest or white-bearded gnu (*Connochaetes taurinus albojubatus*), Defassa waterbuck (*Kobus ellipsiprymnus defassa*), Burchell's zebra (*Equus burchelli*), black-backed jackal (*Canis mesomelas*), bat-eared fox (*Otocyon megalotis*), eland (*Taurotragus oryx*), African buffalo (*Syncerus caffer*), Masai giraffe (*Giraffa camelopardalis tippelskirchi*), hippopotamus (*Hippopotamus amphibius*), African elephant (*Loxodonta africana*), 4 species of vultures, spotted hyena (*Crocuta crocuta*), lion (*Panthera leo*), cheetah (*Acinonyx jubatus*) and ostrich (*Struthio camelus massaicus*). We probably counted more than one species of jackal, mongoose, hyena, hare, duiker, but grouped these harder to distinguish species into the most abundant species we observed above. We also counted cattle, donkeys, dogs, and sheep/goats (called shoats). We estimate that our ground count underestimates the abundance of about half of the wild species we counted (23 of the 38 wildlife species) because we could not see them well for various reasons, as is explained in the methods section below. In order to improve our estimates of hippo numbers, one of our aerial teams (Lamprey) surveyed all known bodies of water from the air. The locations of all hippos were recorded on a GPS and paper data sheets, and later corrected for sightability.

3.4 Other information collected

We also collected a wide range of other information that we can use to explain why animals use different areas of the ecosystem more than others. These include the following:

1. **Animal carcasses.** We mapped the type, number and the decomposition state of wild and domestic animal carcasses that were still articulated (joined at the joints).

2. **Multiple species associations.** We mapped the location of all multiple species associations (MSA's) of wildlife. A multiple species association is a group of 2 or more species that graze in sight of each other (within 300 m of each other), probably for predator protection, to access particularly rich grass where soils are more fertile and/or to graze on more nutritious short grass[9]. We consider 2 species an association if they are within 300 m of

[9] Rainy and Rainy (1989), McNaughton (1990)

each other – animals farther apart than this are not interacting closely and do not form an MSA.

3. **Vegetation.** In the centre of each of the three central sub-blocks in each block, we visually estimated the percent cover of the herbaceous plants (%), the average height of the herbaceous plants (in meters), and greenness on a 20-point scale within a 2-by-2-m plot. One time per 1-km-by-1-km block, we also visually estimated the cover, height (in meters) and color of trees and shrubs across the whole block.

4. **Burns, cultivated fields (shambas), fences.** We mapped the location of all burns and recorded their age (recent or old). We also mapped the location and size of all shambas and fences of any type.

5. **Water sources**. We collected information about water sources from the ground and in the air. On the ground, each counting team recorded the locations and types of all water sources containing water during the count. These include wetlands, streams, rivers, ponds, dams, tanks, towers, wells and springs. From the air, one of our flight teams flew all the water-courses and recorded the presence and absence of water in streams and rivers. The team also marked all wetlands, springs, ponds, and dams visible from the air.

6. **Tsetse flies.** We recorded any presence of tsetse flies within the counting vehicle.

7. **Bomas (traditional Maasai settlements).** Each currently inhabited and abandoned boma was also mapped. At each boma, we counted the number of houses and recorded the type of roof on the house (dung, grass, or tin).

8. **Other infrastructure and rubbish (or trash).** In villages or towns, we counted all shops, schools, clinics, houses and other buildings. For houses, we recorded the type of roof. We also recorded all other infrastructure we saw like football fields, park gates, lodges (plus their type), and airstrips. We also recorded the presence of any rubbish in each sub-block.

9. **Vehicles.** We recorded the type and number of all vehicles we saw.

10. **Areas we did not sample.** We excluded from the count all areas with dense trees or shrub, those with too much rock to traverse in a vehicle and wetland areas we could not see into. This covered about 5-8% of the total counting area. Counting teams mapped all areas they did not count. We also missed collecting data for some areas during the count, but there are few areas missing.

3.5 What does this method count well and what does it miss?

Because much of the Mara is grassland with few trees, our ability to detect medium to large-sized animals is high. Even so, we miss some of the individuals of all species. A spotters' ability to see animals is affected by the size of the group of animals, how far away they are and what is blocking their view (shrubs, tall grass, sharply varying topography). It is also affected by animal behaviour. Our ground counting technique does a poor job of counting 23 of the 43 animal species we counted. We underestimated the abundance of species that are small and thus hard to see when counting (hare, mongoose, tortoise, honey badger, some carcasses), those that hide from prey (all six carnivores on land), those that inhabit wooded or bushy areas (bushbuck, dik-dik, buffalo, vervet), those active mostly at night (hyena, lion), those in rivers (hippos, crocodiles) and those that fly (vultures). In the tables that follow, all these species are indicated with a code (H for hidden species and S for small species) to distinguish them from other species that we counted relatively well. This second group that was counted well include 15 medium- and large-sized species of wildlife (for example, wildebeest, zebra, topi, Thompson's gazelles), all five species of livestock and other information on things that do not move (bomas, vegetation, burns, farms, fences). Even for the species we counted well, we missed some individuals[10]. We include all 43 species in our tables; note that the numbers for those species we did not count well are thus the smallest population size for that species in the part of the ecosystem that we counted. For the species we counted well, the count also represents a minimum population size, although this minimum is probably closer to the actual population size for these 15 species than the estimates for those species we did not count well. Species that we did not count well will need to be counted in a different way to obtain reliable information.

3.6 How we analysed the count data

We first entered into computer format all the data collected only on paper by 8 of our teams. We then combined these data with that from the 12 handheld PC's and 'sewed' together all the 21 separate counting areas into one set of maps. This required very careful checking so that the edges of each counting area fit together without losing or doubling any data. Once combined, we had a data set with 155 maps that included 43 species of wildlife and livestock, 9 vegetation characteristics and 103 other maps of other information about the Mara. The entire data set contains 3,265,872 numbers or data points. We then checked each of these data points by hand against the set of paper data that all teams collected in the field. Our team then created the maps in this report, carefully checking and re-checking any problems with the maps with the counting teams. We used the ESRI mapping software, Arc Info, Arc View and Arc Pad, for all mapping tasks.

We statistically analysed the data to understand how confident we can be that the numbers we counted were different in comparing from place to place and from one year to another. We first computed descriptive statistics including the total number of individuals, the density (number per km^2) and standard error of mean for each type of information we collected (wildlife, livestock, bomas, infrastructure, burns, tsetse, etc.). We separated the information in the reserve from that in the group ranches because we wanted to compare the two areas to each other. We also separated the reserve and group ranches into different regions as described above. We then compared each type of information between the group ranches and the reserve for each species separately for the 1999 and 2002 census data. We also compared the animal densities between 1999 and 2002 separately for the group ranches and the reserve. We used three different statistical procedures to test whether the densities differed statistically between the reserve and the group ranches or between years for each species. Two of the three statistical procedures consisted of Wilcoxon and Kruskal-Wallis tests. The third method was a repeated measures analysis of variance. Our analysis accounted for the fact that objects that are close to each other are usually more related to or dependent on each other (spatial autocorrelation) than ones that are far away. We accounted for spatial autocorrelation among density estimates made in all counting sub-blocks as well as blocks. Accounting for this spatial interdependence allowed us to use a wide range of tests (those above) so that we could test the reliability of our conclusions in different ways. All the three methods we used led to the same conclusions.

[10] Note that none of the data we have collected was corrected for sightability. We did collect information on group size and distance to each group, so the data can be corrected in the future.

We analyzed the distribution of animal densities from the nearest water source or boma using a negative binomial regression analysis. We first showed that the frequency distribution of animal counts made in each block was best described by a negative binomial distribution. We then did a regression of animal counts on distance to water (boma) defined as continuous variables and allowed for spatial dependence among the counts (spatial autocorrelation). The regression model also included an effect for region (ranch, reserve) and how this effect interacted with distance from water (boma). We then tested whether a linear or quadratic model better described the variation in animal counts with distance from water (boma) for each species. SAS statistical software was used for all statistical analyses.

4. What did we find and what might it mean? (Results and discussion)

4.1 General comments about the count information
We present two types of tables in this report. We compare numbers in the group ranches to those in the reserve in order to understand how the two areas differ for people, wildlife and livestock. We also split up the reserve and group ranches into administrative units. The reserve is presented in three divisions: 1) the Mara Triangle (or Conservancy), 2) the Musiara section and 3) the Sekenani section. These divisions are designed to mimic the broad management units used by the Conservancy and the Narok County Council. Outside the reserve, we also divide the group ranches into three parts: 1) Koyiaki Group Ranch, 2) Ol Chorro Oirowua, and 3) Other ranches. The last category includes small pieces of Lemek, Siana and Olkinyei Group Ranches.

There are three cautions to the reader in looking at these results:

1. First, as explained above, we think we counted 15 wildlife species well and another 23 not so well. However, we present the information for all species, and indicate these two groups in the tables.
2. Second, it is very important to only compare the density figures between different areas (for example, compare group ranches with the reserve; compare the Triangle with Musiara) because all these counting areas were of different sizes. We have shaded the density figures on all tables to help the reader to compare numbers by eye. The totals are presented to give an idea of minimum population size, but totals should not be compared across areas.
3. Third, whenever we compare numbers over time from 1999 to 2002 (for example in Tables 1-7), we make comparisons using only the part of the 2002 data that overlaps with the same area counted in 1999. This is indicated in the tables as 1999 (small) and 2002 (small); the information under the column marked 2002 (large) is all of the larger 2002 counting area.

4.2 How many people, livestock and wildlife were counted altogether in 2002?
We counted a 2,212 km^2 area in November 2002. In this area, teams counted 373 bomas, more than 2000 huts, and 400,000 wildlife and livestock (Table 1, also see Appendix Table A2 for the number of animals counted by each counting team). About 40% of all animals counted were wildebeest, 15 % were sheep and goats, 10% were cattle and 10% were zebra. These five species accounted for 75 % of all animals in the counting area. We also counted 250 fresh carcasses in the counting area (see Tables 7 and Appendix Table A6).

4.3 People, bomas and huts: where and how many, now and in the past
How many bomas in 1999? In 1999, we counted 256 bomas in the smaller 1999 counting area, with 246 in the group ranches and 10 in the Mara reserve (Table 1). There were 25 times as many bomas on the ranch than in the reserve. The number inside the reserve is probably about half this number because the reserve boundary drawn on the 1:50,000 maps from the Survey of Kenya (which we use here to define the boundary of the reserve) is different than that marked on the ground with cement markers. The ground markers are at least 300 m south of the mapped boundary in the Olare Orok area, which means that some of the bomas that we counted in the reserve, at least in this area, are actually outside the

Table 1. The total number, density (#/km^2) and standard error (SE) of Maasai bomas, huts, types of huts and human populations counted in the reserve and the adjacent group ranches in November 1999 and November 2002.

	1999 counting area (small)						2002 counting area (small)						2002 counting area (large)					
	Ranches (649 km^2)			Reserve (808 km^2)			Ranches (649 km^2)			Reserve (808 km^2)			Ranches (977 km^2)			Reserve (1,235 km^2)		
Variable	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE
Bomas	246	**0.379**	0.032	10	**0.013**	0.005	275	**0.424**	0.030	14	**0.017**	0.006	352	0.360	0.023	21	0.017	0.005
Dung-roofed huts	984	**1.517**	0.178	49	**0.060**	0.027	1,301	**2.005**	0.196	95	**0.118**	0.041	1,885	1.930	0.160	131	0.106	0.040
Grass-roofed huts	227	**0.350**	0.070	2	**0.003**	0.002	219	**0.338**	0.058	4	**0.005**	0.003	234	0.239	0.039	18	0.014	0.010
Tin-roofed huts	296	**0.456**	0.076	15	**0.019**	0.010	544	**0.838**	0.090	19	**0.024**	0.012	673	0.689	0.068	45	0.036	0.015
All huts	1507	**2.323**	0.236	66	**0.082**	0.036	2,064	**3.181**	0.260	118	**0.146**	0.051	2,792	2.858	0.003	194	0.157	0.006
Human population estimate*	6,947	10.705		304	0.469		9,515	14.661		544	0.838		12,871	13.714		894	0.724	
Proportion of dung-roofed huts		0.653			0.742			0.630			0.805			0.675			0.675	
Proportion of grass-roofed huts		0.151			0.030			0.106			0.034			0.084			0.093	
Proportion of tin-roofed huts		0.196			0.227			0.264			0.161			0.241			0.232	

*Human population estimate =Number of huts x 4.61 persons per hut (Lamprey, 1984).
Densities that differ significantly ($p<0.05$) between the group ranches and the reserve in each year are shown in **bold face**.
Densities that differ significantly ($p<0.05$) between 1999 and 2002 for each area are underlined.

reserve. Even so, there appears to be increased encroachment by pastoralists on the reserve.

How many bomas in 2002? In the same area counted in 1999, we counted 33 more bomas than in 1999, or 289 bomas, with 275 in the ranch and 14 in the reserve (Table 1, see 2002 smaller counting area, middle column). This is a growth rate of 13% or about 4.3% per year. The growth rate outside the reserve was 12% and inside the reserve was 40%, using the same reserve boundary (probably incorrect) as was used in 1999. There were 20 times more bomas in the group ranches than in the reserve in both years. In 2002, we also counted other areas not included in the 1999 count. These areas included the Mara Triangle in the reserve, and additional parts of Koyiaki and Ol Kinyei group ranches. In this larger counting area in 2002, we counted 373 bomas in the entire and larger 2002 counting area with 352 in the group ranches and 21 in the Mara reserve (Tables 1 and Appendix Table A3). Comparing parts of the reserve, boma density is about 2 times higher in the Triangle as Sekanani, and more than 2 times higher in Musiara than the Triangle. Across the group ranches, Koyaki supports 34% more bomas than Ol Chorro Oirowua.

Where were the bomas in 2002? Most of the bomas in 2002 were clustered near the small settlements of Mara Rianta, Talek, Sekenani, and between Aitong and Ol Doinyo Orinka (see Map 2). There is also a cluster of bomas between the Olare Orok and Ntiakitiak Rivers, just north of the reserve and upstream along the Olare Orok. The biggest group of bomas is in Talek, within 1 km of the boundary of the Mara reserve. The Triangle has 7 bomas, all near the northern entrance to the reserve. There are large areas of the group ranches with few or no bomas. These areas are north of Talek along the Talek-Aitong road, in eastern Koyiaki and west of the Ngorobop in Koyiaki. As can be seen if you look ahead to Map 12, the first two areas are heavily infested with tsetse flies and relatively far from water (Map 7 & 8), and the Ngorobop area is far from water, particularly in the dry season. Most of the bomas in the reserve appear to be in the Olare Orok area, although, as noted above, the boundary of the reserve used on our maps is incorrect by about 300 m in this area.

How many and what kind of huts in each boma in 1999 and 2002? The average boma on the group ranches had 6.1 huts in 1999; in 2002, each boma had 22% more huts or an average of 7.5 huts/boma (Table 1, Map 3). This means that the number of huts in the count area grew faster than the number of bomas between 1999 and 2002. The new huts in 2002 had either dung or tin roofs. On the group ranches, there were 32% more huts with dung roofs in 2002 than 1999. There were 83% more huts with tin roofs over these 3 years. In 2002, the bomas with only 1-2 huts were clustered near towns, with the exception of some along the Mara River. There were a few bomas with more than 20 huts and these are both near and far from towns. Between the Olare Orok and Ntiakitiak Rivers, none of the bomas had either very few or very many huts. Bomas in the reserve had 8% more huts (6.6 huts/boma) than bomas in the ranch (6.1 huts/boma) in 1999, and 12% more huts/boma in the reserve (8.4) than the ranch (7.5) in 2002.

The average boma had traditional dung roofs in 1999 and 2002 (Table 1 and A3, Maps 4-6). In 1999, 65% of huts had dung roofs; this fell slightly to 63% in 2002. The bomas in the reserve had more dung roofs than those on the group ranches. About 15% of the bomas had grass roofs in 1999, this fell by almost half to 11% in 2002. The proportion of huts in each boma with a tin roof rose from 20% in 1999 to 26% in 2002. This increase was only true for the group ranches; the number of tin roofs on bomas in the reserve decreased from 23% to 16% between 1999 and 2002.

Dung roofs are found on bomas throughout the count area, but a higher proportion of bomas away from towns have only dung roofs (Map 4).

More of the bomas on the western side of the count area have grass roofs, presumably from the influence of the Kipsigis people west of the Mara River (who use grass roofs, Map 5). Most of the tin roofs are in bomas in towns, although there is a wide scatter of tin roofs throughout the count area (Map 6).

How many people in 1999 and 2002? We estimate that the total number of pastoral people in bomas in the large 2002 counting area was about 13,765 in November 2002 (Table 1 and A3). This number is calculated from our counts of the number of huts per boma. Work by Richard Lamprey shows that about 4.61 people lived in each hut[11] in 1984. Comparing the smaller counting areas, human population density on the group ranches in 1999 was 10.7 people/km^2 and 14.7 people/km^2 in 2002. This is a 37% increase in human population in the group ranches in only 3 years (= about 12%/year). Inside the reserve, human populations, by our calculations, grew 79% in just 3 years (= about 26%/year). These growth rates either show a massive movement of people into the Mara area or that the number of people in each hut changed dramatically between 1999 and 2002 (which seems unlikely). Maasai on our team say that many families are building a tin-roofed hut in bomas for the 'mzee', which is for resting and for visitors. In some bomas, people do not sleep in the tin-roofed huts used for this purpose (in others they do). This means that the average number of people per hut is probably decreasing below the 4.61 people per hut counted in 1984. The ILRI team will make a follow up count of people per hut with community members in the second half of 2003 to verify these numbers.

How have human populations changed since the 1950's? Human population on these group ranches has increased steadily since the 1950's. According to Lamprey's figures, human population was about 0.8 people/km^2 in 1950, 2.5 people/km^2 in 1973, 5 people/km^2 in 1984 and 10/km^2 in 1999. These growth rates are above the national average for Kenya and are partly due to immigration of people from other parts of Kenya into the Mara Area[12]. Figure 2 below shows this dramatic increase.

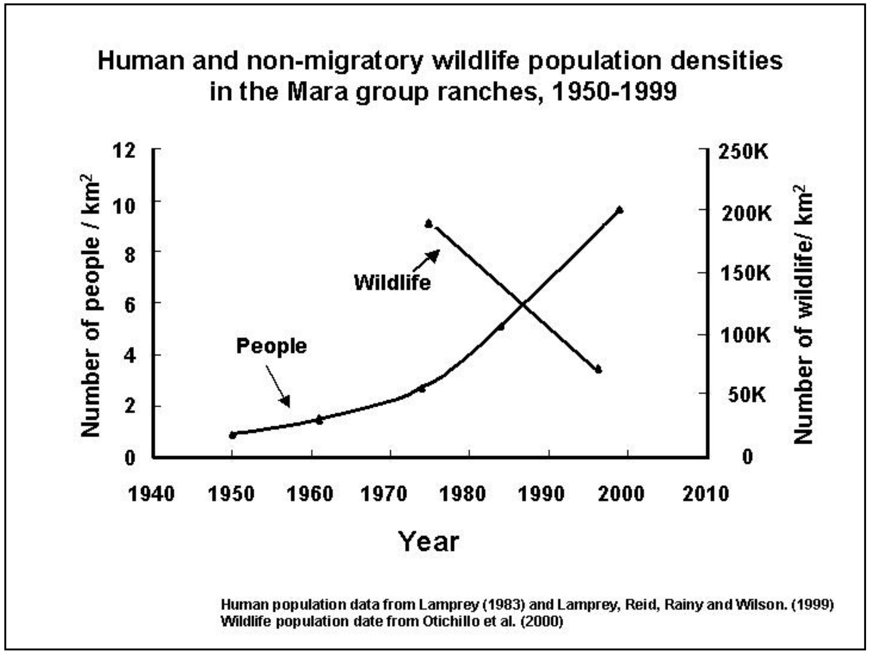

Figure 2. Estimated human population growth in Koyaiki and its surrounding group ranches from 1950 to 2002[13].

