Spring 2017

What, where, why: a survey of Felidae populations at Enashiva Nature Refuge, Tanzania

Lucrecia Aguilar

Follow this and additional works at: https://digitalcollections.sit.edu/isp_collection

Part of the Biodiversity Commons, Environmental Indicators and Impact Assessment Commons, Other Animal Sciences Commons, Population Biology Commons, and the Zoology Commons

Recommended Citation

https://digitalcollections.sit.edu/isp_collection/2532

This Unpublished Paper is brought to you for free and open access by the SIT Study Abroad at SIT Digital Collections. It has been accepted for inclusion in Independent Study Project (ISP) Collection by an authorized administrator of SIT Digital Collections. For more information, please contact digitalcollections@sit.edu.
What, where, why: a survey of Felidae populations at Enashiva Nature Reserve, Tanzania

Aguilar, Lucrecia
Academic Director: Kitchin, Felicity
Advisor: Nyakunga, Oliver
Rice University
Major: Ecology and Evolutionary Biology

Submitted in partial fulfillment of the requirements for Tanzania: Wildlife Conservation and Political Ecology, SIT Study Abroad, Spring 2017
Abstract

As felid populations worldwide continue to deteriorate due to human activities, understanding how felid species utilize various landscapes, along with what factors affect such use or disuse, becomes essential to the preservation of these species. While previous research has examined felid populations around the world, many species and locations remain understudied. This study surveyed felid species at Enashiva Nature Refuge (ENR) in the Serengeti-Mara ecosystem to determine (1) what felid species are present at ENR, (2) where these species generally occur, and (3) why felids reside at ENR in low or high numbers. Through the use of opportunistic camera trapping, path sign surveys, and direct searches, the general abundance and habitat usage of felid species was investigated, along with the presence of felid prey and potential competitor species. Five species of felids were documented at ENR to varying degrees of frequency, with the caracal (Caracal caracal) proving absent. Many prey and competitor species were also recorded, including high numbers of spotted hyenas (Crocuta crocuta). Additionally, staff reports and literature comparisons indicated four main elements impacting ENR felid populations. Overall, understanding felid utilization of ENR may help expand knowledge of resident felid populations and inform local conservation efforts, which may assist in facilitating sustainable compromises between human and wildlife needs.

Introduction

As human populations continue to expand, wildlife populations worldwide have begun to decline, often at alarming rates. Large carnivores, such as big cats, are some of the most affected species, owing to their low population densities, large home ranges, and predatory natures (Gittleman et al., p. 3). Thus, despite being vastly important ecologically, economically, and culturally, species of the Felidae family are in severe decline due to threats such as habitat
degradation, poaching, human population expansion, and prey depletion (IUCN SSC Cat Specialist Group). Despite substantial study of felid populations, many questions remain concerning the distributions and population dynamics of felid species. Knowledge of the use of different kinds of protected lands and habitats by different felid populations remains fragmentary. Understanding these characteristics on both local and range-wide scales is vital to felid conservation.

**Felid Species in Tanzania**

Tanzania hosts an incredible diversity of wildlife, including high numbers of many iconic African species. Six of the ten African Felidae species exist in Tanzania: lion (*Panthera leo*), leopard (*Panthera pardus*), cheetah (*Acinonyx jubatus*), caracal (*Caracal caracal*), African wildcat (*Felis silvestris lybica*), and serval (*Leptailurus serval*) (Table 1). All three resident large cat species – lion, leopard, and cheetah – are considered vulnerable to extinction over their species ranges. Lions only occupy 8 to 22% of the species’ original historical range (Bauer et al., 2016), while leopards have suffered range reductions of at least 30% in the last three generations (Stein et al., 2016). Cheetahs occupy only 10% of their historical African range, and almost none of their historical Asian range (Durant et al., 2015). Though nearly 20% of Tanzanian land has been set aside for conservation in a variety of ways, habitat degradation (especially from an increase in human populations and agricultural practices), poaching, and a lack of sufficient resources for conservation management continue to threaten wildlife populations (Foley et al., p. 11). Understanding how important species such as felids survive in various types of Tanzanian landscapes is crucial to preventing species extinctions.
Table 1. Species data for Tanzanian *Felidae* species. Information from the IUCN Red List of Threatened Species (Bauer et al., 2016; Stein et al., 2016; Durant et al., 2015; Avgan et al., 2016; Yamaguchi et al., 2015; Thiel, 2015).

