A Case-Study of the African Leopard (Panthera Pardus Pardus)
Population on the Nambiti Private Game Reserve

Erica Castaneda
University of Central Florida

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A CASE-STUDY OF THE AFRICAN LEOPARD (*PANTHERA PARDUS*) POPULATION ON THE NAMBITI PRIVATE GAME RESERVE

by

ERICA CASTANEDA

A thesis submitted in partial fulfillment of the requirements for the Honors in the Major Program in Biomedical Sciences in the College of Medicine at the University of Central Florida Orlando, Florida

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Thesis Chair: Robert Borgon, Ph.D.
ABSTRACT

The Nambiti Private Game Reserve in KwaZulu-Natal, South Africa is a nature reserve that aids in the conservation of some of the world’s most renown species. This includes members of the “Big Five,” which is comprised of the African lion (*Panthera leo*), the African elephant (*Loxidonta africana*), the Cape buffalo (*Syncerus caffer*), the black & white rhinoceroses (*Diceros bicornis* and *Ceratotherium simum*, respectively), and the African leopard (*Panthera pardus pardus*). These animals represent the top five African animals desired by trophy hunters and by tourists hoping to view wildlife (Caro & Riggio, 2014). While studies concerning the African leopard population status have been completed on surrounding game reserves (Balme et al., 2009; Chapman & Balme, 2010), there have not been any studies done investigating the African leopard population on Nambiti. It is important that the population on Nambiti be identified since conservation management of leopards is largely influenced by their population numbers. For example, southern African countries rely on population estimates to establish trophy hunting quotas (Balme et al., 2010). Furthermore, knowledge on the reserve’s leopard population can also lead to ecotourism benefits by attracting tourists to visit areas of known leopard activity (Lindsey et al., 2007). This case study investigated baited camera trapping footage, obtained by Nambiti rangers between May 2015 – May 2017, to determine the African leopard population on Nambiti. Camera footage results revealed that there were four leopards identified in six different locations on the reserve between May 2015 – May 2017. Baited Location J in the Western region of the reserve showed the greatest amount of leopard activity, indicating that it is the baited location most likely to provide ecotourism benefits. Furthermore,
23 non-target species were identified from the camera trapping footage, providing insight into the reserve’s biodiversity, prey availability, and competition among predators.
ACKNOWLEDGEMENTS

I would like to thank Dr. Robert Borgon, Dr. Katherine Mansfield, and Dr. Martin Dupuis for their support and guidance throughout the development of this thesis. I would also like to thank the Burnett Honors College for providing me with the opportunity to travel to South Africa and take part in conservation efforts on the Nambiti Private Game Reserve.

To my parents, thank you for always believing in me, challenging me, and encouraging me to follow my dreams. I would not be where or who I am today without your unwavering love and support.
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INTRODUCTION

Nambiti Private Game Reserve

The Nambiti Private Game Reserve is a 9,859-hectare (22,000-acre) private game reserve located northeast of Ladysmith in the KwaZulu-Natal province of South Africa (Figure 1). Originally a cattle farm, the Nambiti Private Game Reserve was established in 2000 by the purchase of multiple independent ranches and the introduction of wildlife species including the African elephant (Loxidonta africana), the African lion (Panthera leo), the Cape buffalo (Syncerus caffer), and the black and white rhinoceroses (Diceros bicornis and Ceratotherium simum, respectively) over a 13-year time span. In 2013, Nambiti was declared a nature reserve by the KZN Biodiversity Stewardship Programme, granting it the highest level of protection (Taylor, 2016). Since Nambiti’s establishment, the African leopard (Panthera pardus pardus) has also migrated its way onto the reserve, making Nambiti the only game reserve in the surrounding area home to the “Big Five.” Originally considered to be the five most difficult animals to hunt on foot, the “Big Five” are now considered to be the most sought-after animals by wildlife-seeking tourists and trophy hunters, and they are the most important flagship species for African wildlife conservation since they attract the greatest number of tourists to protected areas (Williams et al., 2000; Lindsey et al., 2007; Caro & Riggio, 2014).
Nambiti is now an active wildlife conservation site that utilizes the commercial hospitality of 10 independently-owned lodges to support its conservation efforts (Seid, 2015). This form of ecotourism acts as a source of revenue for the reserve and stimulates the surrounding area by providing jobs and boosting tourism. As a private conservancy, this reserve works to protect and maintain balance among its inhabitants. For example, dehorning efforts have been successfully carried out to protect white rhinoceroses from poachers, and contraceptive injections have been administered to female lions to help limit their reproduction to control the lion population. This is important for regulation of the predator to prey ratio and the balance between predators on the reserve (Cousins et al., 2008). Nambiti also boasts over 40
other game species, is in a malaria-free zone, and is closely situated near the Anglo-Zulu and Anglo-Boer War Battlefields and the Drakensberg Mountain Range, making it a hot spot for tourists (Nambiti “Big Five” Private Game Reserve, n.d.).

