# Human-Lion conflict around Nairobi National Park: Lion (Panthera leo melanochaita, Hamilton Smith, 1842) Population Structure, Landscape Use and Diet, in a Semi-Fenced Park

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# 7

# Synthesis and General Discussion

## 7.1 Background

Lions have been extensively studied as a top predator and as an indicator of healthy ecosystems and as a flagship species in the tourism industry (Schaller 1972; Macdonald 1983; De Iongh et al. 2009). Before the 1980s, research on lions focused on social status, population dynamics and interactions with prey and habitat. However, in the past two decades, lion research has become more focused on human–wildlife interaction (Ogada et al. 2003; Patterson et al. 2004; Woodroffe et al. 2007; Inskip & Zimmermann 2009). The African lion (*Panthera leo)* has declined as a result of habitat fragmentation, retaliatory killing and prey depletion (Woodroffe et al. 2007; Riggio et al. 2013; Tuqa et al. 2014). The African lion (*Panthera leo*) is listed as Vulnerable on the global "Red List" of the International Union for the Conservation of Nature (IUCN), based on criterion A2abcd (Bauer et al. 2016). The lions in West and Central Africa and India (*Panthera leo leo* Linnaeus, 1758) are classified as Regionally Critically Endangered while lions in East Africa (*Panthera leo melanochaita* Hamilton Smith 1842) are Regionally Endangered (Bauer et al. 2016). This has become a global concern (Riggio et al. 2013).

As a country, 8% of Kenya's land area has been declared as national park, national reserve or as government-managed sanctuaries (KWS 2015). This land mass excludes the private ranches and community conservancies that also host wildlife and cover some 11% of land area (KWCA 2016). This large land area, still holds a population of 2,000 (6.2% of the global population) lions. The problems facing lions in Kenya are similar to those lions are facing in Africa as a whole, including habitat destruction and fragmentation; prey depletion; and retaliatory killing as a result of human–carnivore conflict (Ogutu & Dublin 2002; Woodroffe et al. 2007; Riggio et al. 2013). To address these threats facing the lion population, Kenya has developed a number of policies and strategies (KWS 2008, 2011). Among the strategies is a long-term re-

search program on lion ecology within specific lion conservation units (KWS 2008). Lion research in Nairobi National Park is part of this strategy. My research addresses specific research objectives and questions aimed at finding possible solutions and recommendations for enhancing the conservation of lions. The main objective of my PhD research is to analyze factors influencing livestock depredation by lions around Nairobi National Park, impact of climate variability on lion movements and to investigate mitigation measures used by livestock farmers to prevent livestock depredation. To address the main objective of this study, we used the following research questions:

1 What is the population size and social structure in time and space?
2 What are the home range sizes and movements of lions in space and time?
3 What is the diet composition of lions and which independent factors (climate variability, carcasses and scats) influence their diet?
4 What is the livestock contribution to the lion diet and which independent factors influence livestock raiding and economic costs incurred by farmers?
5 What is the response of lions to LED flashlight installed at livestock bomas?

## 7.2 Population size, social structure and pride takeovers in Nairobi National Park

The results of my study show that Nairobi National Park has a relatively high lion density of 26 lions/100km$^2$ (including adult and sub-adults). In Africa, lion density is only higher in the Ngorongoro Crater, Tanzania (38.8 lions/100km$^2$ (Hanby et al. 1995) and in Maasai Mara National park, Kenya (37 lions/100km$^2$) (Ogutu et al. 2005). The high density of lions is an indicator of prey abundance and lack of competition with other predators (Ogutu & Dublin 2002; Bauer et al. 2008). During my research period, from 2012 to 2018, the lion population of NNP has fluctuated between 34 and 43 lions, including cubs (<1 year). We have established that NNP has three prides (Northern, Middle and Southern) during 2012 and 2014-2018. Despite human-induced causes are suggested to contribute significantly to lion mortality in NNP, my findings show that the current reproductive rate has sustained the lion population in the park. The transition of 5 newborn cubs annually into reproductive stage confirms that this lion population is relatively stable, despite its small size and "hard edges".