<table>
<thead>
<tr>
<th>Species</th>
<th>IUCN Categorization</th>
<th>Population Trend</th>
<th>Number of Mature Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lion</td>
<td>Vulnerable</td>
<td>Decreasing</td>
<td>23000-39000</td>
</tr>
<tr>
<td>Leopard</td>
<td>Vulnerable</td>
<td>Decreasing</td>
<td>Unknown</td>
</tr>
<tr>
<td>Cheetah</td>
<td>Vulnerable</td>
<td>Decreasing</td>
<td>6674</td>
</tr>
<tr>
<td>Caracal</td>
<td>Least Concern</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>African wildcat</td>
<td>Least Concern</td>
<td>Decreasing</td>
<td>Unknown</td>
</tr>
<tr>
<td>Serval</td>
<td>Least Concern</td>
<td>Stable</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

Tanzania is home to the largest population of lions in Africa. Lions in Tanzania are of the subspecies *P. l. nubicus* and range throughout much of the country. Though protected lands form the strongholds for lions in Tanzania, lions will also move through areas of human habitation. The species is versatile, being found in grassland, shrubland, or woodland and taking prey such as gazelles, Cape buffalos (*Syncerus caffer*), and giraffes (*Giraffa camelopardalis*). An estimated 15,000 lions roam in Tanzania, though this figure has been declining in recent decades due to threats such as habitat degradation, prey base depletions, and retaliation killings for livestock predation (Foley et al., p. 130-131).

Leopards have a very wide distribution in Tanzania, including diverse habitats such as woodland, shrubland, montane regions, and urban areas. Leopards in mainland Tanzania belong to the subspecies *P. p. pardus*, with the Zanzibar subspecies *P. p. adersi* probably extinct. Leopards eat a variety of prey, including rodents, primates, impala (*Aepyceros melampus*), and gazelles (Foley et al., p. 132-133). The roughly 15,000 - 40,000 leopards that likely reside in
Tanzania are threatened by prey depletion, persecution by poisoning, and habitat loss (Shoemaker, 1993).

Despite comprising over 10% of the world’s cheetah population, Tanzanian cheetahs are rare outside of the Serengeti ecosystem. Suitable cheetah habitat ranges from arid land to woodland; the species preys upon hares, gazelles, impala, and Common wildebeests (*Connochaetes taurinus*), among others. About 1,180 cheetahs reside in the country, though population statuses outside of the Serengeti ecosystem are not well understood. Habitat degradation and poaching pose serious threats to the species (Foley et al., p. 122-123).

Of the three species of smaller felids in Tanzania, the caracal is the most rare. Little is known about Tanzanian caracal populations, though it has been found in many of the northern and central parts of the country. Caracals prefer arid areas and prey primarily on animals such as rodents, Kirk’s dik-diks (*Madoqua kirkii*), and birds. Habitat loss threatens this species (Foley et al., p. 124-125). The serval, in contrast, is quite common in Tanzania, especially in the north. However, population trends and threats remain largely unknown. This species prefers grassland and forest margins, preying upon species such as hares and birds (Foley et al., p. 126-127). African wildcats are most common in northern and central Tanzania, though their similarity to domestic cats can make identification difficult. They range throughout many habitat types, including grassland, woodland, and urban areas. Prey of the African wildcat include rodents, birds, and reptiles. The hybridization of African wildcats with domestic cats is jeopardizing to the species (Foley et al., p. 128-129).

**Felid Population Research Approaches**

Felid distributions and population dynamics have been investigated in a variety of ways throughout the world, often demonstrating the negative impacts of human activities on these species. Many advances have been made in the use of direct and indirect detection methods for wildlife studies, allowing for more
accurate and detailed population assessments (Gittleman et al., 2001). In particular, the use of camera trapping and sign survey techniques in researching elusive felid species is prevalent. Camera trapping to assess felid populations, along with other taxa, has been expanding because this technique is non-invasive and can capture natural behaviors without disturbance (Gittleman et al., p. 377-378). In a camera trap study of leopard behavior, human activity and the resulting forest edge effects were found to be correlated with less diurnal activity in Asiatic leopards (Ngoprasert et al., 2007). In Sumatra, the occurrence, ecology, and coexistence of five felid species were assessed through systematic camera trapping in forest blocks, along with opportunistic trapping. Potential prey and competitor species were also documented (Sunarto et al., 2015).

For sign surveys, researchers may walk along transects or paths to look for spoor (i.e. tracks, scat) and other signs of presence (Gittleman et al., p. 376-383). Such sign surveys allow for the systematic detection of big cat species across various landscapes. Sunarto et al. (2012) used transects to identify the presence or absence of tigers (*Panthera tigris*) in various habitat types. This study found that tigers preferred forest habitat to plantation habitat, though the authors indicate that plantations and fragmented forest areas could help link separate tiger populations, allowing for greater connectivity if managed well. A study comparing true population densities to road spoor counts for leopards, lions, and African wild dogs (*Lycaon pictus*) in Namibia found a strong linear correlation between true density and spoor density for these species (Stander, 1998).

