**CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE**

**Faculty of Tropical AgriSciences**

# Camera trap survey of small carnivorans in Pendjari National Park in Benin

MASTER'S THESIS

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# Declaration

I hereby declare that I have done this thesis entitled Camera trap survey of small carnivorans in Pendjari National Park in Benin independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 22$^{nd}$ of April

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Vendula Josefína Benešová

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## Abstract

This study is focused on analysis of species richness, occupancy, and activity patterns of small carnivorans. In year 2020 during dry season 56 camera traps were placed in systematic grid inside of core area of Pendjari National Park. Data were processed in ZSL-CTAP and 3 habitats – Grass savannah, Shrub savannah and Tree savannah were compared between each other. 9 species of small carnivorans from 5 families (Canidae, Felidae, Herpestidae, Mustelidae and Viverravidae) were found in the area. The most diverse area was Grass savannah and the least diverse was shrub savannah. However, in terms of diversity no significant differences were found between the areas. Most common species were white-tailed mongoose and side-striped jackal. Suitability of occupancy models was tested, and it was found out, that for most of the species habitat does not play a role in terms of occupancy or detection probability estimates. The exception was genet spp. and serval. The occupancy estimates were affected by habitat for genet spp. that occupied mostly Tree savannahs. The detection probability estimates for serval were also affected by habitat, but serval was least probable to detect in Shrub savannah and most probable to detect in Grass savannah. Majority of detected species had nocturnal activity with exception of Egyptian mongoose and honey badger, who showed strictly crepuscular activity.



**Key words**: Mesocarnivores, species diversity, species richness, occupancy, activity patterns, ZSL-CTAP

# Content

## List of tables



## List of figures

## List of the abbreviations used in the thesis

AIC Akaike Information Criteria

APN African Parks Network

ASCaRIs African Small Carnivore Research Initiatives

AVIGREF Village Associations for the Management of Wildlife Reserves

CBD Convention on Biological Diversity

CENAGREF National Centre for the Management of Wildlife Reserve

CITES Convention on International Trade of Endangered Species

CR Critically endangered

CT Camera trap

EN Endangered

GABI Great American Biotic Interchange

GDP Gross domestic product

ID Identification

IUCN International Union for Conservation of Nature

LC Least concern

mya Million years ago

NP National Park

NT Near threatened

RAI Relative abundance index

SCSG Small carnivora specialist group

spp. Species

UNESCO United Nations Educational, Scientific and Cultural Organization

VU Vulnerable

WAP W-Arly-Pendjari complex

ZSL-CTAP Zoological Society of London - Camera Trap Analysis Package

# 1. Introduction and Literature Review

## 1.1. Carnivores

The mammalian order Carnivora includes species we most love and fear. Our love for predators is reflected by numbers of domesticated dogs and cats – their population outnumbers any wild carnivoran. On the other side, large predators are among the most endangered mammals. Our relationship with predators is complex and intertwined with conflicts, but we admire their strength and beauty. (Van Valkenburgh & Wayne 2010) (Gittleman 2013)

Species of this order invaded nearly every continent (with exception of Antarctica) and ocean of the world and evolved wide variety of diets, from bamboo eating pandas to bone-cracking hyenas, from frugivorous kinkajous to ant-eating aardwolves. We use term carnivoran do denote species from the order Carnivora, as not all of them are pure meat-eaters and there are other carnivorous creatures, that don't belong into this order. There are about 286 species of living carnivorans and about 250 of them are terrestrial. (Van Valkenburgh & Wayne 2010)

Order Carnivora is characterized by great morphological, ecological and behavioral variation. Body size range from 100 g least weasel to gigantic polar bear weighing as much as 800 kg. Reproductive rate can be from 1 offspring in every five to seven years in some black bears to as high as three litters per year with 8 offspring per litter in dwarf mongooses. Mating system vary as well with many species being promiscuous but others showing varying degrees of monogamy. Most carnivorans are solitary, some with overlapping territories, some are aggregating in time of abundant resources and some are highly social with complex social behavior. There are even some species that seems to be obligate social mammals, such as meerkats or african wild dogs, where individuals cannot survive alone. They adapted to every environment. They can live in deserts (fennec fox), thick forests (banded palm civet) or even oceans (sea otters). This spectacular diversity made carnivorans favorite group for comparative evolutionary studies. (Van Valkenburgh & Wayne 2010) (Gittleman 2013) (Goswami & Friscia 2010)