## 7.3 Home range sizes, dynamics and movements of Nairobi National Park lions

I found that there is no difference in home range size between the wet and the dry seasons. The only change observed in my study is a shift in the position of the lion range. Most of the pride home ranges shift longitudinally towards the southern section of the park into the open corridor. The NNP home range sizes were very small with an annual average of 34 $km^2$ (95% KDE). This is smaller compared to Waza National Park in Cameroon with an annual average of 641 $km^2$ (95% KDE) (Tumenta et al. 2013) and Amboseli National in Kenya with an annual average of 56.4 $km^2$ (95% KDE) (Tuqa 2015). As a consequence, some prides have extended their home range into relatively unoccupied and secure habitats in the community land at AKP. This high vigilance to protect the small home ranges and resources (females, food, cubs) has resulted in the death of three males during my study period (2012-2018) and it resulted in injuries to some females.

In NNP, male choice of habitat and home range size is influenced by their tenure status in relation to whether the pride has been taken over or not. I found that the southern part of the park has fewer compared to the northern part and when a pride male moves to the southern part of the park, he settles in the same pride home range without expansion of the territory size. This suggests that in such areas prey is probably equally distributed and access to preferred habitat (riverine) is secured.

My research indicates that lions mostly roam into pastoral land during the hours of low human activity (mainly at night). A study by Oriol-Cotterill et al. (2015) on lion home ranges and movements in a human-dominated landscape using satellite collars found that lions adapt their movements to human disturbance. Similar findings were reported by Tumenta (2012) for lions being nocturnal in the community land.

Overall, the Nairobi National Park lions avoid the urban fringe of Nairobi City. They prefer the riverine zone, despite its proximity to a zone with low human density. In this zone, lions have the advantage of accessing wildlife in the park and to both dispersing wild prey in the community area and to livestock during the wet season. I conclude that lions in NNP are partly dependent for their survival on community land for hunting livestock despite the relatively high densities of wild prey.

## 7.4 Feeding ecology and climate variability

I found that lions in the southern part of the park substitute the preferred weight class of wild prey with livestock during the wet season when there is a low density of wildlife in the park. The larger prey, such as African buffaloes, are consumed during the dry season when they are vulnerable to drought. These results reflect those of Bauer & De Iongh (2005) and Tuqa et al. (2014), who also found that lions feed on medium (50-200 kg body mass) to large prey (>200 kg body mass). Several studies have shown that lions are opportunistic feeders (Schaller 1972; Funston et al. 2003; Hayward & Kerley 2005; Davidson et al. 2013). According to these results, I can infer that selection of different prey in different seasons of the year is an important factor for lion survival and being adaptive to changing condition.

When I compared my results from microscopic prey hair morphology from lion scats and carcass counts with another method, i.e. analysis of DNA, I found that carcass counts underestimate the number of small (5-50 kg body mass) and cryptic prey. Carcasses of very small (<5 kg) prey are generally not found because they are entirely consumed by lions. Scat analysis through microscopic prey hair morphology analysis and DNA analysis have proven to be a better method for identifying very small (<5 kg), small (5-50 kg) as well as larger prey than carcass counts. I compared the results of scat analysis and carcass counts, and the results showed a broader spectrum of prey species in the scat than in the carcass counts.

I found some small (5-50 kg) and very small prey (<5 kg), such as Suni (*Neotragus moschatus)*, Mole rat (*Tachyoryctes sp*) and birds, both in eDNA and microscopic hair morphology analysis from the lion scats. The presence of very small prey confirms the opportunistic nature of lions, as suggested by Schaller (1972) and Hayward & Kerley (2005) and Davidson et al. (2013).

In my study, a cost-benefit analysis for lion prey choice provided more insight into the factors contributing to livestock raiding and human–lion interactions around Nairobi National Park. The wet and the dry seasons have been erratic, and this had an important impact on wildlife migration out of the park and the duration of stay in the community land. The lower the available natural prey biomass and density in the NNP during the wet season, the more difficult it becomes for lions to locate and catch natural prey species. According to Gichohi (1996); Owino et al. (2011) and Ogutu et al. (2013), the density of herbivores in Nairobi National Park is lower during the wet season compared to the dry season due to wild prey migration into community land. This could imply that the wild prey species base inside the park is not sufficient to sustain the current lion population during the wet season. Although non-migrating resident ungulate species such as hippo, rhinoceros