Two other methods may be employed for investigating felid distribution and activity. The application of radio telemetry for habitat use studies has been comprehensively described (see Aebischer et al., 1993). Although this method allows researchers to track the movements, and thus distributions, of individual animals, radio telemetry is very costly in terms of time and money, making its use impractical in many situations (Gittleman et al., p. 392). Additionally, interviews with local people regarding sightings of felid species may be used as an indirect method to examine population dynamics. Gros et al. (1996) found that
interviewing produced cheetah population estimates that were about 75% to 100% of known true population densities. However, this technique is much less accurate than other methods due to human error and the elusive nature of most felid species (Gittleman et al., p. 375-376). The proposed interviewer must also obtain training in and approval for interview practices, along with location-specific language and cultural knowledge.

**Enashiva Nature Refuge**

Enashiva Nature Refuge (ENR) is a private reserve in northern Tanzania owned and run by Thomson Safaris and Tanzania Conservation, Ltd. Since Thomson Safaris purchased the lease for ENR in 2006, the reserve has been utilized as an American tourist safari destination. Prior to 2006, the land was owned by Tanzania Breweries Ltd. and used for barley farming. Additionally, local Maasai people used the area for the grazing of livestock and harvesting of firewood. Poaching also occurred on the land. Once designated as conservation land, grazing was significantly limited at ENR and community-based conservation initiatives were begun. As such, ENR may be considered a recovering natural landscape. Maasai herders are now permitted to water livestock at ENR and to graze herds sparingly during the dry season (Yamat, pers. comm.). Nearly all ENR staff members, including park rangers, come from the local Maasai community. Community development initiatives enacted by Thomson Safaris include a medical clinic, teacher housing for the local primary school, and education for women regarding the construction of fuel-efficient stoves.

Three main studies of predator species at ENR have been conducted, all as Independent Study Projects by students of the School for International Training (SIT). Using walking sign transects during the rainy season, Bowles (2011) documented mammalian, avian, and reptilian predators. Lion (two signs), leopard (seven signs), cheetah (39 signs), serval (two signs), and caracal (two signs) were all secondarily observed. Following this study, Gulka (2011) conducted a comparison transect study of mammalian and avian predators.
during the drier fall season. Felid species recorded included serval (one sign), lion (one sign), leopard (eight signs), cheetah (one sign), and African wildcat (one sign); no caracal signs were observed. The author noted the stark decrease in cheetah signs, along with an increase in spotted hyena (*Crocuta crocuta*) and black-backed jackal (*Canis mesomelas*) observations. Another fall transect study, performed during November 2012, examined mammalian predator species with a focus on denning tendencies. This study found eight leopard signs (including one dead individual) and one serval sign; no cheetah, lion, caracal, or African wildcat signs were recorded (Cathcart, 2012). Thus, while previous studies have inspected ENR felid species through general predator surveys, a felid-focused investigation at ENR has not yet been attempted. In addition, discrepancies in ENR felid data from the aforementioned predator studies have not been well explained.

In this study, a survey of ENR felid species was conducted to investigate (1) what felid species are present at ENR, (2) where these species generally occur, and (3) why felids reside at ENR in low or high numbers. Opportunistic camera trapping, path sign surveys, and direct searches were used to examine felid species richness, habitat usage, prey bases, and competitor species. This study was the first to utilize camera trapping in any capacity at ENR. Additionally, potential reasons for the statuses of felid populations at ENR were explored through staff reports and literature comparisons. This information may not only provide a better understanding of local felid distributions, but may also help guide local managerial action.

**Methods**

**Study Area**

This study occurred at ENR, a 12,600-acre wilderness area in the Loliondo region of northern Tanzania. ENR is a savanna ecosystem connected to both Serengeti National Park in Tanzania and Maasai Mara National Reserve in
Kenya, making it part of the greater Serengeti-Mara ecosystem. The refuge includes open grassland, wooded grassland, woodland, ridge woodland, shrubland, and riverine habitat (see Appendix 1 for map). For the purposes of this study, four main habitats were recognized: grassland, wooded grassland, woodland (encompassing woodland, ridge woodland, and shrubland), and riverine habitat (incorporating woodland near rivers). Three main waterways run through ENR, all of which were mostly dry during the study period. Topographically, ENR is diverse, with forested montane regions surrounding pockets of lower plains. Two permanent campsites exist at ENR: Thomson Camp, for guest lodging, and Askari Camp, for ranger headquarters and residence. Both are located on hilltops in woodland habitat. The study period ran from March 31, 2017 to April 21, 2017. Though this study took place during the rainy season, weather conditions ranged from hot and dry to cool and raining.