African Leopard

Of the members of the “Big Five”, the African leopard (*Panthera pardus pardus*) is the most widespread felid due to its adaptability and habitat tolerance (Ray et al., 2005). It is one of the most prevalent large carnivores and one of the top four most studied felids (Pitman, 2012) despite its elusive predatory nature (Hayward et al., 2006). The African leopard is one of nine subspecies found globally, including parts of Africa, Europe, and Asia, yet it is the only subspecies found on the African continent (Uphyrkina et al., 2001). African leopards are highly sexually dimorphic, with males on average weighing about 60% more than females; they also have a wider neck and chest, and a greater shoulder height (Balme et al., 2012). Male leopards also have larger skulls than their female counterparts (Farhadinia et al., 2014). They are solitary creatures whose home ranges vary greatly due to the availability of prey. Male home ranges are also dependent on the number of females present since they will associate during mating periods (Friedmann & Traylor-Holzer, 2008). Most active between sunset and sunrise, leopards have a wide-ranging diet based on prey availability (Nowell & Jackson, 1996), although they preferably prey on small to medium-sized ungulates, including impala and warthogs (Radloff & Du Toit, 2004). Leopards make roughly one large kill every seven days and to protect their kills from other predators and scavengers, they haul carcasses up trees and keep them there while eating (Bailey, 1993; Nowell & Jackson, 1996). In the wild, leopards live between 15 – 20 years (Khalil
On average, males reach sexual maturity around two years of age while females reach sexual maturity at about two and a half years of age. Females average two cubs per litter and will raise them for approximately two years until they become independent (Balme et al., 2013; Tacutu et al., 2018).

According to the International Union for the Conservation of Nature (IUCN) Red List, the African leopard is listed as a Vulnerable species and its population has continued to decline with leopards experiencing a range loss of 48-67% in Africa since the beginning of the Industrial Revolution (Figure 2) (Stein et al., 2016; Jacobson et al., 2016). This is largely due to habitat fragmentation from livestock ranching and depredation, causing farmers to kill leopards that they perceive as a threat to their livestock (Nowell & Jackson, 1996). Trophy hunting has contributed to the decline in the leopard population with adult male leopards being the most susceptible victims due to their increased size (Braczkowski et al., 2015). Loss of prey species due to increasing human demand for bushmeat, which comprises the most important protein source for rural African areas, also poses a threat to leopard survival. Furthermore, leopard skins are in demand for religious and cultural African clothing and ceremonies, promoting poaching and illegal trade (Lindsey et al., 2012). Human-leopard conflict is the cause of most of the leopard fatalities in protected areas (Woodroffe & Ginsberg, 1998) and non-protected areas, including roadway collisions, which have been found to have a higher incidence among female leopards and therefore affect the reproductive potential of the species (Swanepoel et al., 2015). Leopards may migrate outside of a protected reserve to a non-protected area due to prey availability or increased interspecific competition. This may cause them to fall victim to the edge effect, in which a species is more vulnerable to mortality due to the combined effects of hunting, vehicular
accidents, and fence entanglement that occur at the edge of a reserve (Woodroffe & Ginsberg, 1998). As a result, reserve borders may resemble an ecological trap (Balme et al., 2009). 

Current leopard conservation efforts include policy change aimed towards preventing citizens from inappropriately using their destruction permits to kill leopards that threaten their livestock (Balme et al., 2009) as well as temporary hunting bans (Mathewson, 2016). Although reintroduction of large felids is often unsuccessful, there have been successful reintroductions of leopards in areas inhabited by inexperienced prey and in areas with a low leopard density (Hayward et al., 2007; Weise et al., 2015). In response to collaboration between leopard conservation organizations and South African religious leaders, substitution of leopard skins for
faux fur in religious and cultural ceremonies has also been increasing (Swanepoel et al., 2016). Improved livestock husbandry practices as well as increased guarding of livestock has shown to decrease depredation rates (Woodroffe et al., 2007), and is likely the most effective way to reduce human-leopard conflict related mortalities (Stein et al., 2016).