and giraffe contribute considerably to the available biomass, these species are not predated by lions, probably due to the risk of injury and energy costs involved in the hunt (Prins & Iason 1989; Hayward & Kerley 2005). This makes it necessary for the lions to follow common prey such as warthog, zebra and wildebeest outside NNP and to hunt outside the park borders, where they could encounter livestock. The abundance of livestock, in combination with their highly predictable distribution and inability to escape from the bomas, makes livestock an easy prey species for lions. Little energy is required to find livestock at night due to the fixed locations of the bomas, and once lions are in the boma, the tightly packed herds form an easy prey to catch. In other words, the benefits of livestock raiding in bomas are high and generally outweigh the costs. Therefore, with erratic climate variability, livestock attacks are very likely to continue and may even increase due to the ongoing process of sedentarization of pastoralists (Lesilau et al. 2018).

## 7.5 Impact of partial fencing of the park and costs of livestock depredation by lions

In my study, the communities neighboring the unfenced section of NNP suffer both significant social and economic costs of livestock attacks. Woodroffe et al. (2014) found that, although the construction of effective fencing systems around national parks requires intensive management of species, it could both resolve existing human-carnivore conflicts and increase the density of predators inside the park. The related risk of herbivore extinction through a "predator dip" should however not be underestimated.

My study shows that cultural and economic values of a particular livestock species determine the level of herding and protection. I found that unherded livestock such as donkeys, dogs and pigs also become a victim of lion depredation. This unherded livestock is more vulnerable to depredation by lions compared to herded livestock, such as cattle and shoats, especially at night when they enter the park unaccompanied by human guardians. Woodroffe et al. (2007) found that livestock with a child herder is more vulnerable to depredation as opposed to guards that are of adult age or operate in teams. Thus, our data show that when we look for a solution to address human-lion conflict in the importance of unherded livestock and age of herder must be given consideration.

Livestock is a major source of livelihood to all pastoral communities in Kenya (Tuqa 2015). Livestock with a high economic value are herded by mature persons (warriors). I found evidence of depredation of livestock species through microscopic prey hair morphology and DNA analysis. Live-

stock farmers around NNP incur 39,820 USD of costs to lion attacks annually compared to 22,498 USD at Tsavo National Park in Kenya (Patterson et al. 2004) and 610 USD annually at Gokwe in Zimbabwe (Butler 2000) (Table 7.1). These differences can be largely explained by the regional livestock price differences. In my study, lions predate more shoats due to less energy expenditure and high density in the area compared to cattle and donkeys. In West Africa, Bauer & De Iongh (2005) also found that lions prefer cattle and donkeys.

**Table 7.1**
**Economic cost incurred by livestock farmers neighbouring protected areas to lion.**

| No. | Protected area/Ecosystem | Country | Economic cost (USD) annually | Source |
|---|---|---|---|---|
| 1 | Gokwe | Zimbabwe | 610 | Butler 2000 |
| 2 | Tsavo National Park | Kenya | 22,498 | Patterson et al. 2004) |
| 3 | Waza National Park | Cameroon | 113,366 | Van Bommel et al; 2007 |
| 4 | Makgadikgadi Pan N. P. | Botswana | 24,385 | Hemson et al, 2009 |
| 5 | Nairobi N. Park | Kenya | 39,820 | Lesilau 2018* |

* The source of data is from this study

The pastoral communities around NNP are rapidly becoming sedentary and pastoralist activities around the park (Lesilau et al. 2018) are gradually declining. With less livestock available around NNP, the future challenge could be to tackle problems arising from lion–urban conflicts.

I found that partial fencing of the protected areas is not a solution to human–lion conflict and complete fencing is not always a solution. In the case of NNP, the Athi-Kaputei corridor in the south-west of NNP could be crucial to sustain the lion population. Complete fencing would block the access for both the NNP lions and present prey populations to this corridor, and although lion numbers could increase in the short term, the dip in prey numbers would eventually make this a less sustainable option. In addition, after complete fencing, lions will no longer have access to suitable habitat in the buffer zone to hide cubs and escape from pride male(s) during pride takeover, while roaming for nomadic males will be difficult (Lesilau inprep). Wildlife authorities could prevent this development by securing the available space through land acquisition and the purchase of land from land owners for wildlife.