Carnivorans differ from other groups in key aspect of their teeth that is diagnostic feature of the order. They have single pair of cutting teeth on either side of their jaw, known as carnassials. These two teeth, the upper fourth premolar and first lower molar, bear blades that come together in a scissor-like fashion to cut tough skin, tendon, and flesh. Behind them in the tooth row are more blunt-cusped molars that function in grinding plant matter and crushing bones. This configuration allowed better evolutionary plasticity and adaptability in terms of diet. (Van Valkenburgh & Wayne 2010)

The precise origins of carnivorans are poorly understood, but they probably evolved from small insectivorous civet-like ancestor that lived some 60 million years ago (mya). However, there are many earlier fossils with the diagnostic carnassial teeth that represent the stem leading to the living families. There are two major groups of stem carnivorans: Viverravidae and Miaciodae. There was previously thought, that feliforms evolved from viverravids and caniforms from miacoids. But now it is thought that Viverravidae is the most basal group of Carnivoramorpha. They were small to medium sized terrestrial mammals and insect was large part of their diet. In late Paleocene (61-55 mya) viverravids are known from Asia and North America, spreading to Europe by early Eocene (37-34 mya). In early Eocene viverravids were already extinct but first representatives of Carnivora appeared on northern continents. They invaded southern continents in the Miocene (24-5 mya). (Goswami & Friscia 2010)

The order Carnivora comprises 16 families. (Wilson et al. 2009) These families are divided into two suborders reflecting divergence in order’s early evolution: Caniformia and Feliformia. Caniformia or the dog-like carnivorans comprises families Canidae, Ursidae, Procyonidae, Ailuridae, Mephitidae and Mustelidae, as well as the three pinniped families and are evolutionary older than Feliformia, comprising cat-like families Felidae, Hyaenidae, Herpestidae, Eupleridae, Prionodontidae, Viverridae and Nandiniidae. (Hunter & Barrett 2018) All caniform families have global distribution, while feliform families are restricted to the old world with exception of Felidae. (Goswami & Friscia 2010) Also caniforms evolved and stayed mostly in temperate zones, but feliforms remained in tropics. The only exception is South America, because when Great American Biotic Interchange (GABI) began, North America was colonized mostly by caniforms and just one family of feliforms, hence from feliforms only Felidae family was able to take part in Carnivoran colonisation of South America. (Pedersen et al. 2014)

## 1.2. Small carnivorans

Large carnivorans such as lions, wolf or hyenas are widely known, but most of the carnivorans are not very large. They are rather small or midsized species with average body mass lower than 15 kg. These carnivorans are collectively termed small carnivores, small carnivorans or mesocarnivores. Out of 16 carnivoran families, small carnivorans can be found in 12 of them. (Roemer et al. 2009) According to International Union for Conservation of Nature (IUCN) Small Carnivore Specialist Group (SCSG) we can find them in those families: Ailuridae (red panda), Eupleridae (Malagasy carnivorans), Herpestidae (mongooses, meerkats), Mephitidae (skunks, stink badgers), Mustelidae (weasels, martens, minks, badgers, otters), Nandiniidae (African palm civet), Prionodontidae (Asian linsangs), Procyonidae (raccoons, coatis, olingos, kinkajou) and Viverridae (civets, genets, African linsangs or oyans). But of course, we can find them also in family Canidae, Felidae and even in Hyaenidae. ((ASCaRIs 2022)

### 1.2.1. Small carnivorans of Africa

Africa is home to more than 80 species of small carnivorans in 8 different families: Canidae and Mustelidae from caniforms and Eupleridae, Felidae, Herpestidae, Hyaenidae, Nandiniidae and Viverridae from feliforms. (ASCaRIs 2022)

This chapter introduce families of small carnivorans important for this thesis.