[11] Lamprey 1984

[12] Norton Griffiths 1995

[13] Lamprey, Reid, Rainy and Wilson, unpublished data

Map 2. Distribution of pastoral bomas (settlements) in the count area, November, 2002.

Map 3. Mean number of huts in each boma in the count area, November, 2002.

Map 4. Percentage of huts with dung roofs in each boma in the count area, November, 2002.

Map 5. Percentage of huts with grass roofs in each boma in the count area, November, 2002.

Map 6. Percentage of huts with tin roof in each boma in the count area, November, 2002.

4.4 Rainfall and the location of water, fences, farms, burns and tsetse flies

Rainfall.. Wet season rainfall was 34% lower in 1999 than 2002, but dry season rainfall was 32% greater in 1999 than 2002 (Figure 3). Wet season rainfall in the year immediately previous to each count was well above normal. Dry season rainfall in the 1997 and 1998 were slighter lower than the rainfall in the two years just before the 2002. Our impressions of the conditions in the field in the two count years were quite different: 1999 seemed quite a bit drier than 2002.

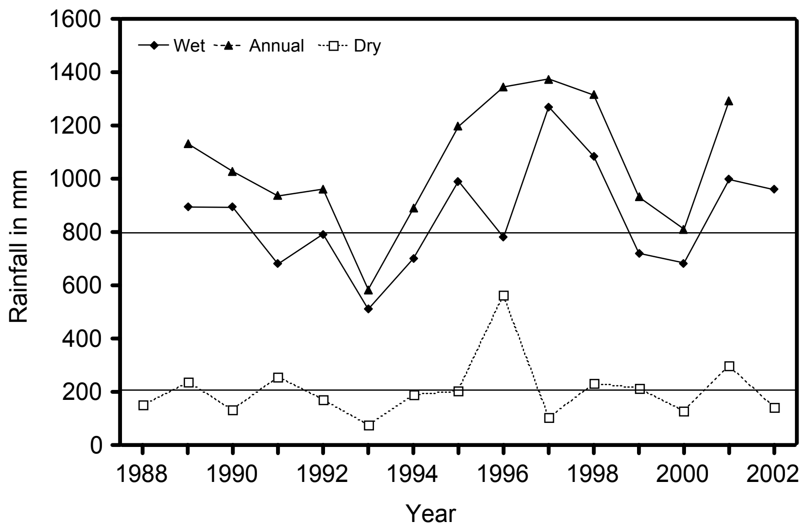

Figure 3. Total annual and seasonal rainfall from 1988 to 2002 in Talek.

Water. At the time of the count, all the principal rivers were flowing (Mara, Talek and Sand) and rains at the beginning of the count created pools in some of the secondary rivers (lower stretches of the Olare Orok, Ntiakitiak, and Ol Keju Gem; see Maps 7 and 8). Rain started 3 days before the count after a long period of dry weather. Thus, water was relatively abundant in certain parts of the area during the count, but had not been abundant for long and water was not nearly as abundant as it is during the wet season. Point sources of water away from rivers were widely scattered throughout the count area, with many more on the western and wetter side of the count area than on the eastern side. Much of eastern Koyiaki and the Sekenani part of the reserve had few sources of water except for the Talek and Sand Rivers.

Farming and fences in 1999 and 2002. Very little of the count area was cultivated for farming and even less of it was fenced either in 1999 or 2002 (Table 2, Maps 9 and 10). None of the Mara reserve was either farmed or fenced. However, there were significant changes in the three years between 1999 and 2002, with faster growth in the amount of land fenced than the amount of land farmed. About 0.21% of the group ranches were farmed in 1999; this more than doubled to 0.70% in November 2002. Most of the farms were medium to large in size both years (about 30-by-30 m to 100-by-100 m in size). Fenced areas took up less area than farms in both years. Some of the farms were fenced and others were not (thus there is some overlap in farms and fences). In 1999, 0.07% of the land was fenced, this increased more than 7 times to 0.53% in November 2002. The fenced areas were medium to large in size (30 x 30 m to 100 x 100 m in size). Most of the farming was in a large area within Ol Chorro Oirowua, with a few farms in Talek, Aitong and Ol Doinyo Orinka areas (Maps 9 and 10). Fenced areas were in Ol Chorro, along the road from Aitong to Mara Rianta, just west of the Ntiakitiak north of the reserve boundary, in the Talek area, and near Sekanani.

Map 7. Sources of surface water in the count area between 9-16 November 2002, as recorded during aerial surveys.

Map 8. Sources of surface water as recorded by ground counting teams between 9-16 November, 2002.

Table 2. The total area (km^2) and percentage burnt, cultivated, fenced or containing tsetse flies or rubbish in the reserve and the adjacent group ranches of the Mara in November 1999 and November 2002.

	1999 counting area (small)				2002 counting area (small)				2002 counting area (large)			
	Ranches (649 km^2)		Reserve (808 km^2)		Ranches (649 km^2)		Reserve (808 km^2)		Ranches (977 km^2)		Reserve (1,235 km^2)	
	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Large fenced area*	0.444	0.069	0.000	0.000	1.444	0.223	0.000	0.000	1.444	0.148	0.000	0.000
Medium fenced area	0.000	0.000	0.000	0.000	1.222	0.188	0.000	0.000	1.222	0.125	0.000	0.000
Small fenced area	0.000	0.000	0.000	0.000	0.778	0.120	0.000	0.000	0.889	0.091	0.000	0.000
Large shamba**	0.667	0.103	0.000	0.000	4.000	0.616	0.000	0.000	4.000	0.409	0.000	0.000
Medium shamba	0.444	0.069	0.000	0.000	0.556	0.086	0.000	0.000	0.556	0.057	0.000	0.000
Small shamba	0.222	0.034	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Recent burn	4.667	0.719	2.222	0.275	102.000	15.719	68.556	8.486	174.778	17.887	107.333	8.691
Old burn	0.333	0.051	0.000	0.000	2.000	0.308	23.556	2.916	6.667	0.682	24.000	1.943
Tsetse fly	19.889	3.066	1.111	0.137	14.556	2.243	3.111	0.385	45.667	4.674	4.444	0.360
Rubbish	12.667	1.953	5.444	0.674	14.000	2.158	6.000	0.743	18.778	1.922	6.667	0.540

*Fence: Large fenced area (>0.1 km^2); medium fenced area (0.01 to 0.1 km^2); small fenced area (<0.01 km^2).
**Shamba: Large cultivated area (>0.1 km^2); medium cultivated area (0.01 to 0.1 km^2); small cultivated area (<0.01 km^2).

Burns. About 1.0 % of the count areas were burnt in 1999; this increased by 27 times to 27.4% in 2002 (Table 2, Map 11). The 1999 count took place in the middle of a long and severe drought, and thus there was probably little grass to burn in 1999. There was a bigger difference in the proportion of the group ranches and reserve burnt in 1999 than in 2002; 200% more land was burned on the group ranches than the reserve in 1999; in 2002, only 50% more savanna was burned in the ranches than reserve. Most of the burns occurred within 1-2 months of the beginning of each of the counts (there were no old burns in the reserve in 1999 at all). In 2002, burns were widely distributed on the group ranches, but restricted to particular areas in the reserve. The only two large areas that were not burned in the group ranches were a large area northwest of Aitong and in and south of Ol Doinyo Orinka. In the reserve, only the eastern and western parts of the Triangle were not burned, and the large area south of the Ol Keju Gem River. The only large older burn was in the Keekorok area inside the reserve. None of the burned areas overlapped with where there were high concentrations of bomas, but many of the large burns were within 1 km of groups of bomas.

Tsetse flies. Our method of counting tsetse flies (we count flies only if we find them inside the vehicle) probably only measures the areas heavily infested with tsetse. Only a small part of either the group ranches or reserve were heavily infested either year; 2-3% of the group ranches were infested either year and 0.1-0.3% of the reserve were infested either year (Map 12, Table 2). However, the flies were much more common in the group ranches than in the reserve, infesting about 23 times as much area of land on the group ranches than in the reserve in 1999 and 5-6 times more in 2002. There are more flies in the group ranches probably because there is more wooded tsetse habitat here than in the reserve. Tsetse flies were also more common in 1999 than 2002 in the group ranch, but the opposite was true for the reserve. The area infested grew by almost 2 times in the group ranches from 1999 to 2002, but grew four times (twice as fast) in the reserve from 1999 to 2002, probably because the 1999 drought reduced the number of flies. Flies were most common in southeastern Koyiaki and just to the west of the Talek-Aitong road; these areas have the best tsetse habitat (see shrub and tree cover, Maps 20 and 23). We also found flies in an area on the mid-western edge of the Triangle near the Siria Escarpment. Most of the flies were in large patches that covered 10's of square km. As expected, people rarely established bomas in these tsetse belts. There were also few tourist lodges where there were tsetse flies! This is true even though some of the largest, multiple species associations of wildlife are found in the tsetse-infested areas.

4.5 Location of tourist lodges, other infrastructure, vehicles and rubbish

Lodges and other infrastructure. Nearly all the lodges were built along permanent water courses, with the exception of some mobile tented camps (Map 13). Most of the lodges are within the reserve or clustered along the Talek River near Talek village. There are 10 schools in the counting area, 4 football pitches, 13 airstrips, 72 tourist lodges and camps, 7 veterinary dips, 10 cattle crushes, and 69 shops (Map 14 of other infrastructure).

Rubbish. Even though we found rubbish in a small part of the count area, it was often common where we found it. Most of the rubbish was in the form of plastic bags. About 75% of the rubbish was in the group ranches, with 25% in the reserve. However, even on the group ranches, we found rubbish only in one of every 50 sub-blocks (2% of sub-blocks) we counted (see Table 2 above). Most of the rubbish was in town centers or around bomas in the group ranches, but the rubbish (probably left by tourists) was near roads in the reserve (Map 15). The amount of area covered with rubbish in the group ranches and the reserve did not change between 1999 and 2002 (see % figures in Table 2).

Vehicles. We counted 329 vehicles in the large count area in 2002 during the 5 days of the count, or 65 vehicles each day (right columns, Table 3). There were about the same number of vehicles in the small counting areas in 1999 and 2002. In both years, there were nearly twice as many vehicles in the reserve as there were in the group ranches (Table 3, Map 16). Tourist vehicles made up just over 50% of the vehicles in the reserve and the group ranches in 1999. Three years later, 75% of the vehicles in the reserve were tourist vehicles and 60% of those in the group ranches were for tourists. Personal cars and pickups were the second most common type of vehicles seen in both the reserve (10% in 1999 and 24% in 2002) and the group ranches (22% in 1999 and 26% in 2002). We saw 9 buses and 3 matatus in the reserve in 1999 and none in 2002. There was only one bus in the group ranches in either year and no matatus. Lorries were more common in 1999 than 2002, and we saw them more often on the group ranch than in the reserve in both years. We found vehicles widely distributed in the reserve but mostly around towns in the group ranches. There was only one vehicles to the east of the Talek-Aitong road north of Talek village, despite the fact that this large area (about 50% of Koyaiki Group Ranch) contained abundant wildlife, and supports five large multiple species associations of wildlife (see below).

Table 3. The total number and density (#/km^2) of vehicles in the reserve and the adjacent group ranches of the Mara in November 1999 and November 2002.

	1999 counting area (small)						2002 counting area (small)						2002 counting area (large)					
	Ranches (649 km^2)			Reserve (808 km^2)			Ranches (649 km^2)			Reserve (808 km^2)			Ranches (977 km^2)			Reserve (1235 km^2)		
Vehicles	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE
Cars	6	0.009	0.004	7	0.009	0.004	11	0.017	0.0010	30	0.037	0.001	14	0.014	0.005	35	0.028	0.007
Lorries	10	0.015	0.007	8	0.010	0.004	4	0.006	0.000	0	0.000	0.000	7	0.007	0.003	1	0.001	0.001
Tourist vehicles	32	0.049	0.011	78	0.097	0.020	50	0.008	0.003	106	0.131	0.003	59	0.060	0.020	185	0.149	0.023
Buses	0	0.000	0.000	9	0.011	0.005	1	0.002	0.000	0	0.000	0.000	1	0.001	0.001	0	0.000	0.000
Pick-ups	8	0.012	0.005	8	0.010	0.005	11	0.017	0.0010	4	0.005	0.000	12	0.013	0.004	6	0.005	0.003
Matatus	0	0.000	0.000	3	0.004	0.003	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.001	0.001
Others	7	0.011	0.005	32	0.040	0.013	7	0.011	0.001	1	0.001	0.000	7	0.007	0.004	1	0.001	0.001
All vehicles	63	0.011	0.002	145	0.020	0.003	84	0.129	0.004	141	0.174	0.004	100	0.103	0.003	229	0.185	0.003

SE= standard error of the mean density.

Map 9. Distribution of cropland in the count area, November, 2002.

Map 10. Distribution of fenced areas (cropped plus not cropped) in the count area, November, 2002.

Map 11. Areas burned by bush fires at different times before the count.

Map 12. Distribution of tsetse flies in the count area, November, 2002.

Map 13. Distribution and types of tourist lodges in the count area, November, 2002.

Map 14. Distribution of other infrastructure in the count area, November, 2002.

Map 15. Presence and absence of rubbish (plastic bags, paper) in the count area, November, 2002.

Map 16. Distribution of motor vehicles during the count in November, 2002.

4.6 Height, amount (cover) and colour of grass, trees and shrubs

How much grass? The percentage grass cover[14] measures how much of the ground's surface is covered by live grass, regardless of the colour or height of the grass. Grass tends to cover more ground where the soil is wetter and grass is more productive (around rivers, swamps and floodplains), where it has not burned or where animal grazing is low. A loss in grass cover can be an indication of degradation, but not always (for example, burned areas often have low grass cover right after a burn, but this does not usually mean the areas is degraded). Grass cover was greater in the reserve (71-73% cover) in both years than the group ranches (60-63% cover, Table 4). Many of the areas with high grass cover in 2002 were also areas that had not been recently burned (compare Maps 11 and 17). In 2002, there were pockets of high grass cover in the group ranches (near Mara Rianta and to the northeast of the Talek). The grass in these areas was also very tall (Map 18). There were large areas of very high grass cover and tall grass in the reserve, in the northern and central Triangle and west of Keekorok in an area spanning the Ol Keju Gem River, north and south. Grass cover was very low (blue and green on Map 17) in the western Triangle, in Talek, and around Ol Doinyo Orinka, and along the Ntiakitiak River.

How tall was the grass? In the Mara, the height of the grass seems to be a good indication of how much an area has been grazed recently; it can also indicate areas that were burned recently. In 1999, grass in the reserve (17 cm tall) was nearly 50% taller than that in the group ranches (11.5 cm tall). In 2002, there was no appreciable difference in grass heights (about 13-14 cm tall) in the reserve and group ranches. Outside the reserve, grass was short near clusters of bomas or villages like Talek where livestock grazing is heavy and there was significant burning (Map 18). Mixed with these low grass areas near bomas were many high grass areas that are probably places where the Maasai avoid grazing near bomas as a reserve of forage for their calves in the dry season (an *olekeri*). During interviews in June 2003, Maasai informants in the Olare Orok areas said they often place their grazing reserves near rivers. Inside the reserve, we found short grass in the western corner of the Triangle (where we also found the wildebeest migration), in central Musiara (burning and cattle grazing), and in the southeast near the Sand River. Grass was particularly tall in and southwest of Ol Chorro Oirowua, in places that were far from bomas, south of Mara Rianta and in the northern Triangle, northeast of Talek and in the Ol Keju Gem area.

How green was the grass? Grass was greenest either where it had burned and rained recently or where it had been grazed and rained recently. The grass was much greener in 2002 (37-62% green) than in 1999 (19-23% green, Table 4). Grass was greener in the reserve than in the group ranches in both years, and this difference was most pronounced in 2002 (21% relative difference in 1999 and 71% difference in 2002). In general, grass was greener to the south and the west of the count area than to the north and east (Map 19). During the count, it rained first by the Siria escarpment and last near Ol Doinyo Orinka. In the dry area to the northeast of Talek, grass was only green where it had burned recently. In the wetter areas to the west, areas that had been grazed heavily and burned were green. The areas with the brownest grass were places where there had been no burning and no rain.

How much green grass was there? We calculated two simple indices of the amount of *grass* (green or not) available for grazers and the amount of *green grass* available (Table 4). The first index of available grass gives an estimate of the amount of grass available for wildlife species that do not have to have green grass (they will eat green and non-green grass), like

[14] We measured aerial plant cover (cover of all above ground parts of the plant including all stems, branches and leaves) rather than basal plant cover (cover of just the base of the plant). The former is strongly affected by burning and grazing; the latter often is not affected by burning or grazing.

elephants, buffalo, and zebra. The numbers show that, in both years, there was more grass available for these grazers in the reserve. Interestingly, the difference between the reserve and group ranches was more pronounced in 1999 (75% difference) than 2002 (25% difference). Thus, these species, if attracted to amount of grass available, should be attracted to graze in the reserve more than the group ranches, and to a greater degree in 1999 than 2002. When we look at the *green grass* biomass, it is clear that, in both years, there was more than twice as much green grass biomass in the reserve than group ranches. Also, there was more than twice as much green grass biomass in 2002 than 1999. This provided all grazers that depend on green grass a strong reason to graze in the reserve in preference to the group ranches in both years. It also implies that the ecosystem could support more grazers altogether in November, 2002, than November, 1999.

Shrubs. For this count, we defined shrubs as woody plants that are less than about 2 meters tall or have a shrubby growth form. The group ranches support 7.5% (40% in a relative sense) more shrub cover than the reserve (18.6% compared with 11.1%) in 1999 but there was no difference between the two areas in 2002 (10.7% compared with 9.0%, Table 4). Our shrub and tree cover estimates are difficult to make and thus are approximations, so we interpret the differences between 1999 and 2002 in shrub cover as possible sampling error due to different observers. The areas with the most shrubs were along the Mara River in the reserve and in northern Koyiaki, in the Olkinyei area northeast of Talek (Map 20). Shrub cover is noticeably low in the reserve with many areas with no shrubs, particularly in the southern part of Musiara and Sekanani sectors.