## 7.6 Response of lions to flashlights

I compared different livestock husbandry techniques with a modern technique of preventing nocturnal livestock depredation, i.e. flashlight equipped bomas. I found that the frequency of attacks on bomas equipped with flashlights was significantly lower compared to bomas without flashlights. I found that after the installation of flashlights at livestock bomas, lion attacks took place further away from the park edge, towards areas where bomas without flashlights were still present. I also found a shift in timing of attacks by lions, with more diurnal attacks than nocturnal attacks after 5 years of flashlight installation.

A predator's feeding strategy always serves to maximize energy intake and minimize risk (Schaller 1972; Nathan et al. 2008; Valeix et al. 2012). To optimize energy and maximize profitability, lions often prefer wild prey species of medium (50-200 kg) or large (>200 kg) weight class (Cowie 1977; Hayward & Kerley 2005; Carbone et al. 2007) over smaller prey. Prey profitability can be defined as "the quotient of a prey type's net energy value divided by the amount of time required to catch and handle it" (Scheel & Packer 1991). This is dependent on prey density, prey distribution, biomass and the defense strategy of prey (Scheel & Packer 1991; Hayward & Kerley 2005; Valeix et al. 2012).

In relation to aforementioned, I found that costs of livestock raiding include the risk of encountering humans, travel distance and entering well protected bomas. Evidence to this is shown in the hunting behaviour of lions. Around NNP, lions usually hunt at night when human activity and visibility are low. This is confirmed in other studies (Van Bommel et al. 2007; Valeix et al. 2012). The avoidance of bomas equipped with flashlight systems by NNP lions, could indicate that these lions perceive the cost of encounters with humans as too high, outweighing the benefits of livestock raiding. Livestock protection measures implemented by livestock owners around NNP include the use of barbed wire and an extra outer fence of Acacia branches and wood for bomas. These materials however appeared to be much less effective compared to the presence of flashlights. Lions are known to jump over three meters high fences, despite the presence of barbed wire on top (Lesilau et al. 2018).

Distance to the park boundary seems to be another important factor determining attack rate, with bomas further than three km away from the park boundary experiencing significantly less attacks compared to bomas closer to the park. The question is whether livestock raiding is still attractive when all accessible bomas are located further than three km from the park. The use of geo-fencing in the AWT iridium satellite collars as a means of tracking li-

ons that would venture large distances from the park, did not work well, due to the proximity of bomas to the park boundary.

Currently, the benefits of livestock raiding around the Nairobi National Park still seem to be higher than the costs, given the large contribution of livestock to the lions' diet found in scats (15%). This is comparable to the 22% of livestock in the diet of lions in Waza National Park, Cameroon (Tumenta 2012), but higher than 9% in the diet of lions in Amboseli National Park, Kenya (Tuqa 2015) (Table 7.2). Due to the availability of livestock in close proximity to the park borders, there is no need for the lions to follow their migratory prey during the wet season, as livestock is a perfect substitution and the energy costs associated with travelling are minimized. Consequently, most lions are able to reside inside the park, also during the wet season, and only make short trips outside the park at night to the areas where livestock is held. The application of flashlights seems to be an effective method in preventing nocturnal livestock attacks by lions as the lights mimic risky human activity, which is rather avoided by lions. Despite its success, the LED flashlight technique also has a downside: lions adjust their behavior by attacking livestock during the day and further away from the park border, although the damage suffered during such diurnal attacks is relatively small.

Table 7.2
**Livestock depredation analysis from various parks in Africa**

| Country | Protected Area | Livestock Contribution to lion diet (%) | Source |
|---|---|---|---|
| **Botswana** | Makgadikgadi Pans | 10-26 | Hemson 2003. |
| **Kenya** | Tsavo N. Park | 5.8 | Patterson et al. 2004 |
| **Kenya** | Samburu N. Reserve | 6.2 | Ogara et al. 2010 |
| **Benin** | Pendjari Biosphere Reserve | 18 | Sogbohossou et al. 2011 |
| **Cameroon** | Waza N. Park | 21.6 | Tumenta et al. 2013 |
| **Kenya** | Mbirikani group Ranch | 7 | Maclennan et al. 2009 |
| **Kenya** | Amboseli N. Park | 6-9 | Tuqa 2015 |
| **Kenya** | Nairobi N. park | 15 | Lesilau 2018* |