#### 1.2.1.1. Canidae

Canidae family is probably the most ancient family of order Carnivora, originating 40 mya in North America and spreading to Eurasia after formation of Beringian land bridge. The 35 species of this family are divided into two distinct lineages: large wolf-like canids and small fox-like canids. Members of this family are most widespread within Carnivora. They inhabit all continents with exception of Antarctica. Canids are also the most social family with social relationships centred around monogamous male – female pair and cooperating to raise pups. In some species, yearlings stay with their parents to act as helpers in raising subsequent litters. Canid's sociality is extremely flexible with some species shifting across the continuum from monogamous pair to pack living, depending on resource availability. They are obligate carnivores with animal prey as staple food and fruits and vegetable can be additionally consumed by some species. (Hunter & Barrett 2018)

#### 1.2.1.2. Mustelidae

Mustelidae family comprise around 60 species of badgers, martens, weasels and otters. They are the largest family of carnivorans and arose in Eurasia at least 24 mya. Subdivision of this family is complicated and undergoes regular revision. Generally eight subfamilies are recognised: Taxidiinae (American badger), Mellivorinae (honey badger), Melinae (Eurasian and hog badgers), Helictidinae (ferret badgers), Guloninae (martens, tayra, fisher and wolverine), Ictonychinae (grisons, zorilla and allies), Mustelinae (American mink, true weasels and polecats) and Lutrinae (otters). This family is now globally distributed with exception of Antarctica and Australia and evolved into different forms from aquatic and social otters to semiarboreal martens. Most mustelids have anal glands, that produce strongly smelling secretions. Some are even able to spray these secretions in defence. Approximately third of mustelids has ability of delayed implantation, where development of embryo in womb is temporarily postponed, sometimes as long as 11 months. This adaptation allows mating and birth to occur in spring or summer, when finding mates and raising young is most benign. (Hunter & Barrett 2018)

#### 1.2.1.3. Felidae

The cat family arose approximately 30 mya in Eurasia and spread all around the world with exception of Australia and Antarctica. 40 wild cat species are currently recognised and are divided into 8 lineages. They are hypercarnivores and subsist almost entirely on animal prey. Larger prey is generally killed by suffocating bite to the throat and in case of smaller prey by crushing their skull. Most cats are solitary, territorial and nocturno-crepuscular, with few exceptions such as lions. (Hunter & Barrett 2018)

#### 1.2.1.4. Herpestidae

Mongooses were formerly classified within family Viverridae, but now are recognised in their own family Herpestidae with 34 species. This family is divided into two subfamilies: Herpestinae (solitary mongooses) and Mungotinae (social mongooses). Members of this family occur in Africa, Middle East, South Asia and one specie: egyptian mongoose (*Herpestes ichneumon*) occur also in Spain and Portugal. Mongooses are primarily carnivorous, with vertebrates and invertebrates as staple food, but fruits and vegetable are also eaten to a limited degree by some species. As the two subfamilies indicate, mongooses can be largely solitary or live in complex social systems. The social patterns are best understood in dwarf mongooses (*Helogale parvula*), banded mongooses (*Mungos mungo*) and meerkats (*Suricata suricatta*). Some species of Herpestinae also exhibit semi-social tendencies such as denning together. (Hunter & Barrett 2018)

#### 1.2.1.5. Viverridae

Viverridae is ancient family of Feliformia, which have arisen at least 34 mya in Eurasia and later colonising Africa. It is divided into 4 subfamilies: Viverrinae (large terrestrial civets), Genettinae (genets and oyans), Paradoxurinae (palm civets and binturong) and Hemigalinae (otter civets and allies). This family have 33 species, but classification of genets is a bit problematic. Viverrids are restricted to Africa and South Asia with small spotted genet also occurring in Europe, although it is probably result of human introduction. They are solitary and nocturnal, some species are semi-arboreal or arboreal and have protractile claws. Viverrids are primarily carnivorous, with vertebrates and invertebrates as staple food, bur Paradoxurinae are largely frugivorous. (Hunter & Barrett 2018)

### 1.2.2. Ecology

According to Roemer et al. (2009) small carnivores received little attention regarding their roles in ecosystems compared to large carnivorans. The ecological role of small carnivorans can be far richer than previously considered. In many cases, they may be fundamentally important drivers of ecosystem function, structure, or dynamics. Their impact can be especially profound in several scenarios. When larger carnivores are absent, on island ecosystems or mainland localities where community composition is relatively simple, or where they represent non-native introductions. They can thwart nutrient subsidies, hence completely altering floral communities or potentially facilitate nutrient flows linking adjacent ecosystems. (Roemer et al. 2009)

Small carnivorans can occupy unique roles that cannot be filled by larger carnivorans, thanks to their size and energetic needs. Small carnivorans with more frugivorous diet can disperse seeds together with other species. For example they can disperse seeds longer distances than birds and disperse them on slightly different places. Also small carnivorans can shape plant communities indirectly through predation on seed dispersers. When carnivores reach body sizes above 15 to 20 kg, the energy expended to catch sufficient small prey to sustain their larger body mass exceeds the caloric return, so carnivores must switch to large vertebrate prey. To do so, their skulls, jaws, and teeth are modified to handle greater stresses incurred in killing prey their own size or larger. Hence large apex carnivores are unlikely to play either the role of seed disperser or hunter of seed predators.