Camera Trapping

Remote camera traps (Moultrie A-20 Mini Game Cameras and Moultrie Game Spy L-50) were utilized opportunistically to survey ENR for felid species, prey species, and possible competitor species. Camera traps were set up for a total of 19 nights, from around 6:00 p.m. to around 7:30 a.m. each session (Appendix 2 and 3). Cameras were taken down during the daytime hours due to the potential for theft. One camera, placed in the woodland near the well-guarded Thomson Camp, was left continuously running for 18 days and nights (4/2/2017 – 4/20/2017). Cameras were strategically placed at roughly knee height on live trees in localities where they were most likely to capture images of felids (for example, along paths or near rivers). As such, woodland, riverine, and wooded grassland habitats were favored. Camera identification number, time of installation, habitat, GPS coordinates (using a Garmin Dakota 20 GPS unit), and weather were recorded for each camera every night. A total of 62 trap nights were accrued. The number of cameras set up each night during the study period, along with trap locations, was limited by transportation availability, ranger
schedules, and camera destruction by hyenas. To avoid further damage, cameras were armed with acacia tree thorns to deter hyenas.

After collection, images were examined for all large mammal species, with date, camera identification number, location, habitat, time, species, number of individuals, and number of pictures per event recorded. Number of individuals was determined as the fewest number of individuals of one species possible to produce the number of images of that species in an event. An event was defined as a time span during which one distinct individual or group of a single species was captured. If an event was unclear due to uncertainty in identifying individuals or groups, all individuals of the same species appearing within a ten-minute interval were catalogued as a single event to avoid repeat counting.

Path Sign Surveys

Roads, trails, and dry riverbeds throughout ENR were walked every morning in search of felid spoor, live sightings, or other signs of presence for a total of 17 days (Appendix 4). Supplementary sign sampling was occasionally completed in the afternoon, though mornings were preferable due to the crepuscular natures of some felid species and the lack of disturbance to spoor. ENR was divided into roughly four sections, with one section traversed each day. Sections were determined based on ranger recommendations and logistics. All habitat types were surveyed, though not systematically. Signs were analyzed for species, general age cohort (young versus adult), and sex when possible, with the help of an expert ranger. Additionally, type of sign, habitat, path type, and GPS coordinates (from a Garmin Dakota 20 GPS unit) were recorded for each item. Date, time, weather, road conditions, and prey species seen were also documented. Distance and time walked were logged to calculate sampling effort. A total morning survey distance of 164.9 km was conducted, amounting to 3,470 minutes of morning survey time. Maps were created using Garmin BaseCamp.
Direct Searches and Staff Reports

Five night game drives were completed throughout ENR during the first two weeks of the study period with the aim of observing nocturnal felid species. Drives occurred from about 8:00 p.m. to 9:00 p.m.; one spotlight was used to scan for wildlife. Dates of drives and locations surveyed were determined by vehicle availability and staff expertise. Woodland edges and grasslands were favored. Additionally, one early morning direct search was performed from 6:30 a.m. to 8:30 a.m. on 4/14/2017 with ranger assistance.

Rangers, managers, and drivers at ENR were informally consulted about felid sightings at ENR, as well as potential trends in felid activity over time. In addition, staff members were asked about threats to these species that may exist at ENR.

Results

Camera Trapping

A total of 22 species of large mammals were captured in 1,620 camera trap photographs at ENR (Figure 1). No wild felid species were identified in the images. At least 13 felid prey species were photo-trapped, ranging in size from hares to giraffe. Four species had greater than 20 individuals counted: 118 impala, 104 Common wildebeest, 55 olive baboons (Papio anubis), and 47 plains zebra (Equus quagga). Nearly all olive baboons (53 out of 55) were captured during the day at the location of the one continuously operating camera. Three domestic cows were also photo-trapped.

At least four potential felid competitor species were photo-trapped: large-spotted genet (Genetta maculate), domestic cat, black-backed jackal, and spotted hyena. Almost all individual counts of the large-spotted genet (13 out of 14) occurred at one locality, suggesting that the same individual(s) may have been captured multiple times. Only one domestic cat image was noted, this
coming from a locality near the Askari Camp where domestic cats were known to reside. Of the competitor species, black-backed jackals and spotted hyenas had the highest numbers of individuals at 17 and 19, respectively.

Other noteworthy mammal species captured by the camera traps included crested porcupine (*Hystrix cristata*), white-tailed mongoose (*Ichneumia albicauda*), banded mongoose (*Mungos mungo*), slender mongoose (*Herpestes sanguineus*), and bat-eared fox (*Otocyon megalotis*). Bird, lizard, insect, bat, and small rodent images were also captured, but these taxa were not included in species analyses.
**Figure 1.** Total number of individuals counted from camera trap images by species (counting as outlined in Methods).
Path Sign Surveys

Five species of felids were documented through path sign surveys at ENR: African wildcat, cheetah, leopard, lion, and serval (Figure 2). No caracal signs were found. A total of 63 felid signs were identified. 68.3% of signs were found in woodland habitat, with another 20.6% in wooded riverine areas and 9.5% in wooded grassland. Only one sign, a cheetah track, was recorded in the grassland (Figure 3).