While studies concerning leopard population status have been conducted on reserves surrounding Nambiti, including Zululand Rhino Reserve and Phinda Private Game Reserve (Balme et al., 2009; Chapman & Balme, 2010), there have not been any studies evaluating the leopard population on Nambiti. This case study aims to compile and analyze footage collected from 2015 to 2017 using camera trapping techniques to identify the leopard population on Nambiti. This information will be used to aid the Nambiti Private Game Reserve in their conservation efforts by providing data about its leopard population, which can be used to inform governmental policies and conservation management (Balme et al., 2010). Additionally, knowledge on frequent sightings of leopards in baited camera-trap locations may also provide ecotourism benefits for the reserve and its lodges. Since leopards are one of the most sought-after animals by tourists (Lindsey et al., 2007), knowledge on which baited locations the leopards are drawn to more often may result in a higher chance of a leopard sighting since game vehicle drivers can concentrate on bringing guests to these areas. This may lead to an increase in both tourism and revenue, benefitting the reserve’s conservation efforts.

Camera Trapping

Camera trapping is a non-invasive and relatively inexpensive technique that is useful for monitoring large carnivores, which are often elusive and exist in naturally low population
densities (Goldberg et al., 2015; Brassine & Parker, 2015). This is advantageous since capturing and tagging, such as fitting a GPS collar, for large carnivores can be very stressful and dangerous for both the animal and the investigators (Kelly et al., 2012). Camera trapping is also used for individual identification within a species, due to the unique coat patterns, and for investigating species-specific behavior (Cutler & Swann, 1999; Heilbrun et al., 2006). The use of bait in camera trapping increases the capture frequencies of leopards, allowing for an increased confidence in the population estimate (du Preez et al., 2014). In addition, information gathered on non-target species through camera trapping can provide insight into prey distribution and competition from other predator species (Kelly et al., 2012).
METHODS

Study Area

This study was conducted at the Nambiti Private Game Reserve (28.5000° S, 29.9047° E), which covers 9,859 hectares and is located in the western region of the KwaZulu-Natal province in South Africa. Nambiti sits at an elevation of roughly 1,150 meters and its southern and eastern regions are situated within the Tugela basin, home to acacia trees and thorny vegetation, while its northern and western regions are situated in moist grasslands (Taylor et al., 2016). Inhabitants of Nambiti include giraffe (*Giraffa camelopardalis*), Burchell’s zebra (*Equus burchelli*), greater kudu (*Tragelaphus strepsiceros*), blue wildebeest (*Connochaetes taurinus*), common warthog (*Phacochoerus africanus*), impala (*Aepyceros melampus*), common eland (*Taurotragus oryx*), southern ostrich (*Struthio camelus australis*), serval (*Leptailurus serval*), spotted hyena (*Crocua crocuta*), and black-backed jackal (*Canis mesomelas*), as well as additional mammalian, bird, and reptile species.

The KwaZulu-Natal province is situated between the Indian Ocean and the Drakensburg mountain range, providing the region with warm weather and rain during the summer months and a cold, dry climate during the winter months (Fairbanks & Benn, 2000). The sensitivity of camera trap sensors is dependent on the weather, since the passive infra-red sensors detect “heat-in-motion” and their sensitivity decreases as the ambient temperature and the temperature of the object in motion become increasingly similar. Information on the temperature, rainfall, and humidity of the surrounding environment during the camera-trapping period (Figures 3, 4, and 5, respectively) provide insight to the reliability of the camera sensors due to the current environmental conditions (Meek et al., 2012; Meek et al., 2014).
Figure 3. Minimum, maximum, and average temperatures in Ladysmith from May 2015 – May 2017. Adapted from World Weather Online.

Figure 4. Average rainfall and rainy days in Ladysmith from May 2015 – May 2017. Adapted from World Weather Online.
Figure 5. Average cloud and humidity in Ladysmith from May 2015 – May 2017. Adapted from World Weather Online.