Average shrub height in the group ranches and reserve was about 1.1-1.4 meters in both years. Our shrub height measurements are more reliable than the cover measurements, thus the slightly taller shrubs in 2002 may reflect regrowth of shrubs after the 1999-2000 drought. Shrubs were particularly tall where the grass was tall in the northern Triangle, Ol Keju Gem area, Olkinyei area northeast of Talek and in the north along the Mara River (Map 21). Many of these areas have significant clumps of *Euclea divinorum* and ant gall acacia (*Acacia drepanolobium*). Shrubs were short in the west, in the Triangle, and north and west of the Ntiakitiak River.

Shrub leaves were greener in 1999 than 2002 and also greener in the group ranches (75.4% green in 1999) than the reserve (60.3%), but only in 1999. Shrubs were noticeably green (Map 22) in the western Triangle, east of the Olare Orok River and in the Aitong area. Shrubs were brown where it had not rained in the Olkinyei area northeast of Talek and around Ol Doinyo Orinka.

Trees. There are very few trees in all of the Mara. In both years, tree cover was less than 4% in the reserve, with 3 times more cover in the group ranches (11-12% cover) than the reserve. Most of the trees are in the patch of *Acacia gerrardii* woodland (infested with tsetse) surrounding the upper Ntiakitiak River, in the Olkinyei area northeast of Talek, along the Mara River and near Keekorok (Map 23). The average tree was 5.1 m tall in 1999 and 4.3-4.6 m tall in 2002. There was no significant difference in tree height between the reserve and group ranches in either year. The tallest trees are also where the shrubs and grass are tall in the northern and central Triangle, around and south of the Ol Keju Gem, in the hills above Talek and in Ol Chorro Oirowua (Map 24). Trees were greener in 1999 than 2002, and greener in the group ranches than in the reserve. Trees were greener than shrubs, which, in turn, were greener than grasses. In the dry season (which is when we counted), trees and shrubs are often greener than grass because they have deeper roots and access to deeper underground water. Tree colour was reasonably uniform throughout the Mara (Map 25).

Table 4. Average height, cover and colour of trees, shrubs and grasses and index of grass biomass and green grass biomass in the reserve and the adjacent group ranches of the Mara in November 1999 and November 2002.

	1999 counting area (small)						2002 counting area (small)						2002 counting area (large)					
	Ranches (649 km^2)			Reserve (808 km^2)			Ranches (649 km^2)			Reserve (808 km^2)			Ranches (977 km^2)			Reserve (1,235 km^2)		
Variable	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE
Grass cover (%)	1,377	**60.318**	0.436	2,120	**71.205**	0.399	1,903	**63.094**	0.546	2,369	**73.318**	0.458	2,745	61.038	0.470	3,455	70.880	0.413
Grass height (m)	1,377	**0.115**	0.004	2,120	**0.170**	0.003	1,903	**0.132**	0.022	2,369	**0.139**	0.016	2,745	0.125	0.015	3,455	0.125	0.011
Grass colour (% greenness)	1,377	**19.389**	0.564	2,120	**23.533**	0.506	1,903	**36.566**	0.645	2,369	**62.151**	0.522	2,745	36.231	0.568	3,455	63.827	0.411
Shrub cover (%)	446	**18.572**	0.788	674	**11.099**	0.480	563	10.718	0.782	723	9.043	0.589	849	13.083	0.645	1,051	9.312	0.513
Shrub height (m)	446	1.151	0.032	674	1.234	0.028	563	**1.203**	0.023	723	**1.430**	0.027	849	1.387	0.021	1,051	1.283	0.026
Shrub colour (% greenness)	446	**75.447**	1.189	674	**60.341**	1.243	563	60.157	1.512	723	58.384	1.318	849	49.220	1.281	1,051	59.137	1.038
Tree cover (%)	414	**12.285**	0.794	488	**3.742**	0.287	590	**11.256**	0.821	582	**2.975**	0.314	861	11.367	0.645	903	4.837	0.416
Tree height (m)	414	5.110	0.133	488	5.165	0.135	590	4.391	0.072	582	4.608	0.167	861	4.509	0.058	903	5.146	0.132
Tree colour (% greenness)	414	**88.273**	0.524	488	**85.621**	0.730	590	**73.719**	1.177	582	**55.375**	1.549	861	68.374	1.077	903	61.407	1.167
Index of grass biomass		6.937			12.105			8.328			10.191			7.630			8.860	
Index of green grass biomass		134.493			284.863			304.537			633.393			276.433			565.507	

Densities that differ significantly ($p<0.05$) between the group ranches and the reserve in each year are shown in **bold face**.
Densities that differ significantly ($p<0.05$) between 1999 and 2002 for each area are underlined.
n = Number of sub-blocks sampled, SE=standard error of the mean.
Index of grass biomass = grass cover * grass height; index of green grass biomass = grass cover * grass height* grass percent greenness.

Map 17. Percentage cover of grass in the count area, November, 2002.

Map 18. Height of grass (in centimeters) at block level ($1km^2$) in the count area, November, 2002.

Map 19. Colour of the grass (percentage green) at the block level (1 km^2) in the count area, November, 2002.

Map 20. Percentage of ground covered by shrubs at block level (1 km^2) in the count area, November, 2002.

Map 21. Height of shrubs (in meteres) at block level (1 km^2) in the count area, November, 2002.

Map 22. Colour of shrub leaves (percentage green) at block level (1 km^2) in the count area, November, 2002.

Map 23. Percentage of ground covered by trees at block level (1 km^2) in the count area, November, 2002.

Map 24. Height of trees (in meteres) at block level (1 km^2) in the count area, November, 2002.

Map 25. Colour of tree leaves (percentage green) at block level (1 km^2) in the count area, November, 2002.

4.7 Livestock: how many and where?

As we expected, there were many more cattle, sheep, goats[15], donkeys and dogs in the group ranches than in the reserve in both 1999 and 2002 (Tables 5 and 6). However, a large part of the cattle herd that we counted was in the reserve during the count in 1999 and this proportion grew larger by 2002. In 1999, about a quarter (24%) of all the cattle we counted were in the reserve (and 76% in the group ranch). In 2002, we found more than a third (36%) of the cattle in reserve and two-thirds (63%) in the group ranch. In real numbers, this represents a doubling in the number of cattle in the reserve between 1999 and 2002 (from 10,920 to 22,257 cattle). Most of the cattle were in the Musiara sector (20.6 cattle/km^2), with about 70% as many animals as the Sekanani sector (13.9 animals/km^2) and very few in the Triangle (1.0 cattle/km^2, Appendix Table A4). We found many fewer sheep and goats in the reserve in 1999 (8% of the herd or 1704 shoats) than 2002 (16% of the herd or 7,426 shoats). Like cattle, most of the shoats were found in the Musiara area and the fewest in the Triangle. In terms of biomass, and thus use of forage, cattle biomass in the reserve outweighed that of shoats by as much as 20:1 in 2002 (Table 6 and Appendix Table A5). In absolute numbers, there was more than a 330% increase in the number of shoats in the reserve from 1999 to 2002. We found very few dogs or donkeys in the reserve either year (2-4%, 3-13 animals).

Between 1976 and 1996, cattle numbers on Koyiaki Group Ranch have varied between 20,000 and 45,000, depending strongly on the rainfall received over the previous two years, with no marked long-term increase [16]. R. Lamprey describes this variation in livestock numbers on Koyiaki Group Ranch from year to year as follows:

> 'Livestock estimates for Koyake reflect the general trend for all Mara ranches. The Koyake cattle population increased to about 40,000 head in the late 1980s, following good rainfall and increased primary production. In the early 90's, poor rainfall resulted in a decline to about 25,000 head. A further period of good rainfall in 1997/98, associated with 'El Nino', led to an increase again to 40,000; this was followed by a massive 'crash' in the catastrophic 'La Nina' drought of 1999/2000…'

In the middle of this 'crash', we counted cattle on Koyiaki in November 1999 and cattle numbers had fallen to about 16,300. Our ground counts in 2002 showed that cattle populations recovered rapidly again, with an estimated 33,300 head on Koyiaki.

On a per person basis, there was also an increase between 1999 and 2002. The Maasai of the Mara need an estimated 1125-1575 (average = 1350 kg) kg liveweight of livestock per person (there is some difference in estimates of this requirement from author to author[17]) to rely completely on livestock for subsistence. These come mainly from cattle and sheep and goats. In 1999, there were a total of 283 kg of cattle/person available in our count area and 59 kg of shoats/person, for a total of 335 kg/person or 335/1350 required, only 25% (335 kg/1350 kg required) of their needs. In 2002, this rose to 37% with 497 kg/person available. The Maasai of the Mara find themselves in a position similar to those in Ngorongoro where the amount of liveweight available per person has decreased by 60% between 1987 and 1998[18], with only about 50% of the Maasai requirements met by livestock in 1998.

[15] We counted sheep and goats together in the count because they are difficult to distinguish when herded in tightly packed groups. We will often use the term 'shoats' to refer to them together here.

[16] Broten and Said 1995, Serneels and Lambin 2001, Lamprey and Reid submitted

[17] Brown 1971, Pratt and Gwynne 1977, Jewell 1980, Bekure and others 1971, Kjaerby in Homewood and Rodgers 1991

[18] See Homewood and Rodgers 1991; McCabe and others 1997, and NCAA 1999

For the Mara Maasai, some 65-75% of their requirements must come options other than livestock. There are a range of options available, depending on whether the household is near wildlife-rich areas like the reserve or near agricultural markets[19]. Different income alternatives include cultivation of crops, consumptive use of wildlife, cultivation leases, remittances from family members now living in the cities, employment in lodges, revenues from 'cultural manyattas', and the receipt of small tourism 'dividends' from wildlife associations. This explains the pressure for pastoralists to expand livestock grazing into the reserve.

Cattle, sheep and goat populations doubled in the three years between 1999 and 2002 (Table 5 and 6). Our Maasai team members say that many of the cattle were being herded outside of the Mara group ranches in 1999 because of the drought. Thus, some of the increase between the two years is from reproduction, some from purchase of new cattle and some from the return of cattle that were being herded elsewhere. The ratio of shoats: cattle in the drought year of 1999 was 1.85 : 1 and in the wetter year of 2002, it was marginally lower at 1.80 : 1. R. Lamprey describes sheep and goat populations as follows:

> 'Over the 1990's the Maasai have increased their sheep and goat herds, usually a strategy in times of drought or hardship[20] (Grandin 1988; Homewood and Rodgers 1991). The contribution of sheep and goats to total livestock biomass increased from 7.1% in 1979 to 9.9% in the late 1990s. With current trends this proportion may increase further.'

Donkey populations fell by half on the group ranches between 1999 and 2002. Domestic dog populations grew by about 123% on the group ranches between the two counts.

In 2002, we found cattle mostly around Talek, the Olare Orok area, Ol Doinyo Orinka, northwest of Aitong and at Mara Rianta (Map 26). The largest herds were near Aitong and in the Mara reserve (> 200 cattle per herd). Very few cattle were in the Triangle part of the reserve during the count (1/km^2); more were in the Sekanani section (14/km^2) with the most the Musiara section (21/km^2). Smaller herds of cattle were nearly everywhere on the group ranches except in those areas with significant tsetse flies (see Map 12). We found cattle both near and far from water and both near and far from bomas.

Sheep and goats stayed close to bomas and thus were clustered around village centers or groups of bomas (Map 27). We found large concentrations of these 'shoats' near Aitong, Ol Doinyo Orinka, Talek, Mara Rianta, Sekanani and between the Olare Orok and Ntiakitiak Rivers just north of the reserve. Few shoats were grazing inside the reserve, except in the northern Triangle and around the Olare Orok. There were few sheep and goats where there were tsetse flies.

There were few donkeys in the counting area, and all of them were near a boma (Map 28). Dogs ranged farther from bomas, often with the sheep and goats (Map 29). We counted 7 donkeys in the reserve and a few dogs in 2002, some well within the reserve boundaries.

Altogether, livestock were concentrated in two bands at the edge and north of the Mara reserve (Map 30). One band stretches from Sekanani to Talek and another from Ol Doinyo Orinka to Aitong and beyond to the Mara River. These two bands are separated by an area with very few or no livestock that is infested with tsetse flies.

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[19] Homewood and others 2001; Thompson and Homewood 2002
[20] Grandin 1988, Homewood and Rodgers 1991

Table 5. Total numbers, densities (animals per km^2) and standard errors (SE) of livestock and wildlife in the reserve and the adjacent group ranches of the Mara in November 1999 and November 2002.

	1999 counting area (small)						2002 counting area (small)						2002 counting area (large)					
	Ranches (649 km^2)			Reserve (808 km^2)			Ranches (649 km^2)			Reserve (808 km^2)			Ranches (977 km^2)			Reserve (1,235 km^2)		
Species	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE
Cattle	10,920	**16.835**	2.157	3,445	**4.076**	1.142	22,257	**34.299**	3.251	12,910	**15.984**	2.861	31,683	32.425	2.522	13,350	10.808	1.883
Donkey	375	**0.578**	0.120	11	**0.013**	0.012	168	**0.261**	0.063	7	**0.009**	0.009	296	0.303	0.054	7	0.005	0.005
Sheep & goats	20,289	**31.278**	2.912	1,704	**2.016**	0.614	40,200	**61.956**	4.831	7,426	**9.189**	2.136	51,808	53.022	3.646	7,886	6.385	1.413
Domestic dog	96	**0.148**	0.023	3	**0.004**	0.003	214	**0.330**	0.037	13	**0.018**	0.006	327	0.335	0.032	22	0.018	0.006
Baboon	229	0.353	0.112	275	0.346	0.104	636	0.981	0.277	696	0.864	0.160	838	0.858	0.196	857	0.694	0.115
Bat-eared fox (H)	6	0.009	0.005	12	0.014	0.007	12	0.018	0.008	8	0.009	0.005	20	0.021	0.007	19	0.015	0.005
Buffalo (H)	325	0.501	0.243	1,073	1.271	0.458	50	**0.081**	0.053	1,053	**1.305**	0.488	96	0.098	0.055	2,465	1.995	0.492
Bushbuck (H)	0	0.000	0.000	3	0.004	0.003	3	0.009	0.003	16	0.018	0.009	8	0.008	0.004	57	0.046	0.033
Cheetah (H)	6	0.009	0.005	5	0.006	0.004	4	0.009	0.004	11	0.018	0.008	4	0.005	0.003	13	0.011	0.005
Crocodile (H)	3	**0.005**	0.003	34	**0.052**	0.017	1	**0.000**	0.002	15	**0.018**	0.008	1	0.001	0.001	15	0.012	0.005
Dikdik (H)	25	**0.039**	0.011	7	**0.008**	0.005	68	**0.108**	0.018	8	**0.009**	0.004	226	0.231	0.023	14	0.012	0.005
Duiker (H)	0	0.000	0.000	1	0.001	0.001	3	0.009	0.003	5	0.009	0.003	3	0.003	0.002	6	0.005	0.002
Eland	127	**0.196**	0.072	837	**1.003**	0.281	101	**0.153**	0.068	1,104	**1.368**	0.264	125	0.128	0.050	1,320	1.068	0.182
Elephant	45	**0.069**	0.029	461	**0.557**	0.095	57	**0.090**	0.045	447	**0.549**	0.114	128	0.131	0.041	692	0.560	0.101
Giraffe	384	**0.592**	0.098	199	**0.240**	0.049	421	**0.648**	0.086	200	**0.252**	0.049	566	0.580	0.068	314	0.254	0.046
Grant's gazelle	1,087	1.676	0.257	1,276	1.521	0.137	1,273	**1.962**	0.174	2,194	**2.718**	0.203	2,547	2.606	0.173	2,369	1.918	0.162
Hare (S)	1	0.002	0.002	2	0.002	0.002	10	0.015	0.005	12	0.015	0.005	38	0.039	0.007	12	0.010	0.004
Hartebeest	93	**0.143**	0.039	320	**0.379**	0.075	108	**0.162**	0.050	339	**0.423**	0.073	192	0.196	0.041	425	0.344	0.054
Hippopotamus (H)	61	**0.094**	0.059	480	**0.598**	0.191	76	**0.117**	0.070	334	**0.414**	0.150	120	0.122	0.058	395	0.320	0.107
Honey badger (S)	0	0.000	0.000	1	0.001	0.001	1	0.002	0.002	24	0.030	0.018	1	0.001	0.001	24	0.020	0.012
Hyena (H)	43	**0.066**	0.023	82	**0.097**	0.022	64	**0.099**	0.024	139	**0.171**	0.028	84	0.086	0.017	167	0.135	0.019
Impala	5,995	**9.242**	0.826	3,775	**4.485**	0.452	7,928	**12.222**	0.898	4,907	**6.075**	0.464	12,709	13.007	0.779	6,928	5.609	0.374
Jackal (H)	17	0.026	0.009	17	0.020	0.007	44	0.072	0.014	71	0.090	0.016	70	0.072	0.013	89	0.072	0.012
Leopard (H)	0	0.000	0.000	2	0.002	0.002	0	0.000	0.000	1	0.000	0.001	1	0.001	0.001	1	0.001	0.001
Lion (H)	4	**0.006**	0.005	42	**0.051**	0.023	37	**0.054**	0.033	111	**0.135**	0.039	46	0.047	0.023	123	0.100	0.026
Mongoose (S)	65	0.100	0.048	60	0.074	0.029	274	0.422	0.088	477	0.590	0.099	362	0.371	0.065	726	0.588	0.082
Oribi	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	122	0.011	0.002
Ostrich	18	**0.028**	0.012	142	**0.168**	0.034	58	**0.090**	0.038	238	**0.297**	0.098	83	0.085	0.026	256	0.207	0.065
Reedbuck (H)	0	**0.000**	0.000	27	**0.033**	0.009	0	**0.000**	0.000	143	**0.180**	0.024	0	0.000	0.000	200	0.162	0.019
Rhinoceros (H)	0	0.000	0.000	1	0.001	0.001	1	0.000	0.002	10	0.009	0.008	1	0.001	0.001	10	0.008	0.005
Thomson's gazelle	10,359	15.970	0.832	13,859	16.703	0.765	18,256	**28.134**	1.509	17,210	**21.303**	0.933	24,134	24.700	1.124	26,599	21.533	0.787
Topi	1,735	**2.675**	0.239	3,699	**4.379**	0.360	2,456	3.789	0.244	3,402	4.212	0.290	3,156	3.230	0.178	4,545	3.679	0.227
Tortoise (S)	0	0.000	0.000	1	0.001	0.001	9	**0.018**	0.005	30	**0.036**	0.008	21	0.022	0.005	33	0.027	0.005
Vervet monkey (H)	123	**0.190**	0.066	12	**0.014**	0.007	145	0.225	0.073	142	0.180	0.098	229	0.234	0.059	193	0.157	0.068
Vulture (H)	73	**0.113**	0.047	585	**0.724**	0.193	167	0.257	0.055	712	0.881	0.151	296	0.303	0.070	1,052	0.851	0.117
Warthog	323	**0.498**	0.065	671	**0.832**	0.087	479	**0.738**	0.069	1,110	**1.377**	0.090	608	0.622	0.050	1,661	1.345	0.074
Waterbuck	161	0.248	0.087	275	0.338	0.119	229	0.351	0.077	220	0.270	0.050	253	0.259	0.053	483	0.391	0.062
Wildebeest	8,268	12.746	1.182	62,036	79.209	9.004	16,597	25.578	1.805	87,535	108.351	8.829	19,083	19.532	1.263	135,002	109.293	6.270
Zebra	5,122	7.896	0.575	9,936	11.951	1.085	10,254	15.804	1.088	16,967	21.006	1.652	11,641	11.913	0.743	27,317	22.115	1.225

Densities that differ significantly (p<0.05) between the group ranches and the reserve in each year are shown in **bold face**. Densities that differ significantly (p<0.05) between 1999 and 2002 for each area are underlined.
(S)=species difficult to count because they are small in size; (H)=Species that are difficult to count because they hide, inhabit bush or water.