![Sign Counts by Species](image)

**Figure 2.** Path sign counts for five felid species at ENR.
Figure 3. Path sign counts for five felid species by habitat type.

Leopards had the highest number of signs recorded with one kill site, three rest spots (locations where the leopard had laid during the day, as identified by nearby tracks and odor), and 20 tracks (see Appendix 5 for map). The kill site consisted of a male Thomson’s gazelle at the base of an acacia tree, about 50 m from a road. Two black-backed jackals were found at the site, along with vultures. Based on the characteristics of the kill site and ranger expertise, the kill was attributed to a leopard. In addition, one near-sighting occurred when a leopard was startled from a dry riverbed thicket; however, only tracks and a rest spot were recorded for analysis. Two tracks were documented from leopard cubs. Sex was distinguishable from 15 tracks, with 60% being male and 40% being female (Figure 4 a). Leopard signs were mostly found in woodland areas, though also existed in riverine and wooded grassland habitats (Figure 4 b).
Figure 4. The distributions of leopard signs from path sign counts for a) sex and b) habitat type.

African wildcat signs were documented 18 times, consisting of 17 tracks and one sighting (see Appendix 6 for map). One cat was seen in riverine habitat around 9:00 a.m. when it jumped from the thicket of a dry riverbed. Sex was determined for 15 tracks, 33.3% of which were male and 66.6% of which were female (Figure 5 a). African wildcat signs were found most commonly in woodland and riverine habitats (Figure 5 b).
Figure 5. The distributions of African wildcat signs from path sign counts for a) sex and b) habitat type.

Serval tracks were documented 13 times total (see Appendix 7 for map). Sex was determined for 11 tracks, with 72.7% being male and 27.3% being female (Figure 6 a). Serval signs were only found in woodland and riverine habitats (Figure 6 b). Only four tracks were recorded for the cheetah (see Appendix 8 for map). Three tracks were male and one track was female; two tracks were found in woodland, one in wooded grassland, and one in grassland. Lion tracks were also documented four times (see Appendix 9 for map). Two tracks were determined as male and two as female. One set of male lion tracks was followed by numerous hyena tracks on a road. Three tracks were discovered in woodland habitat, while one was found in wooded grassland.
Figure 6. The distributions of serval signs from path sign counts for a) sex and b) habitat type.

Other species sighted during path sign surveys included Kirk’s dik-dik, Common eland (*Tragelaphus oryx*), giraffe, Grant’s gazelle (*Nanger granti*), Coke’s hartebeest (*Alcelaphus buselaphus*), impala, Thomson’s gazelle (*Eudorcas thomsonii*), Common warthog (*Phacochoerus africanus*), Common wildebeest, plains zebra, bushbuck (*Tragelaphus scriptus*), bat-eared fox, spotted hyena, black-backed jackal, Common ostrich (*Struthio camelus*), olive baboon, and vervet monkey (*Chlorocebus pygerythrus*). Domestic cows, goats, sheep, dogs, and cats were also commonly observed, along with humans.

*Direct Searches and Staff Reports*

No felid species were observed during the night game drives or the early morning search. Certain other species seen included bat-eared fox, honey badger (*Mellivora capensis*), East African springhare (*Pedetes surdaster*), galago, white-tailed mongoose, and owl. Spotted hyenas and black-backed jackals were also observed feeding at a Common eland carcass during one night game drive.
Staff accounts regarding felid populations, paired with information from the literature, were utilized to analyze felid occurrences at ENR. Additionally, four main elements (ENR’s history, habitat fragmentation, human activity, and interspecific competition) were identified that may have major impacts on ENR felid populations.

Discussion

By exploring the occurrences of felids, their prey, and potential competitors at ENR, this study aids in creating a more robust understand of the local statuses of felid populations in the Serengeti-Mara ecosystem. Such information is essential to producing effective and sustainable conservation action.

Felid Occurrences

Based on sign counts, leopards and African wildcats may be the most abundant felid species at ENR, with lions and cheetahs likely being the least abundant. No lion prides or caracals likely exist at ENR. Staff reports regarding ENR felids generally support these conclusions. Rangers frequently discussed the large presence of leopards at ENR, and showed locations where leopards had recently been seen. African wildcats were described as being relatively commonplace; however, due to the possible hybridization of this species with domestic cats, and the presence of domestic cats at ENR, the African wildcat population of ENR may not be pure. Additionally, signs other than tracks (sighting, kill site, etc.) were only documented for leopards and African wildcats.

ENR staff reported that only individual lions passed through ENR, often residing in the woodland near Thomson Camp. This was reflected in the data, as three of the four lion tracks found were near the camp. Though staff described cheetahs as being more prevalent than lions, only four tracks of both species were discovered. Serval were known by staff but rarely mentioned. Rangers
knew both Swahili and Maa species names for lion, leopard, cheetah, and African wildcat. The word for serval was only known in Maa.