Data Collection

Camera trapping data were collected using a Moultrie® M-999i Game Camera (https://www.moultriefeeders.com/). This camera operates via passive infra-red motion sensors and can be set to take photos in 5-second intervals at a 10 MP resolution, and record videos, ranging in length from 10 seconds to 1.5 minutes, at a 1920 x 1080 resolution in 5-second intervals (or both). It has a trigger speed of less than 0.5 seconds and can detect motion up to 21.3 meters away. It contains a light sensor for daytime/nighttime detection and an infrared LED flash for nighttime photos and video recording (Moultrie®, n.d.). Since leopards are primarily active at night, it is important to utilize a camera trap that does not produce an incandescent flash that may frighten and deter the leopards (Myers, 1976; Trolliet et al., 2014).
A biased sampling design was used, in which camera traps were deliberately placed in areas of known leopard activity, due to the presence of leopard markings, or on trails that experience a high traffic volume from game species (Carbone et al., 2001). All camera traps utilized either a warthog or an impala as bait, which was hunted by a ranger and set up near the camera site prior to recording, in order to attract the leopard. The intestines of the baited animal were removed and spread around the tree and surrounding area to both attract leopards and cover the scent left by human presence.

The recording period for each camera in one specific location averaged 6.28 days; therefore, bait was not regularly replenished at each location. During September – October 2015, Location F experienced 26.75 days of camera recording, and therefore the bait during this camera trapping period was replaced roughly once a week due to consumption of the bait and continued signs of leopard activity. Since leopards often drag their prey up trees, the bait was hung in a tree to prevent other predators from scavenging the kill and increase the chances that a leopard would find it.

Each camera-trap day was defined as a period of 24 hours from which the camera recording began collecting information. Data collected by Nambiti ranger staff from May 2015 to June 2015 included the use of five different cameras in five different locations for a period of 37 camera-trapping days. Camera trap data collected from September 2015 to November 2015 utilized six cameras in three different locations for a period of 64 camera-trapping days. Data collected during May of 2016 used three cameras in two different locations for a period of 7 camera-trapping days, and data collected during May 2017 used one camera in one location for a
period of 5 camera-trapping days. The distribution of the camera traps is shown in Figure 6. Overall, this study consisted of 113 camera-trapping days.

Data Analysis

Camera footage was organized using a Microsoft Excel 2016 spreadsheet by date, camera location, and camera number. The GPS location of the cameras during each recording period was mapped via QGIS to visualize the camera distribution on the reserve (Figure 6). Footage was then organized by presence or absence of leopards, and each leopard event was defined as the observation of a leopard with at least a thirty-minute interval between the last capture for that
individual. The time of day the leopard was seen, the number of capture events, and the total time of leopard observation were recorded. Since the cameras only reported time in minutes, no rounding of seconds was used. Individual identification of the leopard was determined based on comparison of unique coat patterns, and a population estimate was determined by totaling the number of identified individuals.

Any additional observations including activity and behavior, as well as the number of other non-target species were also noted since this information may provide insight to the biodiversity, prey availability, and competition among apex predators on the reserve. Since most of these non-target species cannot be individually identified visually, observation was defined as the presence of a non-target animal in the camera footage; however, if the animal never moved out of the frame or moved only for a brief moment, that individual was not counted twice.
RESULTS

Of the 18,612 files collected from Nambiti, 4,874 of those included THM files that did not contain any data or were recordings from Nambiti rangers initially testing out the cameras; therefore, these files were excluded from the study. The camera trapping data collected by the rangers produced 13,738 files, consisting of 4,560 videos and 9,178 photographs. Of these, three videos and 2,106 photographs showed a positive leopard capture.