Small carnivorans may mediate effects of large carnivorans as pathogen reservoirs. The most important diseases of carnivores are caused by generalist pathogens that can spread among carnivorans irrespective of body size. However higher densities of small carnivorans means, that pathogens can spill from small carnivorans to the large ones more likely than vice versa.

Island communities are usually quite simple. In these communities small carnivorans can play role of apex predators by inhibiting competitors and controlling prey populations—especially in systems that lack high species diversity and large-bodied primary consumers. Simple ecological communities represent systems in which the community effects of small carnivorans may be more prominent because interactions in these communities may be linear, strong, and lacking compensation. In more complex communities small carnivorans can strongly affect prey species, but their impact on other aspects of community is less obvious.

Introduced small carnivorans can influence native species by predation or competition and be the primal cause of their decreasing populations. Introduction can also dramatically limit prey species and their geographical distribution. (Roemer et al. 2009)

### 1.2.3. Threats and conservation

There are 172 species of small carnivorans, which represent over half of the species in the order Carnivora. (Glatston & Duplaix 2020) According to IUCN 53 species of small carnivorans are globally threatened (CR, EN, VU) compared to 15 large. Out of this group, 3 species are defined as Critically Endangered CR, 20 as Endangered EN and 30 as Vulnerable VU. (Marneweck et al. 2021) The majority of small carnivorans are not priorities for species conservation as most of them are categorized as Least Concern LC or Near Threatened NT by the International Union for Conservation of Nature (IUCN) Red List. (Willcox 2020) Around half of population of small carnivorans have decreasing pollution trend. Six species were down listed from 2015, but 19 small carnivorans were up listed to higher IUCN category. (Marneweck et al. 2021)

According to Willcox (2020) the group contains a large number of species that are tolerant of significant human-induced changes in habitat, and are able to, if not unduly persecuted, survive and breed in a variety of rural, peri-urban and urban landscapes. In Africa do not live CR or EN small carnivorans. Out of 5 VU species, 4 are distributed in west Africa and are threatened by habitat loss and the bushmeat trade, though large tracts of suitable habitat remain for all 4. Despite this out of 106 small carnivorans distributed in Africa, 42 have decreasing population trend and only 4 have increasing.

The most common threat between carnivorans is overhunting and pouching with different motivations across regions. Demand for wild meat as a luxury consumptive item has driven indiscriminate snaring. Wildlife trade worldwide is driven by desire to own exotic pet, trophy or by traditional medicine usage. The demand puts pressure on source countries, where are limited sources to combat illegal activities and corruption. People in these countries also have their own different motivation for hunting, partially caused by increasing human population that is encroaching on key habitats and result in increased use of their sources or lack of economical opportunities in local communities. (Willcox 2020)

One of the biggest threat for small carnivorans worldwide is the combined loss of habitat and prey**.** More than two-thirds of Earth’s terrestrial land area is now devoted to supporting humans, with the remaining natural habitat disappearing at an estimated rate of 1 % per year**.** Where people replace forests, woodlands and grasslands with cities, agriculture and livestock, most carnivores decline or disappear. (Hunter & Barrett 2018) The land use is changing rapidly, especially in developing countries. Land use change can lead to habitat fragmentation and degradation with reduced connectivity, geneflow and with isolated populations. Large-scale plantations or conversion to industrial agriculture is predicted to expand in Southeast Asia, Africa and South America, overlapping with areas containing the greatest richness of threatened small carnivores. Deforestation and habitat conversion to create residential and commercial development occurs worldwide as a result of increasing human populations. Some species of small carnivorans are able to adapt to areas of human development. Also new roads can lead to increased access to remote areas resulting in further hunting and poaching small carnivorans and their prey. Generally conversion to human land uses can increase human-carnivore conflict. (Willcox 2020)

Invasive species have been and are introduced into many ecosystems globally. Especially species close to humans such as domestic cats and dogs can be very invasive and can threaten many species of small carnivorans by competition for resources, predation, by affecting natural behaviour of native species. Also some closely related species can hybridize with each other or invasive species can introduce novel pathogens. Some infectious diseases can easily spread between native species and reduce or sometimes regionally extirpate small carnivoran populations. (Willcox 2020)

