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The impact of climate variability on the ecology of a lion (*Panthera leo* Linnaeus 1758) population and lion livestock conflicts in the Amboseli ecosystem - Kenya

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Title: The impact of climate variability on the ecology of a lion (*Panthera leo* Linnaeus 1758) population and lion livestock conflicts in the Amboseli ecosystem – Kenya

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Summary

Understanding the Impact of Climate Variability on the Ecology of a Lion (*Panthera leo Linnaeus, 1758*) Population and Lion – Livestock Conflicts in the Amboseli Ecosystem, Kenya

Keywords:

Severe drought, climate variability, lion population, home range, movement patterns, diet, livestock predation, Amboseli National Park, Kenya

Wild carnivores are an important component of many ecological systems and play a significant role in maintaining ecosystem health. Being at the top of the food chain, carnivores have important ecological impacts, including the regulation of mesopredators, maintenance of healthy prey populations, alterations in the spatial distribution of prey and associated changes in vegetation structure. Important cascading trophic effects, caused by population changes of their prey or of sympatric mesopredators, may result when some of these large carnivores are removed from ecosystems. The removal of top predators from ecosystems often causes dramatic changes in biodiversity and community structure, and can have severe consequences for the functioning of ecosystems and ecosystem services.

Historically, the conservation of biodiversity throughout the world has been facilitated by the designation of protected areas (PAs). These are areas set aside principally for the protection and conservation of biological diversity, and of their natural and associated cultural resources. Nevertheless, PAs alone cannot provide a long-term solution for the conservation of certain species such as large carnivores, because many of these PAs are too small to maintain viable populations. An example is Amboseli National Park (ANP) in Southern Kenya, with a surface area of only 370 square km. Large carnivores such as lions usually have large home ranges and therefore only large PAs can provide adequate protection.

Climate change and associated climate variability is one of the greatest conservation challenges of the 21st century. Climate variability is expected to exacerbate climate-mediated biodiversity loss through fragmentation of wildlife habitats and the spread of alien invasive species. The impact of climate variability is generally compounded by environmental degradation.

Moreover, anthropogenic activities are exerting additional pressure on biodiversity. Dwindling natural resources result in deterioration of rangelands and diminishing grazing areas for wildlife. The displacement of animals and increasing migrations due to pastoralist activities may further enhance the impact of increased drought prevalence and scarcity of water resources, which could lead to more human-wildlife conflicts.

In African savanna environments, vegetation growth and hence food production for herbivores depends strongly on rainfall during the wet season. Determining biological and environmental factors that limit the distribution and abundance of organisms is central to our understanding of the dynamics of animal populations. It is crucial for predicting how species may respond to large-scale environmental change, such as drought (short term) and climate change (long term). Wildlife populations may increase or decrease dynamically, depending on rainfall. Plenty of rainfall may lead to an increase in animal populations, as improved range conditions result from the growth of forage and from the abundant water necessary to maintain basic metabolism. Large mammal communities are ultimately limited by their food supply through mortality and reproductive stress.

It is known that droughts may have disruptive effects on the vegetation, which in turn affects animal populations through enhanced mortality, first of the weaker animals and later of the ones that are more fit. Such changes may lead to age-restricted mortality, reduced fecundity and reproduction, the restriction of animal movements and ultimately a strong reduction in population size and density. This was confirmed through my PhD research; I found that drought had a severe impact on herbivore populations and on the social structure of the lion population in ANP.

My research covered three years before/during (2007-2009) and three years after the drought (2010-2012). The main aim of my research was to understand the effects of lion-prey interactions during and after a severe drought and the impact of this drought on lion density and social structure, ranging patterns, diet and prey relations, as well as their interaction with local communities.

My PhD research revealed that human interventions enhance the impact of climate variability and extreme drought. The years after the extreme drought were characterized by increased retaliatory killing of lions by Maa-sai herdsmen in the surrounding cattle areas.

Large carnivores are particularly vulnerable to habitat loss because they have large home ranges and require extensive, intact habitats to survive. Disturbance due to human activities, such as encroachment of cultivation and settlements, causes a decline in areas of natural habitat and reduces space for grazing by wild herbivores. My PhD research confirmed that habitat loss and habitat fragmentation are among the most important factors influencing the threat of species extinction.

Like elsewhere in Kenya, increasing human encroachment into predator ranges is displacing prey species, resulting in increased livestock-predator interactions and subsequent predation incidents. Livestock predation is the main reason why locals kill predators in the Amboseli Ecosystem (AE).