Camera footage results are recorded in Table 1. From May 2015 – May 2017, a total of four individual leopards (Figure 7) were identified by camera trapping footage for a total of 377 minutes of capture footage. These captures occurred in six different locations on the reserve (Figure 8). From May 2015 – June 2015, one leopard (Leopard #1) was identified in one location on the reserve for just one event, which resulted in one minute of captured footage. The camera footage from September 2015 – November 2015 captured two leopards (Leopard #2 and Leopard #3). Leopard #2 was seen in three different location 15 times for a total of 194 minutes. Leopard #3 was seen in one location during one event for a total of one minute. While both leopards were seen at Location F, Leopard #2 was seen 24 hours prior to Leopard #3. From May 2016 – July 2016, one leopard (Leopard #4) was identified in one location during 15 different events for a total of 182 minutes. During May 2017, Leopard #4 was again identified in the same location for one event totaling 10 minutes.
<table>
<thead>
<tr>
<th>Leopard</th>
<th>Date(s) Seen</th>
<th>Number of Events</th>
<th>Total Event Time (min)</th>
<th>Location Seen</th>
<th>Time Seen</th>
<th>Observed Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5/25/2015</td>
<td>1</td>
<td>1</td>
<td>B</td>
<td>6:14 PM</td>
<td>Spraying scent on log</td>
</tr>
<tr>
<td>2</td>
<td>9/15/2015</td>
<td>2</td>
<td>43</td>
<td>F</td>
<td>8:08 PM - 12:13 AM</td>
<td>Eating warthog bait</td>
</tr>
<tr>
<td></td>
<td>9/16/2015</td>
<td>4</td>
<td>75</td>
<td>F</td>
<td>3:24 AM - 4:27 AM, 6:29 PM - 12:00 AM</td>
<td>Eating warthog bait</td>
</tr>
<tr>
<td></td>
<td>9/22/2015</td>
<td>1</td>
<td>17</td>
<td>F</td>
<td>7:53 PM - 8:10 PM</td>
<td>Eating warthog bait</td>
</tr>
<tr>
<td>9/23/2015</td>
<td>1</td>
<td>34</td>
<td></td>
<td>F</td>
<td>12:43 AM - 1:17 AM</td>
<td>Eating warthog bait</td>
</tr>
<tr>
<td>10/12/2015</td>
<td>1</td>
<td>2</td>
<td></td>
<td>F</td>
<td>9:33 PM - 9:35 PM</td>
<td>Eating warthog bait</td>
</tr>
<tr>
<td>10/27/2015</td>
<td>1</td>
<td>9</td>
<td></td>
<td>G</td>
<td>5:56 PM - 6:05 PM</td>
<td>Eating impala bait</td>
</tr>
<tr>
<td>10/28/2015</td>
<td>3</td>
<td>11</td>
<td></td>
<td>G</td>
<td>3:08 AM, 4:30 PM - 8:35 PM</td>
<td>Eating impala bait</td>
</tr>
<tr>
<td>10/30/2015</td>
<td>1</td>
<td>2</td>
<td></td>
<td>H</td>
<td>9:43 PM - 9:44 PM</td>
<td>Eating warthog bait</td>
</tr>
<tr>
<td>11/2/2015</td>
<td>1</td>
<td>1</td>
<td></td>
<td>F</td>
<td>6:06 PM</td>
<td>Walking on road</td>
</tr>
<tr>
<td>3</td>
<td>10/12/2015</td>
<td>1</td>
<td>1</td>
<td>F</td>
<td>9:42 PM</td>
<td>Walking in the bush</td>
</tr>
<tr>
<td>4</td>
<td>5/26/2016</td>
<td>1</td>
<td>1</td>
<td>I</td>
<td>5:43 AM</td>
<td>Walking on road</td>
</tr>
<tr>
<td>5/28/2016</td>
<td>2</td>
<td>31</td>
<td></td>
<td>J</td>
<td>5:16 PM - 6:37 PM</td>
<td>Eating impala bait</td>
</tr>
<tr>
<td>5/30/2016</td>
<td>5</td>
<td>60</td>
<td></td>
<td>J</td>
<td>2:44 AM - 11:19 AM, 4:44 PM - 6:15 PM</td>
<td>Eating impala bait</td>
</tr>
<tr>
<td>5/31/2016</td>
<td>2</td>
<td>14</td>
<td></td>
<td>J</td>
<td>6:55 AM - 7:52 AM</td>
<td>Eating impala bait</td>
</tr>
<tr>
<td>5/25/2017</td>
<td>1</td>
<td>10</td>
<td></td>
<td>J</td>
<td>7:43 AM - 7:53 AM</td>
<td>Eating impala bait</td>
</tr>
</tbody>
</table>