* The source of data is from this study

If livestock raiding is only favorable when natural prey availability is low, a decrease in the number of livestock attacks would be expected during the dry season (when natural prey density is highest) according to e.g. Patterson et al. (2004), Van Bommel et al. (2007) and Valeix et al. (2012). During my study, increased livestock attacks during the wet season was confirmed. Once

livestock raiding has proven to be an efficient and beneficial hunting strategy, lions are more likely to stick to this strategy, even in periods when wild prey is abundant, e.g. during dry season. This means that adapting the lion population or prey population numbers to the predicted carrying capacity of the park will not automatically solve the livestock depredation problem. Proximity of livestock to the park and illegal grazing by livestock inside the park may further encourage lions to select livestock over wild prey. The best solution seems to make the energy costs of livestock depredation higher than the energy benefits, thereby making the choice for livestock raiding less optimal and forcing lions to adapt their prey choice. This is achievable through proper fencing, presence of a proactive lion control team and an increase in the installation of flashlights at livestock bomas around the park. With effective livestock protection measures in place, the number of lions residing in the park during the wet season may eventually stabilize, as lions will again be forced to follow their natural migratory prey in order to survive.

## 7.7 Conclusions

In my study, I focused on lion population structure, home range and movement, feeding ecology, impact of partial fencing of parks and a comparison of modern and traditional protective measures. The following conclusions can be drawn from this study:

With respect to methodology, I have defined the following conclusion that I applied in my research:

1. Scat analysis focusing on microscopic prey hair morphology has proven to be a better methodology to identify very small (<5 kg), small (5 - 50 kg) and larger prey than carcass counts. It results in a broader spectrum of prey species in the diet than carcass counts.
2. The use of DNA has proven to be a potential method to identify an even broader spectrum of prey compared to scat analysis, but still needs further development and calibration.
3. The use of Irridium satellite collars in order to track movements and home ranges of lions has been successful in detecting conflict areas around the park but the use of geo-fencing in the collars for early warning has not functioned well due to the close proximity of livestock bomas to the park boundary.
4. Soco-economic surveys clearly complement empirical data gathered in my study and have added value to get more insight in the drivers of lion-livestock conflicts around Nairobi national park

I have also defined the following conclusion with respect to research results, that come from the five chapters of my research:

5 Nairobi National Park lions have small home ranges (among some of the smallest in Africa), due to high human disturbance from urban fringe (tourism, retaliatory killings, light, noise) but they are still able to survive in high densities by living in small prides, and high reproductive rates, in relation to relatively high prey densities.

6 Lions in Nairobi National Park are partially dependent on community land for their survival (hunting livestock and migrating wild prey) and as a refuge for males and females after pride takeovers.

7 Lions are opportunistic hunters, feeding on very small prey (<5 kg) such as Mole rat (*Tachyoryctes sp*) and birds to supplement their diet.

8 The localized high abundance of livestock, dependency on human guardians and their predictable distribution in combination with their inability to escape bomas, makes livestock a favorable prey species for lions in our study area.

9 Neither complete fencing, nor partial fencing of the Nairobi National Park areas is a solution to human–lion conflict. Complete fencing of NNP may cause herbivore extinction through a "predator-induced dip", which could eventually result in a drop in lion numbers below critical levels.

10 The Athi-Kapiti corridor in the south-west of NNP is crucial in providing suitable habitat for both lions and herbivores.

11 Application of LED flashlights at livestock bomas is a more effective method for protecting livestock against nocturnal lion attacks compared to the traditional fencing materials (wood, post, barbed wire, and Acacia branches). The only problem is that lions adapt to flashlights by attacking livestock in the daytime and further away from the park border.

12 The communities around NNP incur both social and economic costs from lion interactions, related to their proximity to the park boundary, in particular to the unfenced section of the park.

13 The population numbers of waterbuck and reedbuck have been very low throughout our study period (2012 - 2018). They appeared in scats diet in wet seasons. They may experience local extinction in future.