Infectious disease is a natural part of wildlife populations worldwide, but it can be particularly problematic to carnivores when introduced by humans and their domestic animals. Wild canids are especially vulnerable to rabies and canine distemper transmitted by domestic dogs. (Hunter & Barret 2018)

Energy production and associated activities can negatively affect many terrestrial mammals by further habitat fragmentation, multisource pollution and increased human exploitation. Especially some pollutants can accumulate in the environment and threaten all the links in food chain. This had become evident most in carnivorans dependent on aquatic environment. Semi-aquatic carnivorans are also threatened by fragmenting of rivers by hydroelectric dam construction hence changing river dynamics. (Willcox 2020)

The persistence of most carnivores relies on large expanses of wilderness relatively free from human influences. Any meaningful effort to conserve carnivores must set aside vast protected areas and ensure that they are truly protected. That means vigorously limiting impacts of people, such as clearing habitat, hunting wildlife and introducing livestock and diseases. However protected areas will not be sufficient to guarantee survival of some carnivorans. The same attention should be devoted also to human-modified landscape that now dominate the globe. Even carnivorans difficult to conserve are able to survive in such modified environment, creating further conflicts between human and predators. The key is in fostering mechanisms for coexistence, typically through reducing the problems that carnivores create, or by making carnivores valuable to people who bear the burden of living with them. Most communities living with predators are trying combination of both. (Hunter & Barret 2018)

Ex situ conservation is also important, as some threatened species depend on it. Zoos generally can play important role in conservation of small carnivorans, as they are successful in breeding species they already have. Unfortunately, species frequently kept in zoos do not always correspond with species that are threatened the most. These species are usually kept just in few institutions resulting in lower genetic variability. Zoo managers keep species, that are considered interesting for visitors, but are fairly common in their original habitat. The relatively limited space requirements of many small carnivorans mean that they lend themselves particularly well to smaller zoos or aquariums, that can expand their conservation credential if focused on more threatened species. Zoos are invaluable source of research. Many species are hard to study for their elusive behaviour or obscure lifestyle, so research held in zoological institutions can provide knowledge base for studies held in nature. (Glatston & Duplaix 2020)

## 1.3. Benin

The Republic of Benin is located in West Africa at the Gulf of Guinea coast, neighbouring Burkina Faso, Niger, Nigeria and Togo. Its capital is Porto-Novo, but the government resides in Cotonou. The chief of Benin is president who is also head of the government and is voted for 5-year term. Benin has over 13,5 million inhabitants who belong into about 42 ethnic groups, with Fon, Adja, Yoruba and Baribe being most abundant. Official language of this country is French, but there exist around 55 of indigenous languages, with Fon (a Gbe language) and Yoruba the most important ones. Almost half of Beninese are Christians and around quarter of them are Muslims. Around 11 % of people in Benin practise Vodoun, local religion, that is similar to voodoo. Over 65 % of population is under the age of 25 years, which is bolstered by high fertility. Benin’s total fertility has been decreasing over time, but is still high. Beninese women on average become mothers for the first time at the age of 20 and have 5 children. The population is unevenly distributed with majority of population concentrated on south in and around big coastal cities. The north is sparsely populated with higher concentrations of residents in the west. Around 40 % of population lives below the poverty line. Only 42.2 % of population over 15 years can read and write. (CIA factbook - Benin 2022)

Benin was under French colonial rule from 1904, forming one state of eight in West French Africa. The country gained full independence in 1961. Benin has since ratified many international conventions on the protection of the environment including the Convention on Biological Diversity (CBD), the Convention on International Trade of Endangered Species (CITES) and the Ramsar Convention on Wetlands of International Importance.

The Beninese economy is agrarian-based with 43.2% of the population employed in agriculture. In the north-west region, the growing population drives the transformation of savannah and grassland into agricultural fields for sustenance with sorghum (Sorghum bicolor), peanut (*Arachis hypogaea*), yam (*Dioscorea* sp.), corn (*Zea mays*), cassava (*Manihot esculenta*) and rice (*Oryza sativa*) as primary crops. Cotton (*Gossypium hirsutum*) is the main cash-crop in Benin, accounting for 40% of GDP and 80% of agricultural exports. Livestock rearing is the second most important economic activity of rural people in the country. Cattle exhibits highest densities in the northern regions of the country, where is essentially nomadic. (Goad 2019)

Climate in Benin can be divided into coastal zone, also called Guinean region, and inland of the country, called Sudanian region. There is also transition area called Sudano-giunean region.