Diseases such as canine distemper virus and feline immunodeficiency virus are also known to severely impact large carnivore populations, including lions, elsewhere in sub-Saharan Africa. In my research area however, no cases of disease in the lion population have been reported in the recent past.

The lion population in the AE has strongly declined since the last century, with only small populations remaining in the Amboseli National Park (ANP) and in the Mbirikani-Chyulu area. In the early 1990s, the entire Amboseli lion population was destroyed through poisoning and killing, but dispersal into the ANP from surrounding lands ensured that a new population was re-established. Considering the rate of killing which occurred during 2000-2007, this reservoir population headed towards depletion again, almost leaving ANP without any lions, and no source of replacement.

In an attempt to improve the status of ANP's lion population, retaliatory killing was strongly reduced after the start of a compensation scheme supported by the Maasai Conservation Trust in 2007. However, in spite of the reduced overall mortality due to retaliatory killing, I found that in the years after the drought, mortality due to increased human-lion conflicts increased considerably. My research also showed a negative Vulnerability Index (VI) after the severe drought in 2009, indicating higher vulnerability of the lion population during that time. The positive VI in 2011 marked the first signs of recovery. We recorded 28 lions killed around the park during the post-drought period of 2010-2012, compared to 14 before/during the drought (2007-2009); among the first were five pride males. After the drought (2010-2012), the lion population showed a significant change in structure, with a decrease in male-female sex ratio (due to a decline of males), a sig-

nificant increase in adult group size and a significant decline in juvenile to adult ratio (due to an increase of juveniles). All these changes corresponded to increased lion vulnerability in 2010. We noticed that during this period, male lions were targeted more than females by Maasai warriors (Moran), potentially due to cultural practices (use of manes and claws). The increase in juveniles may have been the result of less competition between pride males and consequently less infanticide. The reduced group size was probably a response to lower prey densities and a drought-resilience mechanism. We found strong positive correlations between the home range size and distance moved in 24 hours before and during the drought, indicating that lions moved more in a smaller home range, while after the drought there was a significant negative correlation, indicating that the lions moved less in a larger home range. This could be explained by the lower densities of prey animals after the drought. A weak positive correlation was evident between lion home range size and rainfall (2010-2012). The male and female home ranges varied over the study period, with male home ranges being significantly larger. The core home range areas (10% Kernel and MCP) and movement patterns overlapped with permanent swamps and areas of high prey density inside the protected area. During the years before/during the drought (2007-2009), the lions' preferred prey species were wildebeest and zebra. The drought resulted in mass mortality among wildebeest and zebra, forcing the lions to shift towards smaller prey species (Thomson's gazelle, ostrich, and warthog) and larger prey species (giraffe and buffalo), in addition to livestock in the year directly after the drought (2010). Diet composition recovered to some extent in 2011 and 2012, when the lions shifted back to their preferred medium-sized prey such as zebra and wildebeest. There were significant differences in livestock predation patterns before/during and after the severe drought (2008-2009): before/during the drought, 1982 head of livestock were killed compared to 2544 after the drought. In total, 3497 of the kills were sheep and goats, 742 cattle and 295 donkeys. Results further show a negative relationship between rainfall intensity and the number of livestock predation incidences for both the periods before and after the drought, with more livestock killed during periods with higher rainfall. We also found that herbivore abundance within the park had a significant effect on livestock predation intensity. Livestock predation increased exponentially after the drought, when wild herbivore numbers were low.

My research demonstrated that the structure of the lion population in ANP changed (male-female ratio; juvenile-adult ratio and group size) in response to the severe drought of 2009. The lions' diet composition changed mark-

edly in the year directly after the drought, when fewer medium sized zebra and wildebeest were taken, but more larger and smaller prey species.

The lion-prey system showed a remarkable resilience, with signs of restoration within two years after the drought (2011), indicated by an increased reproduction rate of the lion population and a return to the pre-drought diet composition. The increase in reproduction is remarkable, considering the high mortality, particularly of male lions, through retaliatory killing by Maasai warriors in the years directly after the drought (2010-2011). A possible explanation of this may be a substantial reduction in pride takeovers and subsequent infanticides by adult male lions.

My research showed that with the existing animal corridors intact, allowing gene flow between distinct prides, the lion-prey system was able to cope with sudden extreme droughts. I suggest that these corridors are essential for the long term survival of the lion population in the Amboseli ecosystem.