Table 6. Biomass totals, densities* (kg per km^2) and standard errors (SE) for wildlife and livestock species in the reserve and the adjacent group ranches of the Mara in November 1999 and November 2002.

	1999 counting area (small)						2002 counting area (small)						2002 counting area (large)					
	Group ranches (649 km^2)			Reserve (808 km^2)			Group ranches (649 km^2)			Reserve (808 km^2)			Group ranches (977 km^2)			Reserve (1,235 km^2)		
Species	Total	kg/km^2	SE	Total	kg/km^2	SE	Total	kg/km^2	SE	Total	kg/km^2	SE	Total	kg/km^2	SE	Total	kg/km^2	SE
Cattle	1,965,613	3,030.220	388.189	620,099	767.345	205.554	4,006,205	6,174.030	585.208	2,323,807	2,876.390	514.951	5,702,940	5,836.532	453.995	2,403,000	1,945.399	338.921
Donkey	48,750	75.154	15.609	1,430	1.770	1.617	21,840	33.658	8.210	910	1.126	1.126	38,480	39.381	7.056	910	0.737	0.737
Sheep & goats	365,204	563.004	52.416	30,672	37.955	11.048	723,592	1,115.140	86.951	133,668	165.453	38.453	932,544	954.389	65.630	141,948	114.917	25.430
Domestic dog	1,920	2.960	0.460	60	0.074	0.055	12,280	18.925	12.349	260	0.322	0.129	14,540	14.881	8.210	440	0.356	0.125
Baboon	4,580	7.061	2.239	5,500	6.806	2.077	12,720	19.603	5.543	13,920	17.230	3.194	16,760	17.152	3.928	17,140	13.876	2.304
Bat-eared fox (H)	30	0.046	0.027	60	0.074	0.033	60	0.092	0.039	40	0.050	0.023	100	0.103	0.034	95	0.077	0.028
Buffalo (H)	146,251	225.462	109.546	482,849	597.504	206.312	22,500	34.675	23.658	473,851	586.529	219.503	43,200	44.212	24.669	1,109,250	898.016	221.523
Bushbuck (H)	0	0.000	0.000	90	0.111	0.083	90	0.139	0.103	480	0.594	0.268	240	0.246	0.097	1,710	1.384	0.987
Cheetah (H)	30	0.046	0.024	25	0.031	0.021	20	0.031	0.019	55	0.068	0.041	180	0.185	0.113	585	0.473	0.245
Crocodile (H)	225	0.347	0.259	2,550	3.156	1.258	75	0.116	0.116	1,125	1.393	0.594	75	0.077	0.077	1,125	0.911	0.389
Dikdik (H)	175	0.270	0.077	49	0.061	0.034	476	0.734	0.127	56	0.069	0.030	1,582	1.619	0.159	98	0.079	0.031
Duiker (H)	0	0.000	0.000	20	0.025	0.025	60	0.092	0.053	100	0.124	0.055	60	0.061	0.035	120	0.097	0.040
Eland	44,450	68.525	25.369	292,950	362.512	98.511	35,350	54.478	23.767	386,401	478.284	92.470	43,750	44.775	17.251	462,000	374.022	63.777
Elephant	63,000	97.122	41.218	645,399	798.653	133.685	79,799	122.979	62.850	625,801	774.611	160.261	179,200	183.418	57.539	968,800	784.312	141.336
Giraffe	480,002	739.979	122.657	248,750	307.817	61.246	526,243	811.002	107.380	250,000	309.448	61.438	707,500	724.155	85.828	392,500	317.757	57.097
Grant's gazelle	43,480	67.030	10.266	51,040	63.160	5.490	50,919	78.473	6.965	87,760	108.629	8.125	101,880	104.267	6.904	94,760	76.715	6.494
Hare (S)	3	0.005	0.005	6	0.008	0.005	32	0.049	0.016	38	0.048	0.017	122	0.124	0.023	38	0.032	0.012
Hartebeest	11,625	17.921	4.828	40,000	49.498	9.353	13,500	20.805	6.231	42,375	52.452	9.174	24,000	24.562	5.133	53,125	43.008	6.748
Hippopotamus (H)	61,000	94.039	58.675	479,999	593.978	190.944	75,999	117.123	70.105	334,000	413.423	149.587	120,000	122.811	57.336	395,000	319.781	107.550
Honey badger (S)	0	0.000	0.000	11	0.014	0.014	11	0.017	0.017	264	0.327	0.198	11	0.010	0.010	264	0.218	0.129
Hyena (H)	1,935	2.983	1.045	3,690	4.566	0.969	2,880	4.438	1.077	6,255	7.742	1.256	3,780	3.868	0.783	7,515	6.084	0.858
Impala	239,801	369.681	33.044	151,000	186.855	18.087	317,116	488.712	35.933	196,280	242.954	18.551	508,360	520.268	31.193	277,120	224.348	14.986
Jackal (H)	255	0.393	0.137	255	0.316	0.100	660	1.017	0.206	1,065	1.318	0.242	1,050	1.075	0.183	1,335	1.081	0.176
Leopard (H)	0	0.000	0.000	90	0.111	0.079	0	0.000	0.000	45	0.056	0.056	45	0.046	0.046	45	0.036	0.036
Lion (H)	320	0.493	0.390	3,360	4.158	1.825	2,960	4.562	2.664	8,880	10.992	3.127	3,680	3.767	1.834	9,840	7.966	2.070
Mongoose (S)	85	0.130	0.062	78	0.097	0.037	356	0.549	0.115	620	0.768	0.129	471	0.482	0.084	944	0.764	0.106
Oribi	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1952	0.176	0.032
Ostrich	2,052	3.163	1.315	16,188	20.032	3.898	6,612	10.190	4.323	27,132	33.584	11.201	9,462	9.684	2.998	29,184	23.627	7.356
Reedbuck (H)	0	0.000	0.000	810	1.002	0.265	0	0.000	0.000	4,290	5.310	0.724	0	0.000	0.000	6,000	4.857	0.563
Rhinoceros (H)	0	0.000	0.000	1,000	1.237	1.237	1,000	1.541	1.541	10,000	12.378	8.021	1,000	1.023	1.023	10,000	8.096	5.246
Thomson's gazelle	155,386	239.545	12.476	207,885	257.248	11.478	273,836	422.014	22.628	258,150	319.537	13.992	362,010	370.490	16.857	398,985	323.006	11.795
Topi	173,501	267.472	23.882	369,899	457.734	35.954	245,597	378.493	24.376	340,200	421.098	29.034	315,600	322.993	17.815	454,500	367.950	22.715
Tortoise (S)	0	0.000	0.000	10	0.012	0.012	90	0.139	0.051	300	0.371	0.076	210	0.215	0.049	330	0.267	0.053
Vervet monkey(H)	1,230	1.896	0.662	120	0.142	0.068	1,450	2.250	0.731	1,420	1.800	0.981	2,290	2.340	0.594	1,930	1.566	0.675
Vulture	350	0.540	0.226	2,808	3.475	0.925	802	1.236	0.262	3,418	4.230	0.724	1,421	1.456	0.337	5,050	4.087	0.562
Warthog	14,535	22.408	2.938	30,195	37.365	3.912	21,555	33.218	3.086	49,950	61.828	4.062	27,360	28.001	2.235	74,745	60.512	3.329
Waterbuck	25,760	39.712	13.855	44,000	54.448	18.980	36,639	56.466	12.389	35,200	43.570	8.039	40,480	41.428	8.439	77,280	62.564	9.972
Wildebeest	992,167	1,529.540	141.892	7,444,309	9,212.000	1,080.450	1,991,614	3,069.310	216.621	10,504,218	13,002.040	1,059.490	2,289,960	2,343.869	151.556	16,200,240	13,115.244	752.392
Zebra	1,024,406	1,579.240	115.026	1,987,199	2,459.070	216.916	2,050,772	3,160.480	217.578	3,393,405	4,200.330	330.358	2,328,200	2,382.738	148.442	5,463,400	4,423.010	245.036
W. herbivores	3,463,057	**8.261**	301.365	12,463,436	**15,425.045**	1,204.280	5,728,121	8,826.072	390.460	16,969,700	21,002.104	1,230.520	7,076,484	7,243.075	31.059	26,394,194	21,371.817	99.987
W. carnivores	2,795	**4.307**	1.144	10,030	**12.413**	2.077	6,655	**10.254**	2.884	17,465	**21.615**	3.408	8,910	9.120	0.001	20,540	16.632	0.252
All wildlife	3,486,285	**5,371.779**	2,712.490	12,509,387	**15,481.914**	10,839.600	5,770,990	**8,892.126**	3,515.640	17,053,678	**21,106.037**	11,074.850	7,132,617	7,300.529	31.070	26,510,125	21,465.688	99.989
**Livestock	2,379,567	**3,666.513**	396.794	652,201	**807.180**	206.074	4,751,636	**7,321.474**	599.002	2,458,385	**3,042.556**	516.700	6,673,964	6,831.079	51.703	2,545,858	2,061.423	37.826

*Total biomass can only be compared between regions of equal size. **Livestock biomass excluding the domestic dog.

Map 26. Number of cattle per sub-block (0.11 km^2) in the count area, November, 2002.

Map 27. Number of sheep and goats (shoats) per sub-block (0.11 km^2) in the count area, November, 2002.

Map 28. Number of donkeys per sub-block (0.11 km^2) in the count area, November, 2002.

Map 29. Number of domestic dogs per sub-block (0.11 km^2) in the count area, November, 2002.

Map 30. Aggregated livestock biomass in kg/ km^2 in the count area, November, 2002.

4.8 Wildlife and multiple species associations (MSA's): how many and where?

We counted individuals of 38 wildlife species in the 2002 count. There were 15 of these 38 species that we counted relatively well. We will present mostly the species we counted well; maps of the bat-eared fox, black rhino, bushbuck, crocodile, duiker, hare, honey badger, mongoose, leopard, tortoise are available on request.

Do wildlife prefer the reserve (protected savanna) or the group ranches (pastoral savanna)? We compared wildlife density between the group ranches and the Mara reserve to find out where there were more wildlife (Tables 5 and 6). We found three different ways that wildlife responded to protection in the reserve and pastoralism in the group ranches:

1. **No preference between protected and pastoral savanna: 6 species.** Many species of wildlife were just as abundant in the reserve as in the group ranches. Many showed this same pattern in the count in 1999 and the one in 2002. These species included baboon, jackal, mongoose, waterbuck, wildebeest and zebra. Note that in absolute terms, there were many more wildebeest and zebra in the reserve than the group ranches, but they were clustered so strongly that there is no significant *statistical* difference in their average densities in the two areas.
2. **Preference for pastoral savanna: 5 species.** In both 1999 and 2002, there were more dik dik, giraffe, and impala in the group ranches than the reserve. Vervet monkeys showed some preference for the group ranches with more in 1999 but no difference in 2002. There were more Thomson's gazelles on the group ranches in 2002 only.
3. **Preference for protected savanna: 16 species.** In both years, there were more crocodile, eland, elephant, hartebeest, hippo, hyena, lion, ostrich, reedbuck, tortoise and warthog in the reserve than in the group ranches. There were the same number of buffalo, Grant's gazelle, and oribi in the reserve and ranches in 1999, but more in 2002. Topi and vulture were more abundant in the reserve during the drought year of 1999, but showed no preferences in 2002.

We did not observe enough bat-eared foxes, bushbucks, cheetahs, duikers, hares, honey badgers, leopards, and rhinos to make distinctions between the reserve and group ranches for these species.

These data strongly support the conclusion that most species of wildlife (3 times more species) prefer to forage in the reserve than in the group ranches. We must be cautious about what this means. When there are more wildlife in the reserve, are they repelled by conditions on the group ranches or attracted to conditions in the reserve (or both)? Why? Similarly, when there are more wildlife in the group ranches, are they attracted to the group ranches or driven out of the reserve or both? Why? As becomes clear later in this report, the answers to these questions are probably not simple.

4.9 How were types of wildlife and MSA's distributed around the counting area?

Wild herbivores. Wild herbivores (plant eaters) gathered in two distinct bands in the counting area in November 2002 (Map 31). One band was just north of the reserve boundary in south Koyiaki Group Ranch to the west of the Olare Orok River and to the east of the Ntiakitiak River. Another band was in the southern half of the reserve from the western edge of the Triangle across to Keekorok. There were very few wildlife near and south of Ol Doinyo Orinka, Aitong, in Talek, and in parts of Musiara and Sekanani. It is striking how areas with lots of wildlife were often surrounded by areas with very little wildlife, when mapped at the resolution of 1 km.

Wild carnivores. Wild carnivores (meat eaters) were not necessarily found with their prey (Map 32). For example, there were fewer carnivores with the southern band of herbivores in the reserve than there were within an area with comparatively few wildlife in central Musiara in the reserve. We saw no carnivores near Ol Doinyo Orinka, within Talek town or in Ol Chorro Oirowua. Carnivores did not concentrate in a particular place except for just north of the bomas along the Ntiakitiak River in the group ranch. Note that any conclusions about the abundances and distribution of carnivores are tentative because these species are very hard to count during a short, ground count.

All wildlife species and multiple species associations. The greatest concentration of wildlife species was in the central Triangle, to the west of the Olare Orok in the group ranch, just east of the Ntiakitiak in the group ranch, Koyiaki Group Ranch, northeast of Talek in the Olkinyei area, and to the east of the Mara River in the reserve (Map 33). We saw few species in the rest of the Triangle, around the Ol Keju Gem, near Ol Doinyo Orinka and Aitong, in Ol Chorro Oirowua and near the base of the Bardamat Hills. Surprisingly, there were few species but lots of biomass south of the Ol Keju Gem, in the eastern Triangle and around Keekorok. Similarly there was little biomass, but many species just to the northwest of Talek. This means that during the count, many areas of the reserve were good places to find many animals and large-bodied animals, but the most diverse group were in the group ranch.

A multiple species association (MSA) is two or more wildlife species in a group with individuals not more than 300 m from each other. They associate in MSA's for a variety of reasons:

1. To share vigilance (watching) costs against ambush killing predators (lions) and to reduce the individual risk of being killed by gathering in big groups.
2. To access areas where soils are particularly fertile and contain particularly high quality grass.
3. To graze on relatively short grass areas growing in soils that have been nutritionally enhanced by the presence of dung from abandoned Maasai boma sites.
4. To graze on relatively short grass that is repeatedly grazed and fertilized by wildlife droppings and thus kept in a younger, more nutritious growth state.
5. To associate at resting locations that are intermediate between access to water and access to forage of higher quality. Note: MSA's are most developed in the middle of the day after the morning grazing period and before the afternoon and evening grazing period.
6. Finally, wild species nearest in body size to domestic livestock (between 18 and 200 kg) may associate together to prevent pastoralists and their livestock from using these areas.

In the Mara during the 2002 count, only the largest MSA's in the group ranch and in the reserve have been preliminarily analyzed (Map 34). They cover 11% of the areas sampled on the ranch and the reserve. On the group ranches, there were fewer, larger MSA's and they were distributed in a broad 10 - 20 km band running parallel to the northern boundary of the reserve. The 17 largest MSA's averaged 6.5 km^2 in size but ranged between 1.5 km^2 and 23 km^2. In the reserve, there were 32 MSA's ranging in size between 1.5 km^2 and 15.3 km^2. MSA's in the reserve were smaller than those on the group ranch. Their average size was 4.3 km^2 and they were much more widely scattered.

MSA's in both the group ranches and the reserve are strongly associated with relatively short grass areas averaging 6.5 cm leaf height or less. These short grass areas in turn are strongly associated with the following:

1. recent burns,

2. the grazing areas of cattle both on the group ranches and on the northern edge of the reserve where cattle penetrate up to 8 km into the reserve on a daily basis in the dry season,
3. in the reserve they are also associated with the very short grazing lawns that are maintained by hippos emerging at night to graze within 5 km of the Mara and Talek Rivers, and
4. in the group ranches, MSA's are strongly associated with the broad band of tsetse-infested woodland that parallels the reserve boundary on the rocky slopes between the lower and higher grassland plains of the Koyiaki Group Ranch.

In order to develop an effective conservation strategy for the Mara, it is important to try to understand the conditions which lead to MSA formation, expansion, contraction, and collapse. Very large herbivores which are nearly predator-proof are almost never found as members of MSA's, and when they are found in MSA's the association is not long lasting. Thus, cape buffalo (400 kg), elephant (1400 kg), hippo and rhino (each 1000 kg) occur least (in order) in MSA's.

In contrast, for five resident herbivore species, MSA membership is most frequent. These are, in order of frequency of association, Thomson's gazelle (20 kg), topi (100 kg), Grant's gazelle (40 kg), impala (40 kg), and warthog (40 kg). For at least three of these species (topi, Grant's and impala), MSA association is on average 70% more frequent on the group ranch than it is in the reserve. This suggests that avoidance of livestock and/or people may be a factor restricting wildlife movement in the group ranch areas. The principal migratory species, zebra and wildebeest, are typically found in MSA's when they are resting or grazing, but are often in single species grouping or mobile migratory paired MSA's when they are moving. In addition to these 7 most frequent members of MSA's, Maasai giraffe, a 750 kg browser, and Maasai ostrich (110 kg) are only occasionally found in MSA's.

Finally, again in order of least occurrence: eland (350 kg), Coke's hartebeest (140 kg) and waterbuck (160 kg) -- the latter are both territorial antelope that select for longer grass and compete poorly with cattle -- are usually not found in MSA's. It is striking that on about 50 to 60 % of the group ranch, where the distribution of bomas and livestock is most uniform (and dense), MSA formation no longer occurs. In both the group ranch and the reserve, lions, hyenas and cheetahs are typically found within a few kilometres of the outside edge of MSA's and probably contribute predator pressure for their formation. In order to be persistent after predator attacks, MSA's must have more than 300 members and more than 4 species. Understanding the development of MSA's that are small and cover less than a kilometre that will grow into to large MSA's of 10 km^2 or more containing thousands of animals is an urgent task and will be part of the further analysis of this data set. If we can do this, we can better protect the classic savanna assemblage of many species living within sight of one another.

Map 31. Aggregated wild herbivore biomass in kg/ km^2 in the count area, November, 2002.

Map 32. Aggregated wild carnivore biomass in kg/ km^2 in the count area, November, 2002.