The coastal band remains throughout the year under influence of oceanic trade winds with moderate thermal ranges. Precipitation in this band follows regime of 2 rainy seasons: a long rainy season (April to July) followed by a short dry season (July-August to September) and a short rainy season (September to October) followed by a long dry season (November-December to March). The annual precipitation varies from 900 mm in the west to 1,300 in the east. Dominant soil type is ferralitic and deep. This zone is closely related to enigmatic “Dahome Gap” which is break in the belt of forest, which links 2 forest blocks of Central Africa and Western Africa.

The transition area, Sudano-guinean region is characterised by progressive merging of the 2 precipitation peaks and marks transition towards typical Sudanian climate. Precipitation varies from 1,100 to 1,200 mm and soul type is tropical ferruginous.

In the country inland or Sudanian region from south to north, influence of harmattan (dry, dusty wind blowing south-westwards from Sahara into Gulf of Guinea during dry season) is more and more perceptible. That results in progressive increase in thermal gaps and just 1 long dry season, that can last even more than 6 months – from October to March. The precipitation is decreasing from South to North with 900 to 1,150 mm. Humidity is low with exception of Atacora massif, where is milder local climate. The soil type is tropical ferruginous. (“Atlas de la biodiversité de l’Afrique de l’Ouest” 2010) (Agbazo et al. 2021)

The annual amount of rainfall increases regularly from North to South and varies from 800 to 1,300 mm. On the coast there is also increase from the West to the East, where there is 970 mm in extreme west to 1,376 mm in extreme East.

The temperature varies from 25°C to 33°C with differences between South and North. In the North maximum temperatures are at the end of April, while in the South occur in December and in February. Difference between hottest and coldest month increases from North (6°C of difference) to South (3°C of difference). (“Atlas de la biodiversité de l’Afrique de l’Ouest” 2010)

The primary forest formations found in Benin are mainly woodlands and savannahs (centre and northern parts), and semi-deciduous and deciduous rain forests in the southern part. (Guidigan et al. 2019)

Benin has 25 % of its territory established in 58 natural sites gazetted by the state. These natural sites are divided into 4 categories. The first category is National Parks with 869,867 ha of total area. The 2 National Parks in Benin, Pendjari and W National Park protect not only its fauna, but its habitat as well as the natural landscape. The second category is Hunting Zones with 443,697 ha of total area. The protecting goal of hunting zone is to promote the rational and controlled exploitation of fauna. This is done according to management rules, which guarantee maintenance of certain prey density and sufficient benefit for country which in recent years is also shared with local communities. Third category is Forest reserve in which we can distinguish 3 types according to goals. In first type, hunting is forbidden, but forest or mining exploitation can be done. In second type, hunting by traditional means is also authorised. The third type is especially reserves of small size created to protect just these particular sites. The forest reserves have in total 1,345,590 ha. The fourth category is Reforestation site with 2,734 ha in total. Hunting in these areas is forbidden, but growing crops and human settlements are tolerated. ("Atlas de la biodiversité de l'Afrique de l'Ouest" 2010)

The 2 national parks of Benin are part of the W-Arly-Pendjari ecosystem (WAP), one of the largest complex of protected areas in West Africa. It consists of Pendjari Biosphere Reserve from Benin, Transboundary Biosphere Reserve "W", that is situated in Benin, Burkina Faso and Niger, and Arly National Park from Burkina Faso.

## 1.4. Camera traps

In recent decades, camera traps have greatly expanded what is possible in mammal research. This is due to their versatility, low effort-to-data volume ratio and ability to cost-effectively monitor multiple species and detect rare, cryptic and elusive animals. (Rowcliffe 2017) As a result, camera traps are now firmly established as a core tool for mammal ecologists and conservationists. (Burton et al. 2015)

The camera traps can be used to quantify species diversity or estimate occupancy and relative abundance. These estimates can be compared across space and time to monitor changes in populations and test hypotheses about the effects of landscape and human factors on species relative abundance, distribution, interspecific interactions and behaviour. (Kays et al. 2020)