Interestingly, all staff reported that caracals had never been seen at or near ENR. Many rangers did not recognize the animal when shown a photograph. Neither a Swahili nor a Maa name for the caracal was confidently known by any staff member. However, rangers occasionally attempted to use the Maa name for genets to describe the caracal. Maasai people often do not differentiate between species that are similar in appearance or somewhat unfamiliar to them (Thomas, pers. comm.). As such, without careful communication and background knowledge, researchers could potentially misunderstand knowledgeable Maasai staff or locals when discussing wild species. This may explain the two caracal signs recorded by Bowles (2011) at ENR, though it is possible that caracals occasionally wander through ENR undetected.

Previous predator studies at ENR and this study often differed in documented occurrences of felid species from sign (Table 2). No caracal signs were recorded by any researcher besides Bowles (2011), as discussed above. Leopard sign ranged from 13.5% of Bowles' total felid sign count to 88.9% Cathcart's (2012); in the present study, leopard percentage was 38.1%. This may be due to population fluctuations over time, identification errors, or differences in methodology. At 20.6%, the proportion of serval sign found in this study was almost double that proportion in any of the other three studies. This could be attributable to the felid-centric nature of the present study. Only this study and Gulka (2011) documented signs of African wildcats, with a substantial difference of 17 signs detected between the two studies. This may be due to methodological differences or identification errors. Cheetah sign numbers were low for all studies apart from Bowles, in which 75.0% of the total sign count consisted of cheetah signs. This sharp contrast may well derive from identification error or methodological differences; however, the possibility of concerning population declines cannot be discounted, and thus cheetahs at ENR
should be closely monitored. Lion sign numbers remained consistently low across studies.

**Table 2.** Comparison of felid sign counts at ENR from four separate studies. Both percentage of total felid sign count and actual sign count are given for each species. Studies differed in methodology and emphases (see Introduction).

<table>
<thead>
<tr>
<th>Study</th>
<th>Total Sign Count</th>
<th>Lion</th>
<th>Leopard</th>
<th>Cheetah</th>
<th>Caracal</th>
<th>Serval</th>
<th>African wildcat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowles 2011</td>
<td>52</td>
<td>3.8% (2)</td>
<td>13.5% (7)</td>
<td>75.0% (39)</td>
<td>3.8% (2)</td>
<td>3.8% (2)</td>
<td>0.0% (0)</td>
</tr>
<tr>
<td>Gulka 2011</td>
<td>12</td>
<td>8.3% (1)</td>
<td>66.6% (8)</td>
<td>8.3% (1)</td>
<td>0.0% (0)</td>
<td>8.3% (1)</td>
<td>8.3% (1)</td>
</tr>
<tr>
<td>Cathcart 2012</td>
<td>9</td>
<td>0.0% (0)</td>
<td>88.9% (8)</td>
<td>0.0% (0)</td>
<td>0.0% (0)</td>
<td>11.1% (1)</td>
<td>0.0% (0)</td>
</tr>
<tr>
<td>Aguilar 2017</td>
<td>63</td>
<td>6.3% (4)</td>
<td>38.1% (24)</td>
<td>6.3% (4)</td>
<td>0.0% (0)</td>
<td>20.6% (13)</td>
<td>28.6% (18)</td>
</tr>
</tbody>
</table>

Overall, felids seem to prefer woodland, with 43 of 63 signs observed in this habitat. An overwhelming 98.4% of signs were found in wooded areas (woodland, riverine, and wooded grassland), suggesting that felid species likely favor areas with significant vegetation cover. Such preference is unsurprising given the ambush hunting strategies and elusive natures of many felid species.

*Elements Affecting ENR Felid Populations*

Four main elements are likely affecting the statuses of felid species at ENR: ENR’s history, habitat fragmentation, human activity, and interspecific competition. These elements, combined with certain distinct traits of individual felid species, can help explain the patterns of felid occurrences observed at ENR.
The past use of ENR land for agricultural practices, intensive grazing, poaching, and overharvesting of resources (such as wood) may have had a lasting impact on resident wildlife populations. ENR is an ecosystem recovering from relatively recent trauma; as such, certain resources may be limited and learned fears may persist in populations. Both camera trap and direct observation data from this study suggest that potential felid prey species are abundant and diverse at ENR. Thus, prey depletion is not a likely threat to ENR felid populations. However, ENR lacks plentiful, consistent water sources, as confirmed by observations and staff reports. Even during the rainy season, water may prove scarce. As water is a vital resource for all organisms, a deficiency of water may hinder felid inhabitance of ENR. In addition, a history of poaching in and around ENR may discourage felid occupation of the area, as animals may have learned to avoid locations with high levels of predation by humans (‘predator avoidance,’ as discussed by Brodie et al., 1991). This could also increase the elusiveness of resident felids at ENR.