Table 1. Leopard camera data results.
Most of the observed behavior included feeding on the baited prey during which the leopards would feed for a short period of time, leave for an extended period of time, and then return to continue feeding. Most of the time, this same pattern would continue between dusk and dawn. Territorial marking was observed by Leopard #1 at Location B, although no other leopards were seen at this location, and all leopards showed the most activity at night. Additionally, Leopard #2 was observed on nine separate dates to be wearing a GPS tracking collar; however, the origin of this collar is unknown. A total of 23 different non-target species were observed between May 2015 – May 2017 (Table 2). Of the “Big Five”, African leopards, African lions, and white rhinoceroses were captured via camera trapping. The most frequently observed prey
species include greater kudu, warthogs, and impala. These prey species were most commonly seen at Location F, which also showed the presence of two leopards during the same time frame between September – November 2015. Predator species observed on the reserve include African lions, spotted hyenas, servals, black-backed jackals, Nile monitors (*Varanus niloticus*), and spotted eagle owls (*Bubo africanus*). Other captured species include Burchell’s zebra, giraffe, common eland, blue wildebeest, nyala (*Tragelaphus angasii*), waterbuck (*Kobus ellipsiprymnus*), Cape porcupine (*Hystrix africaeaustralis*), and vervet monkey (*Chlorocebus pygerythrus*).

**Recorded Leopard Sightings**

![Recorded Leopard Sightings](image)

Figure 8. Recorded leopard sightings.
Non-Target Species Observed

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
<th>Number of Observations</th>
<th>Location(s) Seen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mammals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Aepyceros melampus</em></td>
<td>Impala</td>
<td>75</td>
<td>D, F</td>
</tr>
<tr>
<td><em>Canis mesomelas</em></td>
<td>Black-backed jackal</td>
<td>6</td>
<td>C, D, F, I</td>
</tr>
<tr>
<td><em>Ceratotherium simum</em></td>
<td>White rhinoceros</td>
<td>1</td>
<td>G</td>
</tr>
<tr>
<td><em>Chlorocebus pygerythrus</em></td>
<td>Vervet monkey</td>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td><em>Connochaetes taurinus</em></td>
<td>Blue wildebeest</td>
<td>13</td>
<td>F</td>
</tr>
<tr>
<td><em>Crocotra crocuta</em></td>
<td>Spotted hyena</td>
<td>7</td>
<td>F</td>
</tr>
<tr>
<td><em>Equus burchelli</em></td>
<td>Burchell's zebra</td>
<td>16</td>
<td>D, F</td>
</tr>
<tr>
<td><em>Galerella sanguinea</em></td>
<td>Slender mongoose</td>
<td>8</td>
<td>A, F, I</td>
</tr>
<tr>
<td><em>Giraffa camelopardalis</em></td>
<td>Giraffe</td>
<td>9</td>
<td>E, J</td>
</tr>
<tr>
<td><em>Hystrix africaeaustralis</em></td>
<td>Cape porcupine</td>
<td>6</td>
<td>A, F, I</td>
</tr>
<tr>
<td><em>Kobus ellipsiprymnus</em></td>
<td>Waterbuck</td>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td><em>Leptilaurus serval</em></td>
<td>Serval</td>
<td>6</td>
<td>A, D, F</td>
</tr>
<tr>
<td><em>Panthera leo</em></td>
<td>African lion</td>
<td>2</td>
<td>B, J</td>
</tr>
<tr>
<td><em>Phacochoerus africanus</em></td>
<td>Common warthog</td>
<td>107</td>
<td>A, D, F, I, J</td>
</tr>
<tr>
<td><em>Sylvicapra grimmia</em></td>
<td>Common duiker</td>
<td>5</td>
<td>F, I</td>
</tr>
<tr>
<td><em>Taurotragus oryx</em></td>
<td>Common eland</td>
<td>9</td>
<td>F, I, J</td>
</tr>
<tr>
<td><em>Tragelaphus angasii</em></td>
<td>Nyala</td>
<td>68</td>
<td>A, F</td>
</tr>
<tr>
<td><em>Tragelaphus strepsiceros</em></td>
<td>Greater kudu</td>
<td>204</td>
<td>A, D, E, F, I</td>
</tr>
<tr>
<td><strong>Birds</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Bubo africanus</em></td>
<td>Spotted eagle owl</td>
<td>2</td>
<td>A, F</td>
</tr>
<tr>
<td><em>Buphagus erythrorhynchus</em></td>
<td>Red-billed oxpecker</td>
<td>5</td>
<td>F</td>
</tr>
<tr>
<td><em>Corvus albus</em></td>
<td>Pied crow</td>
<td>23</td>
<td>F, J</td>
</tr>
<tr>
<td><em>Pternistis natalensis</em></td>
<td>Natal spurfowl</td>
<td>8</td>
<td>B, F, I</td>
</tr>
<tr>
<td><strong>Reptiles</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Varanus niloticus</em></td>
<td>Nile monitor</td>
<td>10</td>
<td>F</td>
</tr>
</tbody>
</table>