However, there are a number of issues that remain with using camera traps *in situ*, including theft and vandalism, poor performance in extreme environments and damage by wildlife. There is also big amount of camera traps on the market and we have no knowledge of the relative performance of different types. (Glover-Kapfer et al. 2019)

Camera traps deployed in grids or stratified random designs are a well-established survey tool for wildlife but there has been little evaluation of study design parameters. There exist substantial variation in study designs, e.g. sample size (ranging from 1 to 1000 camera traps) duration of study or placement of cameras. (Kays et al. 2020) It is increasingly clear that camera placement can directly impact data (e.g. placement on trails will increase overall capture rate), yet these biases are poorly understood. (Kolowski & Forrester 2017) Study designs, particularly for small-bodied or cryptic wildlife species often attempt to boost low detection probabilities by using non-random camera placement or baited cameras, which may also bias data, or incorrectly estimate detection and occupancy. (O'Connor et al. 2017)

Also, reliable assessment of animal populations is a long-standing challenge. First opportunity for improvement is more consistent reporting of methodological details. Also, some studies completely ignore possibility of imperfect detection of species, assuming, that all species are equally detectable, while we know, that detection rates can be affected by many factors. There also exist lot of indices or models that can be used while analysing camera trap data, some more used than others, making it sometime difficult to compare data across time and space. (Burton et al. 2015)

## 2. Aims of the Thesis

This thesis focuses on diversity of small carnivorans in Pendjari National Park, that is part of WAP transfrontier ecological complex of protected areas.

The main aim of this study is to describe and identify diversity of small carnivorans in Pendjari NP, study their distribution, abundance and activity patterns.

To achieve this, 56 camera traps were placed in systematic grid in Pendjari NP over period of 3 moths. Data obtained by these cameras were used for several different analysis. In this way, the aim was divided into 4 objectives:

The first objective is to study species diversity and richness throughout the area and within it, their variation between the different main habitats of the area: Grass savannah, Shrub savannah and Tree savannah

Second objective is to study their relative abundance in terms of camera trapping photographic rate, occupancy and detection probability again for whole area and for each habitat

Third objective is to study activity pattern of each species, identifying its activity ranges and compare these activity patterns.

Fourth objective is to compare data of small carnivorans with data of large carnivorans for whole area.

# 3. Methods

## 3.1. Study area

The study carried out in Pendjari National Park, located on northwestern edge of Republic of Benin between 11° to 11°30 northern latitude and 1° to 2° eastern longitude. Pendjari NP have 2,660 $km^2$ and adjoin 2 hunting zones, Pendjari Hunting Zone (1,600 $km^2$) and Konkombri Hunting Zone (250 $km^2$), these 3 areas together make up Pendjari Biosphere Reserve. (Runge et al. 2021)

The Pendjari NP is situated in Sudanian climatic region characterized by alternation of 2 seasons, dry season (November to May) and rainy season (May to October). (Sogbohossou & Aglissi 2017) Dry season can be subdivided into cold dry season from November to February, followed by hot dry season, which lasts from March to mid of May. During the cold dry season, the Harmattan (dry wind from Sahara) coneys dust from Sahara, reducing visibility during the day to 100 m and less. In this part of dry season temperatures usually exceed 35°C but can fall to 15°C during night. In the hot dry season temperatures can climb to 40°C and stay above 20°C during night. With first rains in May, temperature differences between day and night are reduced and temperatures usually vary between 25°C and 35°C. From July to September, monsoon circulation brings heavy rains with monthly precipitation from 200 to 300 mm, but these are only approximations, as precipitation in this area is highly variable in space and time. (Moritz & Lalèyè 2018) Annual precipitation varies from 800 mm on north to 1,000 mm on south. (Sogbohossou & Aglissi 2017)

Major part of Pendjari NP is lowland with altitude from 150 to 200 m above sea level. In south lies Atacora massif, a quartzite mountain chain, which reaches an altitude of 400 to 513 m above sea level. It is origin of Pendjari river and serves as water reservoir, feeding the river during dry season.