While habitat degradation affects all wildlife, habitat fragmentation may especially harm human-intolerant or large-range species, such as many felids. As surrounding human populations and development continue to surge, ENR is increasingly isolated from other protected areas in the Serengeti-Mara ecosystem. This inhibits the dispersal of felids between different populations. Due to its relatively small size of about 51 km$^2$, ENR cannot sustain viable felid populations as an isolated ecosystem. In particular, the territories of cheetahs and lions may be 50-800 km$^2$ and 25-225 km$^2$, respectively (Foley et al., p. 122 & 130). This may explain, at least in part, why these two species were the least common of the five felid species documented at ENR. In contrast, individual leopards may hold territories of less than 16 km$^2$ (Foley et al., p. 132).

High levels of human activity in or around ENR may also deter felids. Both local and foreign Maasai people (from surrounding villages or Kenya) enter ENR to water livestock. These herds often illegally graze on ENR land, as was reported by rangers and directly observed. Additionally, vehicles and human presence are a constant at ENR because the reserve is utilized as a luxury
camping destination. This close proximity with humans may affect felid species considerably, as over 75% of all felid species worldwide conflict with humans in some capacity. Caracal, cheetah, lion, and leopard are four of the nine species most threatened by such conflict. In regards to livestock raiding specifically, caracals may prey upon goats and sheep; cheetahs may kill goats, sheep, and small cattle; lions may take goats, sheep, pigs, donkeys, and cattle; leopards may predate upon poultry, domestic dogs, goats, sheep, and cattle (Inskip and Zimmermann, 2009). Most, if not all, of these domestic species may be found in and around ENR. It is interesting that caracal, cheetah, and lion prove highly affected by human-felid conflict and rare at ENR. Leopards, though seemingly opposite this trend, may be better able to adapt to high human activity levels due to their more generalist natures and tendency of becoming more strictly nocturnal in areas of human habitation (Foley et al., p. 132-133). Further investigation of these themes as they relate to ENR felid populations is required.

Interspecific competition between felids and other mammalian predators, especially spotted hyenas and black-backed jackals, may substantially limit felid populations. In examining competition among African predatory species, Caro and Stoner (2003) found that leopards may experience significant exploitative competition. Leopards, lions, cheetahs, servals, and caracals are also very vulnerable to food stealing by other carnivores. Additionally, cheetahs demonstrated competitor avoidance and lower kill rates when lions or hyenas were perceived, as both these species may steal from or kill cheetahs (Durant, 2000). Spotted hyenas may also steal kills from lions and leopards. For smaller felid species, competition with black-backed jackals may be significant due to prey base overlaps (Foley et al., p. 104). At ENR, hyenas and jackals were spotted frequently and had relatively high numbers of individuals photo-trapped. A concurrent study of these species found 96 occurrences of hyenas and 68 occurrences of jackals (Bullington, 2017). Such high concentrations of potential felid competitors may inhibit felid populations. Furthermore, a deficit of water sources, as is the case at ENR, has been associated with interspecific competition and resource partitioning among carnivores (Edwards et al., 2015).
Overall, many factors may influence the distributions, population dynamics, and future viabilities of felid species at ENR. By identifying how felid species utilize the relatively young ENR, this and future studies may expand knowledge of local felid populations and guide conservation management. Conservation measures must not only be effective ecologically, but must also be feasible given local conditions. Therefore, information regarding ENR felid populations, along with those of other species, may help advise successful compromises between development and preservation. Such compromises are imperative to conserving felid species worldwide.

Conclusions and Recommendations

Enashiva Nature Refuge (ENR) is home to five species of felids: leopard, African wildcat, serval, lion, and cheetah. Of these five, leopards and African wildcats are likely the most abundant, with lions and cheetahs occurring rarely. Caracals do not likely exist at ENR. Felids seem to prefer wooded areas of ENR, though more systematic habitat use studies are required to confirm this trend.

Opportunistic camera trapping revealed no images of any felid species. This is likely due to the shortage of cameras, small area surveyed, and short study period. Future camera trap studies are recommended, especially ones of longer duration, broader range, and systematic sampling.

Differences in methodology between this and previous studies produced somewhat differing results, suggesting that various methods should be tested simultaneously. However, due to felid preference for trails, roads, and wooded areas, camera trapping and path sign surveys are advisable for future felid centric studies. Additionally, the knowledge of local staff should not be underestimated, though thorough understanding of cultural translations must be developed by the researcher.

ENR’s history, habitat fragmentation, human activity, and interspecific competition may all impact ENR felid populations and their future viability. Because felid species are key components of the ecosystem and important
tourist attractions for Thomson Safaris, these four elements should be considered when making decisions regarding ENR management. Trends in felid populations must be carefully monitored and potential declines further assessed. In particular, the absence of caracals, low numbers of cheetahs, and high numbers of felid competitor species should be investigated and closely watched.