Map 33. Number of wildlife species per sub-block (0.11 km^2) in the count area, November, 2002.

Map 34. Distribution of multiple species associations in the count area, November, 2002.

4.10 How were individual species distributed around the counting area?

The order of species that follow is first by what they feed on and then by body weight from heaviest to lightest (with the exception of wildebeest and zebra which come first among the grazers because they are so abundant).

Grazers (grass and leafy herb eaters).

Wildebeest and zebra: abundant in the protected and pastoral savanna. Migrating wildebeest and zebra, mixed with fewer numbers of resident animals (Maps 35 and 36), made up much of the biomass in the wild herbivore concentration points (Map 31). We counted about 6 times as many wildebeest in the reserve as the group ranches in 1999 (13 vs 79/km^2) and 5 times as many in 2002 (26 vs 108/km^2). In the larger counting area in 2002, we counted 135,000 wildebeest in the reserve, with more than half of those in the Sekanani area alone. This is more than a quarter of all the animals we counted altogether. However, a statistical comparison of the average densities between the two areas shows no difference because there is so much variability in the abundance of this species from place to place. *It is also not sensible to compare the number of wildebeest or zebra between the reserve and group ranches because most of the migrants happened to be in the southern part of the reserve on their return to the Serengeti, making a direct comparison invalid. We planned the count so that it would take place after the migration left the Mara for the Serengeti so that we would count only residents, but inadvertently caught the tail end of this huge group of animals in both 1999 and 2002.* Similarly, our teams counted about 1.5 times as many zebra in the reserve than group ranches in 1999 and 1.3 times as many in 2002; but, again, the average densities are not different in a statistical sense. Our counting teams found very large groups of wildebeest and zebra in the southern reserve on both counts, presumably made up of Serengeti migrants. Wildebeest gathered in large groups in the central Triangle, near Keekorok and west of the Olare Orok. Wildebeest appeared to be strongly attracted to recent burns and very short grass (see Map 11). Zebra clustered with the wildebeest here, but also in the southeastern Triangle and east of the Ntiakitiak. Zebra clustered with wildebeest on burns but also where there was no evidence of recent burns and grass was of medium height.

Hippo: strong preference for protected waters. There were 4-6 times as many hippos in the rivers of the reserve (0.4 to 0.6/km^2) than in the group ranches (0.1 to 0.09/km^2) in both years (Table 5). Most of the hippos lived in the Mara River, with many more hippos in the part of the Mara that passes through the reserve than the part that crosses the group ranches (Map 37). Our teams counted hippos along the length of the Talek, in pools on the Ntiakitiak and Ol Keju Gem, but not in the Olare Orok River. No hippos were counted in the Talek River near Talek village.

Cape buffalo: strong preference for protected savanna. Buffalo were 2.5 times more common in the reserve than group ranches in 1999 and 16 times more common in 2002 (Table 5). We counted 84% fewer buffalo in the group ranches in 2002 than 1999. In 2002, buffalo gathered in the tall grass areas south of the Ol Keju Gem and in the northern Triangle (Map 38). We also counted many buffalo along the Mara, Talek and Ol Keju Gem Rivers. Buffalo compete strongly with cattle for forage, thus it is no surprise that they prefer to graze in the southern reserve where no livestock graze.

Defassa waterbuck: no preference for protected or pastoral savanna. Waterbuck were equally abundant in the reserve as the group ranches. Waterbuck were concentrated along permanently flowing rivers, especially in Mara and Talek Rivers (Map 39). Waterbuck also inhabited several areas with tall grass, like the northern Triangle. There were many waterbuck in the northern Mara, in the savannas between Aitong and the Mara River.

Coke's hartebeest: strong preference for protected savanna. Coke's hartebeest was rare in the reserve (0.38/km^2) and the group ranches (0.14/km^2) in 1999 with similar abundances in 2002. This is a species that clearly prefers the protected area more than the pastoral area, perhaps because they often compete with cattle for forage (Kingdon 1997). Groups of hartebeest were most common on the drier eastern part of the reserve in Sekanani than in the Triangle or Musiara (Appendix Table A4, Map 40). We found no hartebeest on the private ranch, Ol Chorro Oirowua.

Maasai ostrich: strong preference for protected savanna. Ostrich were 6 times more abundant in the reserve than group ranches in 1999 (0.17 vs. 0.03/km^2, Table 5) and 3 times more abundant in 2002 (0.30 vs. 0.09/km^2). Ostrich were spread fairly evenly throughout the reserve, with fewer in the wetter Triangle (Map 41). Group sizes appeared to be larger in the group ranches than the reserve.

Topi: weak preference for protected savanna. There were more than 1.6 times as many topi (Map 42) in the reserve (4.4/km^2) as the group ranches (2.7/km^2) in 1999, but there were only 1.1 times as many in 2002 (4.2 compared with 3.8/km^2, no significant difference). Topis avoided areas with very long grass, similar to Thomson's. They also preferred areas with shrub cover. We found the largest concentration just east of the Ntiakitiak with Thomson's gazelles in recently burned areas.

Warthog: strong preference for protected savanna. There were almost twice as many warthogs in the reserve than group ranches in both years (Table 5). Most of the warthogs in the reserve were in the Musiara area and the northern Triangle (Map 43). Warthogs seem to avoid the high grass areas south of the Ol Keju Gem River.

Bohor reedbuck: strong avoidance of pastoral savanna. We found no reedbuck in the group ranches either year. There were 170 reedbuck seen by our teams in the reserve (Map 44). Reedbuck were evenly spread throughout the reserve with some concentration around the Musiara swamps.

Thomson's gazelle: weak preference for pastoral savanna. Thomson's gazelles (Map 45) were the third most abundant species of wildlife in our Mara count, which included many migrants and some residents. We counted about 23,000 Thomson's gazelles in 1999 and about 35,000 in 2002 within the same counting area. This species was equally distributed between the group ranches and reserve in 1999, but were more common on the group ranches than reserve in 2002. These gazelles often clustered with wildebeest and topi, especially on recently burned areas in the Triangle and just east of the Ntiakitiak River. They were also common just south of Talek village along the Talek River, in an area that had not burnt recently. Thomsons' gazelles avoided the long grass areas south of the Ol Keju Gem River, in the northern Triangle and in the north in Ol Chorro Oirowua. We expect this species to be more attracted to short grass than any other species because of their nutritional requirements and their small size makes detection of predators difficult when grass grows to moderate heights.

Tortoise: weak preference for protected savanna. We found only 1 tortoise in the count areas in 1999, but 39 in 2002. We saw 3 times as many tortoises in the reserve as group ranches in 2002. Note that our count of tortoises will strongly under-estimate the real population size and distribution patterns because they are so hard to see in tall grass. We saw most of the tortoises close to rivers and in groups of one (Map 46).

Mixed feeders (grass, shrub and tree eaters).

African elephant: strong preference for protected savanna. We found 6-7 times more elephants in the reserve than the group ranches (Table 5). There were also larger herds in the reserve than group ranches (Map 47). Most of the elephants were in the southern part of the reserve, away from the areas where cattle graze within the northern border of the reserve. We found many elephants, as expected, along water courses, particularly the Ol Keju Gem River in the reserve.

Cape eland: strong preference for protected savanna. We counted 5 times as many eland in the reserve than group ranches in 1999 and 9 times as many in the reserve in 2002. Like elephant, the eland clustered in the southern part of the reserve, away from pastoralists and their livestock (Map 48). Eland seemed to gather in areas of different grass heights.

Grant's gazelle: Weak preference for protected savanna. There were the same number of Grant's in the group ranches and reserve in 1999, but 35% more in the reserve in 2002. Grant's, in contrast to eland, clustered around the reserve-ranch boundary, and avoided the southern reserve (Map 49). There were few Grant's in the Triangle, with the most in the Musiara section. There were also few Grant's in Ol Chorro Oirowua.

Impala: Strong preference for pastoral savanna Impala were the fourth most abundant wildlife species we counted, after wildebeest, zebra, and Thomson's gazelle. Impala clustered along the Mara and Talek rivers in the reserve, the only places where woody plants are common in the reserve (Map 50). Most of the impala were just north of the reserve boundary, especially north of Talek in the wooded savanna there. They also clustered in the Croton patches near the reserve and in the *Acacia gerrardii* woodland where we found many tsetse flies. Impala may prefer the group ranches because their dietary overlap with livestock is low to moderate, depending on the season, and woody plants are more common on the ranch than in the reserve.

Bushbuck: No preference – sample sizes too low? We found only 22 bushbuck in the two counts together. This species is very hard to find and we strongly under-counted its population. The few that we found were mostly along rivers and mostly in the reserve (Map 51).

Duiker, oribi and hares: Too few of these species were counted to make reliable comparisons between the reserve and group ranches. Nearly all the duikers we counted were in the high grass areas south of the Ol Keju Gem in the reserve (Map 52). We found almost all the oribi in the wetter Triangle (Map 53). Hares were equally abundant in the reserve and group ranches and were found mostly in western Koyiaki in the most wooded part of the count area (Map 54).

Browsers (mostly tree and shrub eaters).

Giraffe: strong preference for pastoral savanna. There were more than twice as many giraffe in the group ranches than in the reserve in both years. We found many of the giraffe in the tsetse-infested belt of Acacia woodlands about 7-10 kms north of the reserve (Map 55). The giraffe in the reserve clustered along the riverine areas, the only places with significant numbers of trees.

Black rhino: strong preference for protected savanna. We counted 11 rhinos in the entire count area in 2002. One rhino was in the rhino sanctuary near Ol Chorro Oirowua and the other ten were close to each other south of the Ol Keju Gem in the high grass within the reserve (Map 56).

Dik dik: strong preference for pastoral savanna. We counted 5 times as many dik dik in the group ranches than the reserve in 1999 and 10 times as many in 2002. Most of the dik dik clustered in the woody eastern part of Koyiaki and near Ol Doinyo Orinka (Map 57).

Carnivores and scavengers (meat and carrion eaters). We did not count any of the carnivores well. For some species, this was because of their behaviour, others were small, another in water, another flying. We present the data here, urging the reader to take caution in interpreting this information.

Lion: strong preference for protected savanna. We counted 100 more lion in the same count area in 2002 than 1999. We counted 9 times as many lions in the reserve than group ranches in 1999 but only 2.5 times more in 2002. There were several large groups in both the reserve and group ranches, but only smaller groups in the Triangle (Map 58). The big concentrations of lions were south of the Ol Keju Gem with the migration and around the Talek River near Intrepids Lodge.

Crocodile: strong preference for the protected savanna. We counted 10-15 times as many crocodiles in the reserve as the group ranches. Like hippos, most crocodiles were in the Mara River, but unlike hippos, we did not find any crocodiles in the Talek River (Map 59).

Leopard and cheetah: too few counted. We counted 2 leopards in 1999 and 1 leopard in 2002, all in the reserve (Map 60). Our teams saw 11 cheetah equally distributed between the reserve and group ranches in 1999. In 2002 in the same area, we counted 15 cheetah, with 27% in the group ranches and 73% in the reserve. Our few observations of cheetah were spread throughout the count area (Map 61). We cannot make any conclusions about the populations of these species.

Hyena: strong preference for the protected savanna. We found about twice as many hyena in the reserve as the group ranches in both years. Despite the greater number of hyena in the reserve, there were large numbers in the group ranch, especially in the Ntiakitiak River area. To give an idea of how well we counted hyena, we counted 2 hyena in the same area around Talek where the hyena research team from Michigan State know there is a clan of 50 hyena. Recent work by this research team shows that hyena behaviour is strongly affected by the presence of people and livestock[21] (Map 62).

Jackal: no preference. Our teams counted about the same density of jackals in the group ranches and reserve in both years. Jackals were everywhere, probably the most evenly distributed species that we counted (Map 63).

Honey badger, bat-eared fox, honey badger: too few counted. Honey badgers were rare. Our teams found only 1 in 1999 and 25 in 2002. Of the 25, 1 was in the group ranch and 24 in the reserve (Map 64). We counted 18-20 bat-eared foxes each year, but too few to come to specific conclusions about their distribution. Bat-eared foxes seemed to avoid high grass areas and areas with no trees (Map 65).

Vultures: Weak preference for protected savanna. Most of the vultures we counted were on the ground, feeding on wildlife kills. We did not attempt to make a thorough count of vultures flying high in the sky. Vultures preferred to be where the majority of the carcasses were: in the reserve. Most of them were in the southern reserve with the wildebeest migration (Map 66).

Mongoose: no preference. There were the same number of mongoose in the reserve and group ranches in 1999 and there appeared to be 40% more mongeese in the reserve than group ranch in 2002 (although this difference

[21] Boydston and others 2003

was not significant). This species was also very evenly distributed across the count area (Map 67).

Primates.

Baboon: no preference. We counted about the same density of baboons in the reserve as the group ranches. Baboon group sizes appeared to be larger in the group ranches than in the reserve (Map 68).

Vervet: weak preference for pastoral savanna. In 1999, there were 15 times more vervets on the group ranch than the reserve, but no difference in 2002. Vervets were spread across the count area, and, like baboons, seemed to cluster in larger groups in the group ranches (Map 69).

4.11 Private compared with communal ranching

A comparison of the density of wildlife and livestock in Ol Chorro Oirowua with those in the group ranches may give some comparison of private compared with communal management of livestock and wildlife. However, because Ol Chorro ranch is relatively small and far from the Mara reserve, we would expect fewer wildlife species here and perhaps fewer numbers of each type of wildlife that are present.

There were fewer livestock on Ol Chorro than the group ranches (see Appendix Table A4). There were also many species missing from the half of Ol Chorro that we counted compared with the much larger group ranches, but we expected many to be missing. The species missing in Ol Chorro but found on the other ranches included: bat-eared fox, buffalo, duiker, hartebeest, hyena, jackal, lion, tortoise, vervet, and vulture. However, Ol Chorro is home to the only rhino we found outside the reserve. In general, when a wildlife species was present, there were many fewer on Ol Chorro than the other group ranches. This last point is significant, and may point to differences in management on Ol Chorro compared to the group ranches, or to differences in the suitability of the habitat for wildlife in these two areas.

4.12 Transmara (Triangle) compared with Narok part of the reserve

There was no appreciable difference in the abundance of wildlife comparing between the Transmara (Triangle) and Narok (Musiara and Sekanani together) parts of the reserve (Table A4 in Appendix). We found about 30% more carnivores in the Narok part of the reserve than in the Transmara. This was the case in spite of the fact that there were about twice as many livestock in the Narok part of the reserve as in the Transmara part.

By species, there were many more species that were more abundant in the Narok side of the reserve than the Transmara. Five species were more abundant in the Transmara than the Narok part of the reserve (bushbuck with 79% more in the Transmara, oribi with 79% more, bat-eared fox with 61% more, buffalo with 60% more, and waterbuck with 56% more). There were 12 species more abundant in the Narok than Transmara part of the reserve (ostrich with 86% more in the Narok part of the reserve, Grant's gazelle with 85% more, lion with 81% more, cheetah with 66% more, eland with 63% more, duiker with 62% more, hyena with 62% more, baboon with 56% more, jackal with 52% more, hartebeest with 52% more, topi with 37% more, vervet monkey with 32% more). In general, the species that are more water dependent (waterbuck) or that can tolerate coarse grass (buffalo) were more abundant in the Transmara than in the Narok part of the reserve, probably because the Transmara is wetter than the Narok side. There was no appreciable difference in the abundance of dik-dik, zebra, giraffe, elephant, Thomson's gazelle, wildebeest, reedbuck, impala, vultures, warthog and mongoose between Narok and Transmara parts of the reserve. There were no rhinos, honey badgers, leopards, hares or crocodiles counted in the Transmara, but for all species but rhino, this was caused by the way we attributed animals (all crocodiles and hippos in the Mara River were counted as 'in' the Narok part of the reserve in our analysis so far, which is not correct) or our ability to detect the species (for example, tortoise, hare, leopard).

Map 35. Number of wildebeest per sub-block (0.11 km^2) in the count area, November, 2002.

Map 36. Number of Burchell's zebra per sub-block (0.11 km^2) in the count area, November, 2002.

Map 37. Number of hippo per sub-block (0.11 km2) in the count area, November, 2002.

Map 38. Number of Cape buffalo per sub-block (0.11 km2) in the count area, November, 2002.

Map 39. Number of Defassa waterbuck per sub-block (0.11 km2) in the count area, November, 2002.

Map 40. Number of Coke's hartebeest per sub-block (0.11 km2) in the count area, November, 2002.

Map 41. Number of Maasai ostrich sub-block (0.11 km2) in the count area, November, 2002.

Map 42. Number of topi per sub-block (0.11 km2) in the count area, November, 2002.

Map 43. Number of warthog per sub-block (0.11 km2) in the count area,
November, 2002.

Map 44. Number of Bohor reedbuck per sub-block (0.11 km2) in the count area, November, 2002.

Map 45. Number of Thomson's gazelle per sub-block (0.11 km2) in the count area, November, 2002.

Map 46. Number of tortoise per sub-block (0.11 km2) in the counting area, November, 2002.

Map 47. Number of African elephant per sub-block (0.11 km2) in the count area, November, 2002.

Map 48. Number of Cape eland per sub-block (0.11 km2) in the count area, November, 2002.

Map 49. Number of Grant's gazelle per sub-block (0.11 km2) in the count area, November, 2002.

Map 50. Number of impala per sub-block (0.11 km2) in the count area,
November, 2002.

Map 51. Number of Eastern bushbuck per sub-block (0.11 km2) in the count area, November, 2002.

Map 52. Number of duiker (all species)per sub-block (0.11 km2) in the count area,   November, 2002.

Map 53. Number of oribi per sub-block (0.11 km2) in the count area, November, 2002.

Map 54. Number of hare (all species) per sub-block (0.11 km2) in the count area, November, 2002.

Map 55. Number of Maasai giraffe per sub-block (0.11 km2) in the count area, November, 2002.

Map 56. Number of black rhino per sub-block (0.11 km2) in the count area, November, 2002.

Map 57. Number of Kirk's dik-dik per sub-block (0.11 km2) in the count area, November, 2002.

Map 58. Number of lion per sub-block (0.11 km2) in the count area, November, 2002.

Map 59. Number of crocodile per sub-block (0.11 km2) in the count area, November, 2002.

Map 60. Number of leopard per sub-block (0.11 km2) in the count area, November, 2002.

Map 61. Number of cheetah per sub-block (0.11 km2) in the count area, November, 2002.

Map 62. Number of spotted hyena per sub-block (0.11 km2) in the count area, November, 2002.

Map 63. Number of jackal species per sub-block (0.11 km2) in the count area,November, 2002.

Map 64. Number of honey badger per sub-block (0.11 km2) in the count area, November, 2002.

Map 65. Number of bat-eared fox per sub-block (0.11 km2) in the count area, November, 2002.

Map 66. Number of vulture (all species) per sub-block (0.11 km2) in the count area, November, 2002.

Map 67. Number of mongoose (all species) per sub-block (0.11 km2) in the count area, November, 2002.

Map 68. Number of Anubis baboon per sub-block (0.11 km2) in the count area, November, 2002**.**

Map 69. Number of vervet monkey per sub-block (0.11 km2) in the count area, November, 2002.