Table 2. Observation of non-target species.
DISCUSSION

Leopard Population

This is the first case study investigating camera footage captured by rangers on the Nambiti Private Game Reserve, and the first study to investigate the leopard population on this reserve. From the collected footage, four individual leopards were identified over a two-year span from May 2015 to May 2017. Leopard #1 was seen in May 2015, while Leopard #2 was seen between September 2015 – November 2015. Leopard #3 was seen during October 2015, and Leopard #4 was seen during May 2016 and May 2017. In comparison with other reserves in KwaZulu-Natal, six different leopards were spotted within a four-month period in 2009 on the Zululand Rhino Reserve (23,000 hectares) (Chapman & Balme, 2010) and in that same year, 16 different leopards were identified over a three-month period on the Phinda Private Game Reserve (17,000 hectares) (Balme et al., 2009). Most of the observed behavior included lone leopards feeding on bait in a tree between dusk and dawn, which supports studies regarding leopard behavior (Myers, 1976; Hayward & Slotow, 2009; Bothma & Walker, 2013). Additionally, Leopard #1 was seen both spraying urine and rolling around on the ground next to where the urine had been sprayed, which are both signs of scent-marking in leopards; however, no other leopards were seen in this location (Bothma & Coertze, 2004).

The low number of leopards identified may be a result of the limited number and locations of camera traps utilized on the reserve throughout the recording period. A low recorded leopard population may also reflect the amount of poaching occurring outside of the game reserve or the presence of competition within the game reserve. Since leopards have the capability to jump fences, it is possible that leopards could leave the reserve and fall victim to
illegal killing or hunting (Linnell et al., 2012). Although Ezemvelo KZN Wildlife, a government organization that oversees wildlife conservation in KwaZulu-Natal, has legally protected leopards, they are still killed illegally by farmers and trophy hunters outside of protected areas (Balme et al., 2009). Furthermore, competition with other predators, including lions and spotted hyenas, may also contribute to the low identified leopard population since these species are also night-time ungulate hunters and their presence near bait may deter leopards (Hayward & Slotow, 2009; Vanak et al., 2013). From the collected footage, female lions were seen on two separate occasions investigating the baited areas. The lion seen in Location B in 2015 was seen three days prior to leopard sighting, and the lion seen in Location F in 2017 was seen two hours prior to leopard sighting. Spotted hyenas were seen on three separate occasions sniffing around the baited areas at Location F. Hyenas were seen 24 hours after leopard sighting, and again 4 and 15 days later. Additionally, since leopards were not formally introduced to the reserve by Nambiti staff, the number of females versus males is unknown. Therefore, a lower number of female leopards may result in a slower population growth on the reserve, and since female leopards do not reach sexual maturity until roughly two years of age (Tacutu et al., 2018), this may contribute to the low identified leopard population observed over this two-year time span.

**Ecotourism Benefits**

Since leopards are one of the animals most sought-after by tourists traveling to game reserves (Lindsey et al., 2007), an increased likelihood of viewing a leopard may serve to increase a reserve’s tourism. If baited locations can be used to assist in the viewing of leopards by tourists, the reserve may use this to increase their ecotourism. The Nambiti Private Game
Reserve relies on ecotourism to fund its conservation initiatives; therefore, a greater number of tourists will result in more money going towards maintaining and protecting the reserve’s wildlife. To habituate the leopards to game vehicles, Nambiti rangers station their vehicles near areas of known leopard activity and leave the vehicles there for an extended period of time. By doing so, rangers hope leopards will become less wary of the vehicles and will allow them to approach closer before scaring off, giving guests an opportunity to view the leopards.