14 As communities around NNP are becoming sedentary and pastoralism gradually disappears, the future threats in NNP will likely include a higher risk of conflicts related to urban development.

15 A zone of 25 $km^2$ along the northern urban fringe of NNP is not used by lions, probably due to urban disturbance (noise, smell and lights) arising from City, aircrafts, vehicles and trains.

## 7.8 Recommendations

A single intervention is not usually a long-term solution to human–wildlife conflicts. Human– carnivore conflict solutions that are effective in one region could fail in another, even at a local scale. Anti-conflict measures could become ineffective over time, due to changes in e.g. policies, politics, wildife administration, environmental or social factors. The implementation and enforcement of multiple anti-predation techniques by both livestock owners and wildlife authorities should take such changes into account. Based on my research I would recommend the following:

### A Action by Kenya Widlife Service and Researchers

1. To understand the broader spectrum of the lion diet, the application of microscopic analysis of hair morphology and DNA-metabarcoding will provide a better result on lion feeding ecology and the role of very small prey. Therefore, I recommend further study of the role of very small prey through DNA from lion scats.
2. Based on knowledge from other re-introduction programs in the region, the current NNP lion population should be capable of contributing to lion repopulating schemes in other ecosystems, i.e. where lion populations have disappeared, provided that a wildlife migratory corridor is secured and lion retaliatory killing is controlled. It is advised to rapidly address the existing human–lion conflict situation, considering our suggested livestock protection measures and a compensation scheme for livestock, while securing the Athi-Kapiti Plains for habitat connectivity. This could be achievable through (i) land acquisition and compensation from private land owners (ii) land leasing from private land owners (iii) promotion of tourism activities on private farms which are part of lion home ranges.
3. Support is needed for the communities in the Athi-Kapiti corridor in order to develop ecotourism activities as an alternative form of land use.
4. To conduct a census and to monitor the reedbuck and waterbuck population in Nairobi National Park. The population of these species has been very low and they have been appearing in the lion diets in the wet season based on scat analysis. These shows their density is low and they are being consumed by lion. If urgent measures are not taken, they can go local extinct.
5. With current developments (Standard Gauge Railway, Southern bypass road, Oil pipiline and High Voltage Power cables) within and around NNP, continuous research and monitoring is necessary to understand

the impact of human development on the general biodiversity and especially the lion population in NNP.

6 A longer period of research in NNP is required to monitor human development, particularly regarding the predicted shift from pastoralism activities towards the expansion of urban activities around Nairobi National Park.

7 After de-collaring due to expiring batteries, the same lions could be recollared to understand long-term trends in movement, behavior and impact of collars on individual lions.

## B Action by Kenya Widlife Service and Conservation NGO

8 Despite the effectiveness of the proposed LED flashlight technique in deterring lions from livestock bomas around NNP, its successful implemenation in a different situation is not guaranteed. We suggest long-term studies on the effects of LED flashlights on other large carnivores as well as expansion of this technique into other regions.

9 For wildlife authorities to effectively tackle the predicted increased urban development and related challenges, efforts should focus on securing suitable habitat through land acquisition.

10 Planting a buffer of trees border embankment and park counting embankment) to reduce light and noise pollution could be part of management efforts, especially along the urban fringe, where disturbance is highest.

11 Education and awareness programs focusing on lion conservation could contribute to a general positive attitude towards lions. The risks related to lion behavior (e.g. nocturnal vs. diurnal activities) and effective livestock protection techniques should be incorporated in such programs.

## C Nairobi National Park Management

12 The proper and maintained park fence is effective than partial fencing, so the park management, should repaired and monitored park fence to reduce the number of lions that exit from the park in sections with fences into urban settlements.

13 For rapid response to a problem lion, a Problem Animal Management Unit (PAMU) should be stationed in the southern part of the park where lions exit into community land.

14 Software should be developed on reporting livestock depredation for easy follow-up of depredation cases.

## D Communities

**15** Communities around the park should be educated about avoiding grazing their livestock in the park as to avoid further habituation of lions to catching livestock.

**16** Livestock should be escorted by an adult and not children when drinking water near the park border.

**17** The communities around NNP are increasingly becoming sedentary and will become more dependent on modern livestock husbandry practices in a larger area comprising the Central and Part of Rift Valley.

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