4.13 Did wildlife numbers change between 1999 and 2002?

To compare wildlife numbers between the two years, we used only the 2002 counts that overlapped with the smaller area counted in 1999 (Tables 5 and 6). We found six different ways that wildlife densities changed between 1999 and 2002:

1. **More in 1999, but only in the reserve: 1 species, possible conflict over water in the drier year of 1999.** We found that elephant was the only species to occur at a higher density in the reserve in 1999 compared to 2002.
2. **More in 2002 in both group ranches and reserve: 12 species = population growth and in-migration after drought.** Grant's gazelle, hare, hyena, impala, jackal, mongoose, Thomson's gazelle, tortoise, warthog, wildebeest, and zebra
3. **More in 2002 only in the reserve but not the ranches: 5 species = population increase after drought, but only in the reserve.** Baboon, buffalo, eland, lion, reedbuck and vultures.
4. **More in 2002 only in the ranches and not the reserve: 2 species= little habitat available in the reserve.** Dik dik and giraffe
5. **More in 1999 in the reserve, more in 2002 in the ranches: 2 species = retreat to reserve during dry year, prefer group ranch in wetter year.** Topi and waterbuck
6. **No difference in both years: 5 species.** Crocodile, hartebeest, hippo, ostrich, vervet monkey.

We did not observe enough bat-eared foxes, bushbucks, cheetahs, duikers, honey badgers, leopards, oribi, and rhinos to make distinctions between the reserve and group ranches for these species.

Why these patterns? Why were there so many more wildlife and livestock in both the group ranches and reserve in 2002 than in 1999? First, as mentioned under the vegetation section above, we estimate that there was about double the green grass biomass in the 2002 than in 1999 in both the reserve and group ranches. The difference between the reserve and group ranches (more green grass in the reserve) was more pronounced in 1999 than 2002. This alone could explain the increased populations of livestock and wildlife in 2002 than 1999. It is difficult to come to this conclusion from rainfall records alone (Figure 3), because wet season rainfall in 1999 was lower than 2002 but dry season rainfall was higher[22].
The low numbers in 1999 probably reflect a combination of movement out of the system in search of better water and forage, and drought related mortality. Similarly, intrinsic population increase combined with in migration into the system in the moderate year of 2002 may account for observed increases between 1999 and 2002. Our carcass data (below) seems to support this interpretation – there were many more carcasses in 1999 than 2002 – although there are other explanations for this.

4.14 Carcasses

We found 10-12 times as many fresh carcasses (by density) in the reserve than in the ranches in 1999 and 2002Table 7). Wildebeest contributed 75% (1999) and 86% (2002) of all carcasses counted in the reserve and 42% of all carcasses seen on the group ranches in both years. Zebra carcasses were the second most common type of carcasses recorded for the reserve (both years) and the most common on the group ranches in 1999. In 2002, impala carcasses were the second most common type we found in the group ranches. As we mentioned above, this is probably a result of drought mortality. We did not find any livestock carcasses in either year. We found most of the carcasses in the southern reserve with the wildebeest migration, as we expected (Map 70). There were twice as many wildebeest and zebra per lion in the reserve in 1999 (1713) than 2002 (941) even though there were 30% fewer wildebeest and and 50% fewer

[22] Research in the Serengeti (Mduma and others 1999) shows that dry season rainfall is particularly important to the populations of many of the grazers.

zebra in the reserve in 1999 than 2002. Lion populations were only 65% lower in the reserve in 1999 than 2002. This may suggest that the few lion were more successful hunters in 1999 than 2002 (weaker prey due to drought?) or that there was significant drought-related mortality (independent of lion kills) in 1999 than 2002. However, these calculations need to be treated with caution because our lion and hyena counts under-estimate the number of these predators present.

Map 70. Number of fresh carcasses per sub-block (0.11 km^2) in the count area, November, 2002.

Table 7. The total number and density* (#/km^2) of carcasses by species in the Mara Reserve and the adjacent ranches in November 1999 and November 2002.

	1999 counting area (small)						2002 counting area (small)						2002 counting area (large)					
	Ranches (649 km^2)			Reserve (808 km^2)			Ranches (649 km^2)			Reserve (808 km^2)			Ranches (977 km^2)			Reserve (1,235 km^2)		
Species	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE
Buffalo	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	2	0.0003	0.0002	0	0.0000	0.0000	2	0.0018	0.0009
Eland	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000
Giraffe	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	1	0.0001	0.0001	0	0.0000	0.0000	1	0.0009	0.0009
Grant's gazelle	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	1	0.0001	0.0001	0	0.0000	0.0000	1	0.0009	0.0009
Hippopotamus	0	0.0000	0.0000	1	0.0012	0.0012	0	0.0000	0.0000	1	0.0001	0.0001	0	0.0000	0.0000	2	0.0018	0.0009
Impala	0	0.0000	0.0000	0	0.0000	0.0000	3	0.0005	0.0003	2	0.0003	0.0002	3	0.0027	0.0018	2	0.0018	0.0009
Jackal	0	0.0000	0.0000	2	0.0025	0.0017	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000
Thomson's gazelle	0	0.0000	0.0000	1	0.0012	0.0012	2	0.0003	0.0002	3	0.0004	0.0002	3	0.0027	0.0018	4	0.0036	0.0018
Topi	0	0.0000	0.0000	2	0.0025	0.0025	0	0.0000	0.0000	2	0.0003	0.0002	0	0.0000	0.0000	2	0.0018	0.0009
Warthog	0	0.0000	0.0000	3	0.0037	0.0037	1	0.0002	0.0002	1	0.0001	0.0001	1	0.0009	0.0009	1	0.0009	0.0009
Wildebeest	5	0.0077	0.0034	138	0.1708	0.0432	6	0.0010	0.0004	152	0.0209	0.0029	6	0.0063	0.0027	175	0.1413	0.0180
Zebra	2	0.0031	0.0022	10	0.0124	0.0061	1	0.0002	0.0002	12	0.0017	0.0005	1	0.0009	0.0009	16	0.0126	0.0036
Unknown	5	0.0077	0.0034	28	0.0346	0.0072	1	0.0002	0.0002	0	0.0000	0.0000	1	0.0009	0.0009	30	0.0243	0.0045
Total	12	0.0185	0.0053	185	0.2289	0.0452	14	0.0024	0.0007	177	0.0243	0.0030	15	0.0144	0.0042	236	0.1917	0.0189

*Total number of carcasses in the two areas should not be compared directly because areas have different sizes.

4.15 How are wildlife distributed around water in the reserve and group ranches?

We analysed all the wildlife and livestock maps to discover any effects of protection and pastoralism on where animals distribute themselves on the landscape. We created a map of distance to water (Map 71) to complete this analysis.

Comparing rivers and water points between the reserve and group ranches. The reserve and group ranches had strikingly similar drainage characteristics. About one quarter (26-30%) of all the sub-blocks we sampled contained a stream (small river) in the reserve (29.9%) and group ranches (26.2%). Only 9-10% of the sub-blocks contained a major river in either area. About 1% of the area of each sub-block was covered by a stream and only 0.3-0.4% covered by a major river. However, water points were more than twice as prevalent in the reserve as in the ranches with 7.4% of the 11,117 sub-blocks in the reserve and only 3.5% of the 8,794 sub-blocks in the group ranches containing water. Many of the differences may be in abundance of seasonal pools in the reserve.

How were livestock and wildlife distributed around water? We developed a distance to water source map from the aerial count of water sources (Map 71). We used this map to try to understand how wildlife, livestock and vegetation are distributed around water, and then how protection and pastoralism affects those distributions (Figures 5a and 5b). All the herbivore species showed strong but contrasting distribution patterns around water as follows:

1. **Clustering neither near nor far from water = humped distribution:** For example, buffalo, eland, impala, ostrich, T. gazelle, topi, warthog, waterbuck, wildebeest and zebra were most common about 1-3 km from water in the reserve and group ranches in 1999. This distribution probably indicates that forage is scarce near water[23] due to heavy and constant grazing and trampling by animals visiting water sources and that the riparian woodland habitat fringing most water-courses in the Mara Area is unsuitable for most herbivores because of high predation risks near water[24]. It also suggests that wildlife cannot afford to forage too far from water because of the energy costs of walking long distances. However, forage is likely to be more abundant farther from water where the amount of grazing is lower. Thus, these species are balancing their need for water (near to water) and forage (far from water) by clustering neither near nor far from water. Another contributing factor to wildlife clustering at 1-3 km from water is that hippos grazing at night keeps the grass short within a few km of major rivers and this may attract grazers to the more nutritious grass where short grass makes it difficult for predators to hide.
2. **Clustering close to water:** Some species, like giraffe (reserve 1999, group ranches 2002), sheep and goats in both years, buffalo and impala in the reserve in 2002, waterbuck (2002 only) prefer to graze close to water. Buffalo and giraffe are usually too large to be attacked by predators (although these species are taken by predators) and thus grazing in bushy areas near water is not a great danger for them. Giraffe will also find their preferred forage more abundant near rivers, especially in the reserve.
3. **Clustering far from water:** We found several species far from water – giraffe (group ranches 1999, reserve 2002), G. gazelle (group ranches 1999), hartebeest (reserve in both years), ostrich (group ranches 2002) and cattle (group ranches in both years). Some of these species either need to access abundant forage far from water (cattle) or do not need to drink every day (hartebeest;

[23] Western 1975, Herlocker 1992
[24] Schaller 1972, Packer 1986

Kingdon 1997). We find the weak clustering of giraffe away from water in 2002 difficult to interpret.

4. **Clustering both close and far from water = U-shaped distribution.** We found species like buffalo and waterbuck (in 2002), elephant (1999 and 2002) and much of the livestock clustered both near and far from water, particularly in the reserve. For livestock, this means that our count caught herds while pastoralist brought them to drink and also while grazing far from water. For wildlife, these species need to take in large quantities of food each day and our count caught them both near water and in high grass areas far from water.

The cover and height of grasses, shrubs and trees was greater near water sources than far away in both 1999 and 2002 (figures available on request). Tree cover was most affected by water, with much higher cover around water sources than in the open plains, as is obvious from observation in the field.

Bomas were clustered near water also (Figure 4). In both 1999 and 2002, most bomas were within about 2km from water.

How does protection and pastoralism affect the distribution of wildlife around water? There are three ways that pastoralism and protection appear to affect how wildlife distribute themselves around water:

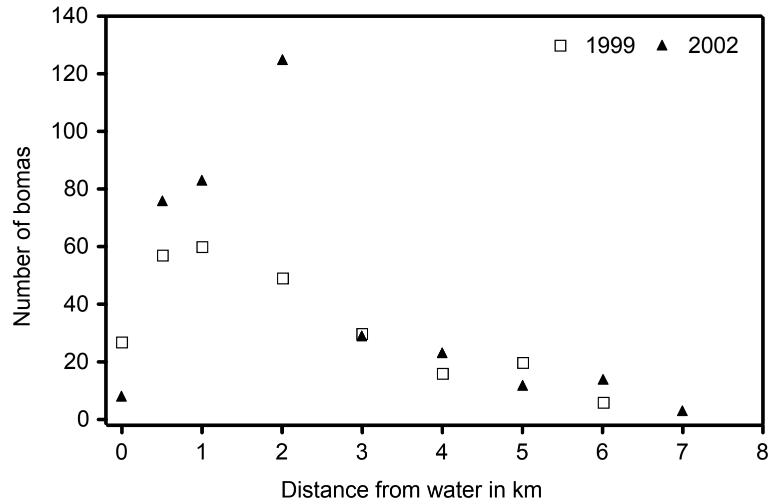
1. **No effect:** some species have the same distribution around water in the reserve and group ranches. This was rare. Only cattle and impala in 1999, elephant and waterbuck in 2002, donkeys, warthog, sheep and goats in both years had similar distributions from water in both the reserve and group ranches. This implies that pastoralism had little effect on the use of water by these species.
2. **Pastoralism appears to push wildlife away from water:** We found a 'hump' in the distribution of species like Thomson's gazelle, impala, wildebeest (1999 only), elephant and ostrich (2002 only) farther away from water in the group ranches than in the reserve. This implies that livestock are competing with these species for water (and forage near water), so the wildlife stay farther from water when livestock are present. Stuart Williams[25] found this to be true for Grevy's zebra in Samburu in northern Kenya – Grevy's stayed away from water in the day and usually came to drink at night when livestock were not at the water points. Note that if pastoralism is pushing wildlife away while livestock are using water points during the day, this increases predation risk greatly, since predators most often hunt and kill at night[26], just when the water points are available for wildlife.
3. **Pastoralism appears to attract wildlife to water points:** The 'hump' in the distribution of eland, topi, Grant's (2002 only), zebra (2002 only) and wildebeest (2002 only) was closer to water points in the group ranches than the reserve. Our predator counts seem to indicate that there are fewer predators in the group ranches than reserve (or that predators hide more on the group ranches than the reserve). Wild grazers may cluster closer to water points in the group ranches because they feel 'safer' there, either because predators are scarce or predators avoid people, as they appear to do around bomas (see below).

These strong differences in the distribution of animals around water may also indicate different ways that wildlife avoid competition with each other around water. For example, Thomson's gazelle were most abundant in the group ranches in 2002 when the migratory eland, wildebeest and zebra populations were more abundant in the reserve. The changes in

[25] Williams 1998
[26] Kruuk 1972, Schaller 1972, Hanby et al. 1995

distributions of animals in different years is probably caused by changes in the amount of water and forage available in these two different years. Also, grazers may forage farther from water sources when there is less available to eat, but it is unclear from our data if the quantity of forage differed between 1999 and 2002. It does appear that many species grazed farther from water in 2002 than 1999, but this may also be a short-term effect of the onset of rain 1 day before our count started in 2002 and the lack of rain during the count in 1999. Similar patterns of distributions of species in relation to water were found in Amboseli, but the predominant effect was a displacement of wildlife from waterpoints, caused by human use.[27]

Figure 4. Distribution of bomas from the nearest water sources in 1999 and 2002.



[27] Worden and others 2003

Map 71. Distance to the nearest water source (in kilometres) in the count area, November, 2002.

Figure 5. Distribution of wildlife and livestock species around water in the reserve and group ranches in November 1999 and 2002.

4.16 How are wildlife distributed around bomas in the reserve and group ranches?
We then created a map of the distance to the nearest boma, using the boma map we developed during the count (Map 72). We then asked how wildlife, livestock and vegetation are distributed around bomas in the reserve and group ranches.

Grass cover and height were somewhat lower near bomas than far away, but the patterns were not strong. This weak pattern may be caused by the inter-mixing next to bomas of heavily grazed areas and little grazed areas saved by pastoralists for grazing reserves. Trees and shrubs were more abundant and taller close to bomas than far away, but these patterns were also weak.

We found that wildlife distributed themselves around bomas differently in the reserve than group ranches (Figure 6a and 6b). Note that the effect of bomas outside but on the edge of the reserve probably spills over into the adjacent reserve, partly because many cattle graze in the reserve from bomas that are next to the reserve boundary.

In the group ranches, nearly all the wildlife were neither near or far (= hump in the curve) from bomas. Ostrich, hartebeest, Grant's gazelle, and waterbuck avoided bomas in 1999 but were collected at intermediate distances from bomas in 2002. The rest of the herbivores grazed at intermediate distance from bomas in both years. Bomas also appeared to have less influence on elephant distribution in the reserve in 2002.

In the reserve, all wildlife grazed farther from bomas than they did in the group ranches. We think the animals in the reserve show a more accurate picture of the impact of bomas, because wildlife in the reserve can choose to graze very far from bomas in the southern reserve (or Serengeti). Animals on the group ranches have fewer choices: the farthest an animal can go from a boma in the group ranch is 6 km, a distance well within the reach of grazing cattle within a day. Thus, wildlife on the group ranch can never 'get away' from livestock unless they graze in the areas heavily infested with tsetse, which are far from bomas. This implies that wildlife distributions are compressed in the group ranches by human use.

Note that some of the patterns on these graphs are confused by the large number of migrating animals that happened to be in the southern reserve during our count, thus the patterns shown by wildebeest, zebra and Thomson gazelle should be treated with caution.

In the reserve alone, wildlife chose to graze around bomas as follows:

1. **Preference for grazing near bomas in 1999 and 2002: 2 species.** Giraffe and impala
2. **Preference for grazing far from bomas (9-15 km) in 1999, but near bomas in 2002: 5 species.** Topi, Thomson's gazelle, buffalo, waterbuck and elephant
3. **Preference for grazing at intermediate distances from bomas (5-8 km): 1 species.** Grant's gazelle.
4. **Preference for grazing far from bomas, both years: 6 species.** Ostrich, zebra, hartebeest, warthog, eland and elephant only in 1999.

The patterns of wildlife around bomas in the group ranches and reserve surprised us. We expected to see wildlife avoiding bomas because livestock can compete with grazing wildlife for forage and dogs can attack or scare wildlife near bomas. Indeed, there appear to be several species that do prefer to graze far from bomas, probably for these reasons. These are species that may need protected savannas for survival

However, there were several species of wildlife that preferred to graze neither close to nor far from bomas. We think there are at least four explanations for this. First, livestock grazing may create expanses of nutrient- and energy-rich forage just beyond the heavily grazed areas surrounding bomas (or settlements). A second explanation is that wildlife may be attracted to the highly productive vegetation growing in nutrient-rich soils in abandoned bomas adjacent to inhabited bomas. In other ecosystems, wildlife and livestock preferentially graze on abandoned bomas compared with nearby areas with no settlements[28]. The third explanation is that wildlife, particularly smaller species highly susceptible to predation, may gather around settlements to avoid predators in the short grass grazed by livestock. A fourth reason that some species of wildlife congregate near people is that pastoralists may choose to settle in habitat near water and woody resources that is ideal for wildlife. Our data are most consistent with the forage nutrient and predation explanations, but only further research will give us confidence in the answer of how and why this occurs.

Livestock grazed at different distances from bomas. Donkeys never ventured beyond 1 km of bomas. Sheep and goats ventured farther from bomas in 2002 (6.6 km) than 1999 (4.5 km). . The humped distributions shown by cattle suggest that food was depleted for cattle close to bomas and that travel costs restricted cattle grazing to within 8 km of bomas. The shifts seen in the locations of peak densities for cattle between 2002 and 1999 support this hypothesis and suggest that cattle foraged farther from bomas in 2002 relative to 1999, when cattle numbers were double what they were in 1999. The concentration of donkeys, sheep and goats closest to bomas suggest that they can cope better with the shorter grass found there than can cattle.

[28] Muchiru 1992, Young et al. 1995, Muchiru et al. 2003

Figure 6. Distribution of wildlife and livestock around bomas both in the reserve and the group ranches, in 1999 and 2002.

Map 72. Distance to the nearest boma (in kilometres) in the count area, November, 2002.