Community involvement with ENR should be continued to help mitigate human-wildlife conflicts, though human activity at ENR requires further study to evaluate potential negative impacts on felids and the ecosystem as a whole. Large predators may exist sustainably in areas of high human densities when wildlife management policies are favorable and effective (Linnell et al., 2001). Thus, ENR should continue to monitor wildlife populations and develop informed policies to ensure long-term viability.

**Biases and Limitations**

Due to the extremely short timeframe and limited resources available for this study, numerous biases and limitations must be acknowledged. Sample sizes for all felid species across all methods were very small. This substantially diminishes the confidence with which conclusions may be drawn. All habitat types or areas of ENR were not equally sampled; wooded areas were favored. Additionally, camera trapping was conducted opportunistically, rather than systematically, over a small area, which introduces bias. The way in which numbers of individuals were determined from camera trap images also introduces uncertainty. Finally, human error, especially with regards to the identification of spoor, may bias results to some extent. Weather conditions also influenced visibility of spoor.

**Acknowledgements**

Thank you to the Rice Undergraduate Scholars Program for funding camera traps for this study. I would like to thank the ENR staff members for
helping make this study possible; in particular, Daniel Yamat (manager), Alias Thomas (driver), Dululu (expert ranger), and all other rangers at Askari Camp. I would also like to thank the SIT Tanzania staff and Dr. Oliver Nyakunga for their advice. Finally, I am deeply grateful to fellow students Grace Bullington, Nathaniel Haviland-Markowitz, and Sam Newkirk for their company and support at ENR.

References


Appendix 1. Map of Enashiva Nature Refuge, including major habitat types (Mallams, 2011).
Appendix 2. Camera trap count for 19 nights of trapping, including one continuously operating camera trap.

<table>
<thead>
<tr>
<th>Night</th>
<th>Date</th>
<th>Number of Cameras</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4/1/2017</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>4/2/2017</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>4/3/2017</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>4/4/2017</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>4/5/2017</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>4/6/2017</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>4/7/2017</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>4/8/2017</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>4/9/2017</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>4/10/2017</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>4/11/2017</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>4/12/2017</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>4/13/2017</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>4/14/2017</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>4/15/2017</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td>4/16/2017</td>
<td>4</td>
</tr>
<tr>
<td>17</td>
<td>4/17/2017</td>
<td>4</td>
</tr>
<tr>
<td>18</td>
<td>4/18/2017</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>4/19/2017</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><strong>Total Trap Nights</strong></td>
<td><strong>62</strong></td>
</tr>
</tbody>
</table>
Appendix 3. Map of camera trap localities for 19 nights of opportunistic trapping. Labels signify camera identification number-locality number. Locality 6-2 (circled) indicates the location of the continuously operating camera trap. Map boundaries: S1° 52.3' E35° 31.1', S1° 52.3' E35° 34.7', S1° 57.6' E35° 31.1', S1° 57.6' E35° 34.7'.
Appendix 4. Map of morning path sign survey routes, showing a total of 17 routes and 164.9 km. Each color represents one route. Map boundaries: S1° 52.3’ E35° 31.1’, S1° 52.3’ E35° 34.7’, S1° 57.6’ E35° 31.1’, S1° 57.6’ E35° 34.7’.
Appendix 5. Map of leopard sign localities from path sign surveys. Labels signify sign number, species, and sign type. Map boundaries: S1° 52.3' E35° 31.1', S1° 52.3' E35° 34.7', S1° 57.6' E35° 31.1', S1° 57.6' E35° 34.7'.
Appendix 6. Map of African wildcat sign localities from path sign surveys. Labels signify sign number, species, and sign type. Map boundaries: S1° 52.3' E35° 31.1', S1° 52.3' E35° 34.7', S1° 57.6' E35° 31.1', S1° 57.6' E35° 34.7'.
Appendix 7. Map of serval sign localities from path sign surveys. Labels signify sign number, species, and sign type. Map boundaries: S1° 52.3' E35° 31.1', S1° 52.3' E35° 34.7', S1° 57.6' E35° 31.1', S1° 57.6' E35° 34.7'.
Appendix 8. Map of cheetah sign localities from path sign surveys. Labels signify sign number, species, and sign type. Map boundaries: S1° 52.3' E35° 31.1', S1° 52.3' E35° 34.7', S1° 57.6' E35° 31.1', S1° 57.6' E35° 34.7'.
Appendix 9. Map of lion sign localities from path sign surveys. Labels signify sign number, species, and sign type. Map boundaries: S1° 52.3' E35° 31.1', S1° 52.3' E35° 34.7', S1° 57.6' E35° 31.1', S1° 57.6' E35° 34.7'.