Based on the results, the baited Location J reported the greatest number of leopard capture events for the longest amount of time. In addition, leopard activity in this location appears to also occur during daylight hours, whereas most of the other locations did not have any daytime leopard activity. This is important since the reserve’s lodges take the guests out for game drives around dawn and dusk, and it is easiest to see animal activity during daylight. Furthermore, this location has the most recent data and recorded the same leopard returning to this site during two consecutive years, which may suggest that this leopard is continuing to show activity in this area when bait is present. Compared to the other locations studied, the reserve should continue to utilize and bait this location to use for game vehicle desensitization and to have the greatest likelihood of guests seeing a leopard.

**Identification of Non-Target Species**

The observation of non-target species was recorded to provide insight into the biodiversity, prey availability, and potential competition between predators on the reserve. There were 23 non-target species observed on the reserve between May 2015 – May 2017, including 18 mammalian species, four bird species, and one reptilian species. The majority of these species
were seen at Location F, which contains a watering hole. The number of observed warthogs and impala show that there is an availability of the leopards’ preferred prey on the Nambiti reserve, and that the selection of prey for baiting purposes is being chosen from the species with the larger populations. Other species that leopards may prey on seen on the reserve include the common duiker, greater kudu, and waterbuck (Owen-Smith & Mills, 2008).

In several instances, spotted hyenas and female lions were seen sniffing around the baited area, which supports studies indicating that both species compete with leopards for food (Hayward & Slotow, 2009), and may be a factor in the low number of identified leopards. Regarding ecotourism benefits, the presence of bait may also provide reserve guests with the opportunity to see other elusive predators, including servals and black-backed jackals, both of which were seen investigating the bait. Other non-mammalian species that were seen going after the bait include spotted eagle owls and Nile monitors. Since most non-target species could not be individually identified, some animals may have been counted multiple times, which would lower the total number of that species observed.

Limitations

Limitations of this study include the narrow area covered by the camera traps during recording periods, the relatively low number of camera-trapping days, and the restriction and variability in time periods sampled between the different years. The camera footage was only collected between the months of May – June and September – November, which represents only the winter and spring months on the reserve, respectively. Furthermore, the length of camera trap recording decreased with each successive year. To get a more comprehensive estimate of the
leopard population on the reserve, camera traps should consistently sample year-round activity since leopards may alter their movement patterns seasonally (Rabinowitz, 1990). The low recorded abundance, along with the limited nature of this study, indicates that the reserve should concentrate conservation efforts towards expanding camera trapping research to better quantify and qualify the leopard population on the reserve.

Since leopard activity was based on the presence of baited camera traps, this may not reflect the true activity pattern of the leopards. If the bait were removed, the leopards may show an altered pattern of movement. Therefore, to take advantage of the possible ecotourism benefits from the viewing of leopards by guests, the reserve would need to continue to bait the areas found to be high in leopard activity in this study. Furthermore, leopards were identified by comparison of coat markings and patterns; however, identification of some individuals was difficult due to the low night-time picture quality. While individual identification was performed carefully, the exact number of identified individuals may be slightly off due to only having a few low-quality photos for one of the leopards.

**Future Directions**

As the Nambiti Private Game Reserve continues its conservation efforts for African leopards, it should consider implementing more camera traps that cover a larger area on the reserve. These cameras should monitor year-round activity at the same locations consistently since thousands of camera-trap days are required for a thorough inventory of large- to medium-sized mammals (Tobler et al., 2008). A more robust trap effort will enable the reserve to get a more well-rounded estimate of its leopard population and will also provide more insight into the
locations with the greatest leopard activity. This could also reveal more information on prey and predator species on the reserve, especially other elusive predators, providing the reserve with more knowledge on its current wildlife population. Furthermore, to measure the true activity pattern, camera traps should be utilized without the presence of bait. Knowledge on the leopards’ natural seasonal movement patterns may allow the reserve to better determine areas of leopard activity, which can then be implemented towards their ecotourism efforts without the need to set up baited locations.

Recent conservation efforts on the reserve include the relocation of elephant bulls to the Somkhanda Game Reserve in March of 2017 and controlled fire burns in November 2017. In March of 2018, the reserve introduced a collared female cheetah, the only one on the reserve. She will join the reserve’s lone male cheetah in an effort to help reestablish the cheetah population in Nambiti.
LITERATURE CITED


Moultrie® (n.d.) *Instructions for M-999i Digital Game Camera*, 1-12.