5. Conclusions

5.1 How is pastoralism affecting wildlife in the Mara and how is wildlife affecting pastoralism in the Mara?

How pastoralism may be affecting wildlife

Wildlife populations have dropped by 70% in the last 20 years because of the expansion of wheat farming in the Loita, drought, habitat change and probably the expansion of settlement closer to the Mara reserve. In our counts, about 75% of the species are more abundant in the reserve than the group ranches, probably principally because of competition with livestock for forage in the group ranches. However, wildlife also appear to be attracted to people and their livestock, perhaps for several reasons. Pastoralists live in the best places, moderate livestock grazing may improve the quality of forage, burning by pastoralists attracts wildlife, pastoralists may 'protect' grazers from predators, and/or wildlife may be attracted to old boma sites. We think that any positive effects of pastoralism on wildlife abundance break down when the density of settlements passes a certain point, and that this point has been reached in and around the small villages in the group ranches of the Mara. Thus, we expect further growth in the number of settlements in the group ranches to result in further, more negative consequences for wildlife abundance.

How wildlife may be affecting pastoralism. The data in this report suggest very little about how wildlife are affecting pastoralists because we did not measure this information. There is a good deal of literature available about the negative aspects of living with wildlife for pastoral peoples and these include: 1) removal of forage by wildlife that could be used by livestock, 2) transmission of diseases from wildlife to livestock (like malignant catarryl fever; but also note livestock have brought new diseases to wildlife like rinderpest), and 3) loss of life by livestock and people through interactions with elephants, buffalo, hippos and predators. Our Maasai colleagues will also to be the first to point to the positive benefits of wildlife from cultural perspectives, the predator warning signals given by crowned plovers around settlements in the night and the current (and hopefully increasing) economic returns from tourism.

5.2 What does all this information suggest about management of the Mara?

Many pastoralists and conservationists agree that pastoralism, of the many ways that people can use the land, is more compatible with wildlife conservation than most others. Indeed, our data here imply that pastoral communities, contrary to traditional views, can sometimes enhance biodiversity, and this enrichment may have a long history. These findings support other evidence that integrated livestock-wildlife systems are more productive than either livestock or wildlife systems alone[29], at least in East Africa[30]. Conservation policy that excludes low to moderate levels of traditional pastoral use may inadvertently impoverish the very lands it was instituted to protect[31]. On the other hand, our data show that there are species that are best conserved in places with no people and no livestock (rhino, eland, most carnivores). In addition, establishment of more bomas

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[29] Western, D. in *Conservation for the Twenty-first Century* (eds, Western, D. & Pearl, M.) 158-165 (Oxford University Press, Oxford, UK, 1989).

[30] du Toit, J.T. & Cumming, D.H.M. Functional significance of ungulate diversity in African savannas and the ecological implications of the spread of pastoralism. *Biod. Cons.* **8**, 1643-1661 (1999).

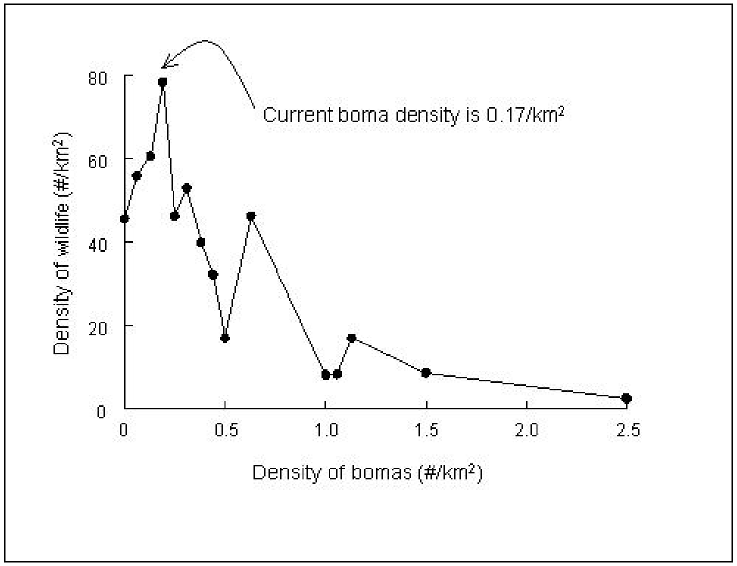
[31] Western, D. & Gichohi, H. Segregation effects and the impoverishment of savanna parks: the case for ecosystem viability analysis. *Afr. J. Ecol*. **31**, 269-281 (1993).

or a different distribution of bomas may have drastic consequences for the region's wildlife. For example, there appears to be a density of bomas ideal for promoting abundant species-rich wildlife; any increase or reduction in the number of bomas may decrease the number of wildlife (Figure 6). Unexpectedly, the average density of bomas in this ecosystem is currently close to this ideal point and any further growth of settlement should lead to wildlife loss. Furthermore, current land privatisation efforts may soon cause current bomas to be redistributed more evenly across the landscape. Our models suggest that this change alone would cause the heavily grazed areas surrounding bomas to coalesce and most MSA's to disappear, leading to a loss of 40% of the wildlife populations (45,000 individuals).

The recent losses of wildlife that we have seen in the Mara are partially caused by the fact that it is increasing difficult for the Mara Maasai to make ends meet through pastoralism. We estimate here that pastoralists in the Mara today meet only 25-35% of their household requirements from livestock. This has steadily decreased over the last two decades because of rapidly growing human populations set against stagnant (but varying) livestock populations. This means that pastoralists today are constantly searching for other options to support their families, and some of the options are compatible with wildlife (tourism) and others are not (leasing land for wheat farming, high density settlement in market centers). Pastoralists are at a critical juncture: will they follow their cousins around Nairobi National Park in the Kitengela and start wildlife-incompatible practices like planting maize and beans and building fences?

Managing the evolution of pastoral settlements in the northern Mara region – in terms of their number and distribution -- therefore appears to be key to protecting the remaining wildlife populations of the greater Serengeti-Mara ecosystem. It is crucially important that we make protected areas more effective, and improve incentives for pastoral communities to maintain lifestyles compatible with wildlife by increasing returns from wildlife to pastoral peoples.

Figure 7. The relationship between human population and wildlife population density.



5.3 Further information and discussion needed

We think that the following information will help better us understand the patterns we see here and contribute to better management of this valuable wildlife-people system:

- Analysis of trends in wildlife species at a fine resolution from 1989- 2003, using Judy and Mike Rainy's fine resolution data.
- Analysis of when, where and why multiple species associations of wildlife form and disband.
- Comparison of DRSRS, KWS and Mara Count data to confirm or refute the conclusions here and evaluate the costs and benefits of different monitoring techniques.
- Survey of the number of people per hut in 1999 and 2003 to make an accurate estimate of human populations
- GPS of the reserve boundary in Narok District
- Regular counts of all wildlife and livestock species. We suggest that aerial surveys are conducted 2-3 times a year (in the wet and dry seasons, at least) and ground counts every 2-3 years.
- A better mechanistic understanding of the distribution of wildlife and livestock in relation to environmental and habitat characteristics
- Develop better methods for counting rare species
- Better understanding of daily, seasonal and decadenal dynamics (for example, night distributions and behaviour)
- Carnivore monitoring and the spatial associations of carnivores and prey
- Better ways to improve returns to wildlife for all stakeholders, especially pastoralists
- More equitable ways to distribute the returns from wildlife enterprises
- More discussions among individuals and organisations concerned about the problems of pastoral people and their solutions, and ways for all concerned to join hands to conserve this valuable people-wildlife system

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7. Appendix

Methods for modeling herbivore distributions from water

We used the negative binomial regression model for overdispersed and dependent count data (Gotway and Stroup, 1997) to relate the total animal counts for each 1 x 1 km^2 block to the distance of each sub-block (0.333 x 0.333 km^2) center from the nearest water source, averaged over all sub-blocks within a block (n = 9), in SAS GLIMMIX MACRO (SAS Institute, 2001). We used the log link function and $\phi u(1+(u/k))$ for the variance function of the negative binomial model, where u is the mean, ϕ is the overdispersion parameter and k is the "aggregation parameter" (Thurston, et al. 2000). We estimated a common k for both landscapes by the method of moments for each species separately for the 1999 and 2002 data sets.

The large sample sizes made it computationally unfeasible to model spatial autocorrelation among all counts made in either year. Thus we allowed for spatial dependence among all counts by modelling the distribution of each species separately in each land use type and year. We fitted the regression models with and without spatial autocorrelation, using restricted maximum likelihood to estimate model parameters and $QAIC_C$ (Burnham and Anderson, 2002) to select the best-fitting variance-covariance structure. We also considered Poisson and logistic regression models but their fits were inferior to the negative binomial model.

Parameter estimates for the selected theoretical variogram models were used to initialise parameters of the variance-covariance matrix of the mixed models for Newton-Raphson iterations. A general specification of the fitted models is given by

$$y_i = \mu_i + \alpha_i \text{ dwater}_i + \beta_i \text{ dwater}^2_i + e_i \qquad (4)$$

$$\text{var}(e_i) = \sigma^2 + \sigma_1^2$$

$$\text{Cov}(e_{i_1}, e_{i_2}) = \sigma^2 \exp(-d_{ij}/\rho), \quad \text{for the exponential model}$$

$$= \sigma^2 \exp(-d^2_{ij}/\rho^2), \quad \text{for the Gaussian model}$$

$$= \sigma^2 \rho^{d}{}_{ij}, \quad \text{for the power model}$$

where y_i is the total count in the ith block, dwater_i is the distance from the centre of the ith block to the nearest water source, μ, α and β are regression coefficients, e_i are unknown random errors, σ^2 is the sample variance, σ_1^2 is the nugget variance, ρ is the correlation range and $d_{ij} > 0$ is the distance separating the ith and jth block centroids. We tested the significance of the distance-to-water effects using Wald type 1 F-tests due to the polynomial terms in model (4). We established whether there was spatial consistency in herbivore distributions from water and whether the quadratic polynomial fitted better than a linear model by examining the interaction terms and the estimated coefficients for significance.

Table A 1. Scientific and English names and weights of the 43 species of wildlife and livestock counted in the Mara Reserve and group ranches in 1999 and 2002.

Common name	Scientific name	Weight (kg)
African buffalo (H)	*Syncerus caffer*	450
African elephant	*Loxodonta africana*	1400
African honey badger (S)	*Raphicerus campestris*	11
Bat-eared fox (H)	*Otocyon megalotis*	5
Black rhinoceros (H)	*Diceros bicornis*	1000
Black-backed jackal (H)	*Canis mesomelas*	15
Bohor reedbuck (H)	*Redunca redunca*	30
Burchell's zebra	*Equus burchelli*	200
Bushbuck (H)	*Tragelaphus scriptus*	30
Cape hare (S)	*Lepus capensis*	3.2
Cattle	*Bos indicus*	180
Cheetah (H)	*Acinonyx jubatus*	45
Coke's hartebeest	*Alcelaphus buselaphus*	125
Common duiker (H)	*Sylvicarpa grimmia*	20
Crocodile (H)	*Crocodilus niloticus*	75
Defassa waterbuck	*Kobus ellipsiprymnus*	160
Domestic dog	*Canis familiaris*	20
Donkey	*Equius asinus*	130
Eland	*Taurotragus oryx*	350
Goat	*Capra hircus*	18
Grant's gazelle	*Gazella granti*	40

Common name	Scientific name	Weight (kg)
Hippopotamus (H)	*Hippopotamus amphibius*	1000
Impala	*Aepyceros melampus*	40
Kirk's dik-dik (H)	*Rhynchotragus kirkii*	7
Leopard (H)	*Panthera pardus*	45
Leopard tortoise (S)	*Geochelone pardalis*	10
Leopard tortoise (S)	*Geochelone pardalis*	10
Lion (H)	*Panthera leo*	80
Masai giraffe	*Giraffa camelopardalis*	1250
Mongoose (S)	*Mungos mungo*	1.3
Olive (or Anubis) baboon	*Papio anubis*	20
Oribi	*Ourebia ourebi*	16
Ostrich	*Struthio camelus massaicus*	114
Sheep	*Ovis aries*	18
Spotted hyena (H)	*Crocuta crocuta*	45
Thomson's gazelle	*Gazella thomsoni*	15
Topi	*Damaliscus korrigum*	100
Vervet monkey (H)	*Cercopithecus aethiops*	10
Vulture (H)	*4 different species*	4.8*
Warthog	*Phacochoerus aethiopicus*	45
Wildebeest	*Connochaetes taurinus*	120

Livestock species are highlighted in grey. (H) and (S) = species that we did not count well. (H) = species that are most active at night, hide during the day, inhabit bushy areas or water, or are often flying and thus difficult to count. (S) = species of small size that are difficult to see in tall grass.
*Average weight for the four species.
We probably counted more than one species of jackal, mongoose, hyena, hare, duiker, but grouped these harder to distinguish species into the most abundant species we observed above.

Table A 2. Number of animals counted by each ground counting team during November 2002.

Area and species ↓	Team 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	X	all	Total
Area covered (km^2)	119.7	207.7	39.0	99.8	93.7	134.6	79.2	121.0	122.4	110.8	116.7	95.0	91.1	53.1	80.2	115.2	109.9	154.7	68.7	72.6	68.7	58.8	2,212.3
Cattle	0	0	0	2,689	2,919	1,945	300	4,982	0	0	1,306	4,894	2,048	947	1,445	6,523	1,510	4,823	3,334	3,264	0	2,104	45,033
Donkey	0	0	0	0	6	7	0	25	0	0	0	11	28	8	21	7	40	20	88	13	0	29	303
Sheep & goats	0	0	0	950	2,232	2,249	0	6,891	0	0	0	6,304	3,512	2,251	3,705	4,107	3,149	7,915	9,906	1,970	0	4,553	59,694
Domestic dog	0	0	0	9	36	20	0	34	0	0	0	9	19	8	19	3	29	32	57	37	0	37	349
Baboon	18	68	0	98	116	77	181	25	31	157	0	52	444	28	3	71	0	31	89	96	14	96	1,695
Bat-eared fox	0	9	2	0	2	0	2	0	0	0	0	0	5	2	3	3	0	0	2	1	1	7	39
Buffalo	17	810	0	586	5	67	262	0	404	32	107	8	35	0	0	31	139	11	0	41	3	3	2,561
Bushbuck	0	40	0	1	2	0	0	1	0	3	0	2	0	0	1	3	3	0	0	3	6	0	65
Crocodile	0	0	0	0	6	4	0	0	0	5	0	0	1	0	0	0	0	0	0	0	0	0	16
Cheetah	1	0	0	2	0	0	0	0	0	4	0	0	2	0	0	1	5	2	0	0	0	0	17
Dikdik	0	2	0	5	2	0	0	13	0	1	0	15	23	5	10	5	13	5	53	80	0	8	240
Duiker	0	1	0	0	0	0	2	0	5	0	0	0	0	0	0	0	0	1	0	0	0	0	9
Eland	21	85	0	137	11	32	29	4	216	478	74	8	3	9	0	143	48	39	5	0	72	31	1,445
Elephant	29	66	109	41	0	0	22	5	114	77	112	42	17	0	7	28	31	33	48	9	30	0	820
Giraffe	15	33	0	101	11	30	13	57	42	53	12	57	139	54	22	48	20	93	27	43	0	10	880
Grant's gazelle	21	154	0	317	88	286	229	87	254	103	236	337	448	235	291	487	182	160	554	201	62	184	4,916
Honey badger	0	0	0	0	0	10	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	1	25
Hippopotamus	0	57	4	0	54	7	91	0	2	255	0	0	0	0	0	0	0	0	44	0	0	1	515
Hare	0	0	0	2	1	7	1	1	0	2	0	1	1	3	1	1	4	1	13	9	1	1	50
Hyena	4	23	1	9	16	22	23	0	20	28	5	22	18	0	7	4	3	8	7	0	7	24	251
Hartebeest	15	34	0	38	18	25	2	6	41	42	32	10	25	28	5	87	67	24	3	42	66	7	617
Impala	584	1,010	44	811	1,698	796	537	967	253	1,351	289	849	2,309	830	860	883	238	1,355	2,156	1,147	231	439	19,637
Jackal	9	4	0	11	4	7	14	1	4	5	2	8	13	11	11	15	7	9	3	1	9	11	159
Lion	6	4	2	19	15	2	4	3	12	18	3	20	0	0	0	8	0	2	4	5	25	17	169
Leopard	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	2
Mongoose	83	75	11	92	112	53	66	1	102	71	33	57	103	24	0	34	41	7	49	36	13	25	1,088
Oribi	8	72	33	6	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	122
Ostrich	7	5	0	6	2	27	15	28	17	39	29	6	6	13	7	20	1	15	0	8	82	6	339
Reedbuck	33	16	0	8	0	3	37	0	35	32	7	0	0	0	0	6	3	0	0	0	20	0	200
Rhinoceros	0	0	0	0	0	0	0	1	8	2	0	0	0	0	0	0	0	0	0	0	0	0	11
Thomson's gazelle	5,771	2,903	526	3,066	3,539	3,355	2,697	1,127	931	2,136	1,378	1,827	4,000	1,440	2,263	2,818	1,560	3,588	1,012	679	1,320	2,797	50,733
Topi	255	694	93	494	498	627	621	229	232	603	369	224	795	183	160	438	149	334	112	196	83	312	7,701
Tortoise	0	0	1	2	3	2	1	0	1	8	4	2	5	0	2	3	2	1	1	9	7	0	54
Vulture	51	218	49	26	1	27	45	18	126	229	87	38	73	24	5	77	1	13	100	25	74	41	1,348
Vervet	45	0	0	7	10	6	0	16	1	9	1	0	117	8	23	1	30	21	0	29	98	0	422
Waterbuck	67	82	22	127	0	120	77	63	21	60	5	2	4	4	0	9	20	29	15	7	0	2	736
Warthog	137	143	4	320	46	241	273	31	168	190	43	36	142	26	17	57	25	170	32	60	82	26	2,269
Wildebeest	24,513	21,483	1,436	978	4,901	767	503	157	24,762	10,844	25,133	581	1,313	500	1,720	15,608	799	2,278	371	262	8,710	6,466	154,085
Zebra	4,480	4,755	220	2,587	3,851	1,592	429	216	1,901	2,069	6,557	1,082	1,961	330	517	2,213	658	980	284	223	769	1,284	38,958
Total	36,310	33,054	2,596	13,645	20,299	12,548	6,558	15,110	29,825	19,018	35,955	16,599	17,700	7,024	11,205	33,857	8,887	22,155	18,438	8,570	11,854	18,581	399,685

Table A 3. The total number and density (number per km^2) of Maasai bomas and huts by sectors of the Mara Reserve and adjacent ranches, and the estimated human population size and density in November 2002.

	Ranches									Mara Reserve								
	Koyiaki (793 km^2)			**Other ranches (133 km^2)			Ol Chorro Oirowua (49 km^2)			Musiara (246 km^2)			Sekenani (561 km^2)			Triangle (427 km^2)		
Variable	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE
Bomas	295	0.372	0.025	45	0.338	0.067	12	0.244	0.075	9	0.037	0.013	5	0.009	0.005	7	0.016	0.008
Dung-roofed huts	1,469	1.853	0.170	361	2.710	0.548	55	1.120	0.625	56	0.227	0.096	39	0.070	0.042	36	0.084	0.084
Grass-roofed huts	211	0.266	0.046	12	0.090	0.059	11	0.224	0.120	3	0.012	0.009	1	0.002	0.002	14	0.033	0.028
Tin-roofed huts	554	0.699	0.072	71	0.533	0.174	48	0.977	0.457	6	0.024	0.021	13	0.023	0.014	26	0.061	0.039
All huts	2,234	2.818	0.221	444	3.333	0.653	114	2.321	0.864	65	0.264	0.111	53	0.094	0.055	76	0.178	0.123
*Human population estimate	10,299	12.987		2,047	15.390		526	10.725		300	1.218		244	0.436		350	0.821	

*Human population =Number of huts x 4.61 persons per hut (Lamprey, 1984).
**Other ranches refers to parts of Lemek (60 km^2), Olkinyei (37 km^2) and Siana (36 km^2) group ranches.
Only density can be compared directly across regions because the regions are of different sizes.

Table A 4. The total number and density* (animals per km2) of animals by species in each sector of the Mara Reserve and adjacent ranches in the entire and larger counting area in November 2002.

	Ranches									Reserve								
	Koyiaki (793 km^2)			**Other ranches (133 km^2)			Ol Chorro Oirowua (49 km^2)			Musiara (246 km^2)			Sekenani (561 km^2)			Triangle (427 km^2)		
Species	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE
Cattle	22,502	28.383	2.583	7,819	58.692	9.601	1,202	24.476	9.445	5,081	20.617	5.355	7,829	13.955	3.382	440	1.030	0.577
Donkey	234	0.295	0.059	62	0.465	0.192	0	0.000	0.000	0	0.000	0.000	7	0.013	0.013	0	0.000	0.000
Sheep & goats	45,345	57.198	4.218	5,036	37.802	7.906	1,277	26.002	12.378	3,319	13.468	5.623	4,107	7.321	1.833	460	1.076	0.597
Domestic dog	655	0.826	0.506	62	0.141	0.104	10	0.203	0.104	10	0.041	0.020	3	0.005	0.003	9	0.021	0.014
Baboon	697	0.879	0.230	117	0.878	0.415	24	0.489	0.412	423	1.716	0.420	273	0.487	0.137	161	0.377	0.140
Bat-eared fox (H)	17	0.022	0.081	3	0.023	0.017	0	0.000	0.000	4	0.016	0.012	4	0.007	0.005	11	0.026	0.014
Buffalo (H)	55	0.069	0.043	41	0.308	0.308	0	0.000	0.000	342	1.388	1.008	711	1.267	0.545	1,412	3.304	1.084
Bushbuck (H)	5	0.006	0.004	2	0.015	0.011	1	0.021	0.021	2	0.008	0.008	14	0.025	0.013	41	0.096	0.094
Cheetah (H)	4	0.005	0.003	0	0.000	0.000	0	0.000	0.000	1	0.005	0.005	10	0.018	0.012	2	0.005	0.004
Crocodile (H)	1	0.001	0.001	0	0.000	0.000	0	0.000	0.000	10	0.041	0.024	5	0.009	0.004	0	0.000	0.000
Dikdik (H)	150	0.189	0.023	74	0.555	0.094	2	0.041	0.041	2	0.008	0.008	6	0.011	0.005	6	0.014	0.010
Duiker (H)	3	0.004	0.002	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	5	0.009	0.004	1	0.003	0.003
Eland	85	0.107	0.041	1	0.007	0.007	39	0.794	0.734	73	0.296	0.114	1,031	1.838	0.377	216	0.506	0.167
Elephant	112	0.141	0.049	15	0.113	0.076	1	0.021	0.021	64	0.260	0.116	383	0.683	0.157	245	0.573	0.196
Giraffe	512	0.646	0.081	21	0.158	0.082	33	0.672	0.329	40	0.162	0.062	160	0.285	0.066	114	0.266	0.094
Grant's gazelle	2,318	2.924	0.205	173	1.299	0.280	54	1.100	0.446	1,032	4.188	0.425	1,162	2.071	0.225	175	0.410	0.268
Hare (S)	31	0.039	0.008	6	0.045	0.018	1	0.021	0.021	8	0.032	0.015	4	0.007	0.004	0	0.000	0.000
Hartebeest	164	0.207	0.049	28	0.211	0.093	0	0.000	0.000	24	0.097	0.042	315	0.562	0.104	86	0.202	0.071
Hippopotamus (H)	120	0.151	0.071	0	0.000	0.000	0	0.000	0.000	77	0.312	0.167	257	0.458	0.203	61	0.143	0.129
Honey badger (S)	1	0.001	0.001	0	0.000	0.000	0	0.000	0.000	10	0.041	0.026	14	0.025	0.023	0	0.000	0.000
Hyena (H)	81	0.103	0.022	3	0.023	0.013	0	0.000	0.000	72	0.293	0.068	67	0.120	0.027	28	0.066	0.016
Impala	10,967	13.834	0.922	1,469	11.027	1.472	260	5.294	1.765	1,866	7.572	0.902	3,041	5.421	0.537	2,021	4.730	0.635
Jackal (H)	65	0.082	0.014	5	0.038	0.025	0	0.000	0.000	36	0.146	0.035	35	0.062	0.017	18	0.042	0.014
Leopard (H)	1	0.001	0.001	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.002	0.002	0	0.000	0.000
Lion (H)	44	0.056	0.028	2	0.015	0.015	0	0.000	0.000	45	0.183	0.103	66	0.118	0.033	12	0.028	0.012
Mongoose (S)	323	0.408	0.077	33	0.248	0.112	6	0.122	0.122	195	0.791	0.201	282	0.503	0.112	249	0.582	0.144
Oribi	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	48	0.022	0.022	0	0.000	0.000	119	0.279	0.255
Ostrich	45	0.057	0.014	19	0.142	0.100	19	0.387	0.387	50	0.203	0.062	188	0.335	0.139	18	0.042	0.016
Reedbuck (H)	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	40	0.162	0.046	103	0.184	0.028	57	0.133	0.029
Rhinoceros (H)	0	0.000	0.000	0	0.000	0.000	1	0.021	0.021	0	0.000	0.000	10	0.018	0.012	0	0.000	0.000
Thomson's gazelle	21,951	27.689	1.348	1,959	14.705	1.750	210	4.276	1.246	8,581	34.819	2.189	8,629	15.382	0.926	9,389	21.971	1.435
Topi	2,819	3.556	0.207	252	1.892	0.345	55	1.120	0.516	1,627	6.602	0.690	1,775	3.164	0.287	1,143	2.675	0.360
Tortoise (S)	13	0.016	0.005	8	0.060	0.022	0	0.000	0.000	5	0.021	0.011	25	0.045	0.010	3	0.007	0.005
Vervet monkey (H)	197	0.248	0.068	32	0.240	0.159	0	0.000	0.000	32	0.130	0.095	110	0.196	0.135	51	0.120	0.061
Vulture (H)	254	0.320	0.079	42	0.315	0.194	0	0.000	0.000	119	0.483	0.180	593	1.057	0.203	340	0.796	0.184
Warthog	443	0.559	0.050	129	0.968	0.176	36	0.733	0.302	553	2.244	0.210	557	0.993	0.092	551	1.290	0.129
Waterbuck	232	0.293	0.064	18	0.135	0.080	3	0.061	0.046	105	0.426	0.129	115	0.205	0.045	263	0.616	0.153
Wildebeest	18,661	23.542	1.548	355	2.665	0.609	67	1.364	1.004	1,881	7.633	1.589	85,654	152.681	12.646	47,467	111.077	7.062
Zebra	11,126	14.035	0.907	442	3.317	0.561	32	0.652	0.372	3,098	12.571	1.374	13,865	24.715	2.299	10,350	24.220	1.670
Total wildlife	71,497	90.189	2.884	5,249	39.401	2.830	844	17.186	3.429	20,465	82.868	3.904	119,470	212.962	13.391	76,395	174.813	8.138
Wild herbivores	69,768	88.042	2.881	4,998	37.516	2.830	813	16.554	3.429	19,460	78.963	3.896	117,981	210.305	13.391	73,735	172.547	8.136
Wild carnivores	450	0.568	0.039	52	0.391	0.036	0	0.000	0.000	283	1.149	0.128	777	1.385	0.050	400	0.936	0.028
Livestock excluding dogs	68,081	85.876	5.124	12,917	96.959	13.724	2,479	50.477	16.324	8,400	34.085	7.779	11,943	21.289	3.867	900	2.106	1.130

*Only density can be compared directly across regions because regions are of different sizes. **Other ranches refers to parts of Lemek (60 km^2), Olkinyei (37 km^2) and Siana (36 km^2) group ranches.

(S)= species difficult to count because of small size; (H)= species difficult to count because they hide, inhabit bush or water. SE: standard error of density

Table A 5. The total biomass and biomass density* (kg per km^2, SE= standard error) by species and by functional categories of species in each sector of the Mara Reserve and adjacent ranches in November 2002.

	Ranches									Mara Reserve								
	Koyiaki (793 km^2)			**Other ranches (133 km^2)			Ol Chorro Oirowua (49 km^2)			Musiara (246 km^2)			Sekenani (561km^2)			Triangle (427 km^2)		
Species	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE
Cattle	4,050,360	5,109.073	464.935	1,407,420	10564.454	1728.142	216,360	4405.521	1700.057	914,580	3711.101	963.968	1,409,220	2511.978	608.768	79,200	185.335	103.889
Donkey	30,420	38.372	7.619	8,060	60.501	24.943	0	0.000	0.000	0	0.000	0.000	910	1.622	1.622	0	0.000	0.000
Sheep & goats	816,210	1,029.557	75.936	90,648	680.427	142.298	22,986	468.041	222.801	59,742	242.416	101.218	73,926	131.775	33.005	8,280	19.376	10.736
Domestic dog	13,100	16.524	10.112	1,240	9.308	2.096	200	4.073	2.070	200	0.812	0.397	60	0.107	0.062	180	0.421	0.269
Baboon	13,940	17.583	4.607	2,340	17.564	8.294	480	9.774	8.242	8,460	34.328	8.409	5,460	9.733	2.735	3,220	7.535	2.805
Bat-eared fox (H)	85	0.107	0.040	15	0.113	0.084	0	0.000	0.000	20	0.081	0.058	20	0.036	0.022	55	0.129	0.068
Buffalo (H)	24,750	31.219	19.571	18,450	138.490	138.490	0	0.000	0.000	153,900	624.481	453.418	319,950	570.321	245.485	635,400	1,486.895	487.559
Bushbuck (H)	150	0.189	0.100	60	0.450	0.319	30	0.611	0.611	60	0.244	0.244	420	0.749	0.371	1,230	2.878	2.809
Cheetah (H)	180	0.227	0.139	0	0.000	0.000	0	0.000	0.000	45	0.183	0.183	450	0.802	0.520	90	0.211	0.149
Crocodile (H)	75	0.095	0.095	0	0.000	0.000	0	0.000	0.000	750	3.043	1.825	375	0.669	0.299	0	0.000	0.000
Dikdik (H)	1,050	1.325	0.161	518	3.888	0.655	14	0.285	0.285	14	0.057	0.057	42	0.075	0.035	42	0.098	0.069
Duiker (H)	60	0.076	0.044	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	100	0.178	0.080	20	0.047	0.047
Eland	29,750	37.526	14.087	350	2.627	2.627	13,650	277.942	257.006	25,550	103.675	40.093	360,850	643.226	131.933	75,600	176.911	58.394
Elephant	156,800	197.814	68.642	21,000	157.631	105.557	1,400	28.507	28.507	89,600	363.571	162.129	536,200	955.793	219.487	343,000	802.652	274.085
Giraffe	640,000	807.401	101.194	26,250	197.039	102.239	41,250	839.932	411.297	50,000	202.885	77.818	200,000	356.506	81.600	142,500	333.464	117.262
Grant's gazelle	92,720	116.956	8.218	6,920	51.944	11.199	2,160	43.982	17.816	41,280	167.503	16.989	46,480	82.852	8.989	7,000	16.381	10.722
Hare (S)	99	0.124	0.026	19	0.144	0.058	3	0.066	0.066	26	0.104	0.049	13	0.023	0.012	0	0.000	0.000
Hartebeest	20,500	25.859	6.022	3,500	26.272	11.548	0	0.000	0.000	3,000	12.173	5.315	39,375	70.187	12.996	10,750	25.156	8.922
Hippopotamus (H)	120,000	151.367	70.665	0	0.000	0.000	0	0.000	0.000	77,000	312.444	166.667	257,000	458.111	202.602	61,000	142.745	129.083
Honey badger (S)	11	0.010	0.010	0	0.000	0.000	0	0.000	0.000	110	0.446	0.287	154	0.277	0.257	0	0.000	0.000
Hyena (H)	3,645	4.598	0.960	135	1.013	0.585	0	0.000	0.000	3,240	13.147	3.043	3,015	5.374	1.217	1,260	2.948	0.713
Impala	438,680	553.345	36.876	58,760	441.068	58.853	10,400	211.765	70.583	74,640	302.867	36.063	121,640	216.827	21.502	80,840	189.173	25.421
Jackal (H)	975	1.230	0.216	75	0.563	0.374	0	0.000	0.000	540	2.192	0.522	525	0.936	0.263	270	0.632	0.221
Leopard (H)	45	0.057	0.057	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	45	0.080	0.080	0	0.000	0.000
Lion (H)	3,520	4.440	2.252	160	1.201	1.201	0	0.000	0.000	3,600	14.608	8.240	5,280	9.412	2.680	960	2.246	0.916
Mongoose (S)	420	0.530	0.099	43	0.322	0.145	8	0.159	0.159	254	1.028	0.261	367	0.654	0.145	324	0.757	0.187
Oribi	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	48	0.022	0.021	0	0.000	0.000	1,904	0.450	0.096
Ostrich	5,130	6.471	1.593	2,166	16.259	11.380	2,166	44.105	44.105	5,700	23.129	7.121	21,432	38.203	15.825	2,052	4.802	1.885
Reedbuck (H)	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1,200	4.869	1.384	3,090	5.508	0.847	1,710	4.001	0.878
Rhinoceros (H)	0	0.000	0.000	0	0.000	0.000	1,000	20.362	20.362	0	0.000	0.000	10,000	17.825	11.551	0	0.000	0.000
Thomson's gazelle	329,265	415.331	20.229	29,385	220.571	26.243	3,150	64.140	18.686	128,715	522.288	32.828	129,435	230.722	13.892	140,835	329.567	21.513
Topi	281,900	355.586	20.676	25,200	189.158	34.438	5,500	111.991	51.577	162,700	660.190	68.999	177,500	316.400	28.682	114,300	267.473	35.981
Tortoise (S)	130	0.164	0.049	80	0.600	0.212	0	0.000	0.000	50	0.203	0.107	250	0.446	0.099	30	0.070	0.052
Vulture	1,219	1.538	0.380	202	1.512	0.929	0	0.000	0.000	571	2.320	0.864	2,846	5.072	0.972	1,632	3.819	0.881
Warthog	19,935	25.146	2.259	5,805	43.574	7.918	1,620	32.987	13.577	24,885	100.976	9.418	25,065	44.679	4.114	24,795	58.023	5.800
Waterbuck	37,120	46.823	10.166	2,880	21.618	12.813	480	9.774	7.278	16,800	68.170	20.638	18,400	32.799	7.196	42,080	98.471	24.484
Wildebeest	2,239,320	2,825.046	185.786	42,600	319.766	73.163	8,040	163.710	120.408	225,720	915.907	190.596	10,278,480	18,321.711	1,517.467	5,696,040	13,329.266	847.425
Zebra	2,225,200	2,806.840	181.444	88,400	663.553	112.220	6,400	130.316	74.251	619,600	2,514.157	274.947	2,773,000	4,942.959	459.785	2,070,000	4,843.994	334.020
All wildlife	6,686,674	8,435.020	336.786	335,313	2,516.939	290.562	97,751	1,990.407	719.286	1,718,077	6,971.288	647.951	15,337,259	27,339.145	1,741.914	9,458,939	22,130.794	1,163.822
Wild herbivores	6,642,395	8,379.172	336.660	326,439	2,450.333	290.574	95,640	1,947.421	719.286	1,675,527	6,798.631	647.763	15,293,394	27,260.953	1,741.883	9,426,303	22,054.424	1,163.801
Wild carnivores	8,525	10.753	2.462	385	2.890	1.385	0	0.000	0.000	8,195	33.253	8.788	9,710	17.309	3.030	2,635	6.166	1.189
***Livestock	4,896,990	6,177.002	477.350	1,506,128	11305.382	1765.242	239,346	4,873.561	1,737.161	974,322	3,953.516	969.618	1,484,056	2,645.375	610.096	87,480	204.711	113.193

*Only density can be compared directly across regions because regions are of different sizes. **Other ranches refers to parts of Lemek (60 km^2), Olkinyei (37 km^2) and Siana (36 km^2) group ranches.
***Livestock biomass excluding the domestic dog. (S)=species difficult to count because the are small in size; (H)=species that are difficult to count because they hide, inhabit bush or water

Table A 6. The total number and density* (number per km^2) of carcasses by species for each sector of the Mara Reserve and the adjacent ranches in November 2002.

	Ranches									Mara Reserve								
	Koyiaki (793 km^2)			**Other ranches (133 km^2)			Ol Chorro Oirowua (49 km^2)			Musiara (246 km^2)			Sekenani (561 km^2)			Triangle (427 km^2)		
	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE	Total	Density	SE
Buffalo	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	1	0.0005	0.0005	1	0.0002	0.0002	0	0.0000	0.0000
Eland	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000
Giraffe	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	1	0.0005	0.0005	0	0.0000	0.0000	0	0.0000	0.0000
Grant's gazelle	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	1	0.0005	0.0005	0	0.0000	0.0000	0	0.0000	0.0000
Hippopotamus	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	1	0.0002	0.0002	1	0.0003	0.0003
Impala	2	0.0003	0.0002	1	0.0008	0.0008	0	0.0000	0.0000	0	0.0000	0.0000	2	0.0004	0.0003	0	0.0000	0.0000
Thomson's gazelle	0	0.0000	0.0000	2	0.0017	0.0012	0	0.0000	0.0000	2	0.0009	0.0006	1	0.0002	0.0002	1	0.0003	0.0003
Topi	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	2	0.0004	0.0003	0	0.0000	0.0000
Warthog	1	0.0001	0.0001	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	1	0.0002	0.0002	0	0.0000	0.0000
Wildebeest	6	0.0008	0.0003	0	0.0000	0.0000	0	0.0000	0.0000	2	0.0009	0.0006	150	0.0297	0.0042	23	0.0060	0.0013
Zebra	1	0.0001	0.0001	0	0.0000	0.0000	0	0.0000	0.0000	2	0.0009	0.0006	10	0.0020	0.0006	4	0.0010	0.0005
Unknown	1	0.0001	0.0001	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000	30	0.0078	0.0015
Total	11	0.0014	0.0046	3	0.0025	0.0075	0	0.0000	0.0000	9	0.0042	0.0122	168	0.0333	0.0387	59	0.0154	0.0187

*Only density can be compared directly across regions because regions are of different sizes.
**Other ranches refers to parts of Lemek (60 km^2), Olkinyei (37 km^2) and Siana (36 km^2) group ranches.
SE=standard error of density.