The Pendjari river is the only major river in Pendjari NP. It has highly seasonal flow regime, in dry season in some parts completely cease to flow or become subsurface river. In rainy season the river spreads from its river bed and inundates extensive parts of the savannah. Pendjari flows into river Volta, drains an area of 72,900 $km^2$ and is roughly 940 km long. Beside the main river there are few smaller springs originating along the Atacora chain flowing throughout the year and maintaining important water points during dry season  (Moritz & Lalèyè 2018)

The landscape is dominated by savannah, mostly Grass, Shrub or Tree savannah, but we can also find open forests or gallery forests. Around Pendjari river we can also find The Pendjari river wetlands classified as Ramsar Sites. ("Atlas de la biodiversité de l'Afrique de l'Ouest" 2010) (Moritz & Lalèyè 2018) (Lopes et al. 2020) (Sogbohossou & Aglissi 2017)

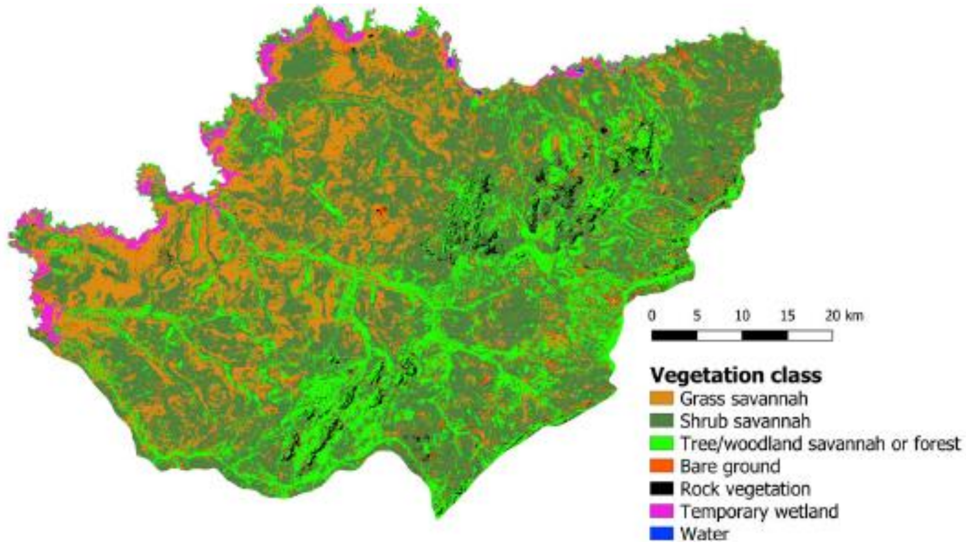


**Figure 1:** Distribution of vegetation classes in Pendjari NP (Lopes et al. 2020)

The mammalian fauna is characteristic of the West African savannah including large carnivorans like lion (*Panthera leo*), leopard (*Panthera pardus*), cheetah (*Acinonys jubatus*), spotted hyaena (*Crocuta crocuta*), large mammals like west african buffalo (*Syncerus caffer brachyceros*), hippopotamus (*Hippopotamus amphibius*), tsessebe (*Damaliscus lunatus*), hartebeest (*Alcelaphus buselaphus*), Buffon's kob (*Kobus kob kob*), Defassa waterbuck (*Kobus ellipsiprymnus defassa*) and elephant (*Loxodonta africana*). Pendjari is also home to over 460 species of birds. BirdLife International has identified Pendjari as an Important Bird Area. The Nile crocodile (Crocodylus niloticus) is also to be found in the reserve. (Sogbohossou & Aglissi 2017) (African Parks – Pendjari 2022)

Pendjari hunting zone is bordered by about 23 villages. Three main ethnic groups live there: Berba (65 %), Gourmantché (23 %), and Waama (7 %). Ethic groups have strong traditions in hunting and communities have often highly influential leaders. Indigenous religion accounts for around 50 % of local belief systems while Christianity (40 %) and Islam (10 %) make up the remainder. (Goad 2019)

In 1934 all people were expulsed from area that was in 1954 inscribed as partial wildlife reserve by colonial authorities. A year later the area was designated as complete reserve and in 1961 it was renamed Pendjari National Park. In 1986, the central areas, surrounding buffer zones and hunting zones were collectively designated as a Man and the Biosphere Reserve. In 1996, the Pendjari Biosphere Reserve, as part of the WAP complex, was officially inscribed as a UNESCO world heritage site.

Until 1992 the park was managed by the national forest department. The prolonged coercive expulsion of people from park land and exclusion from management resulted in an environment of distrust characterised by clashes and conflicts between national authorities and local communities regarding access to park resources. A participatory management scheme was introduced in 1993, however an environment of distrust had already been established which hindered initial engagement and success. In response to the new management scheme, most of the peripheral villages formed a union called the Village Associations for the Management of Wildlife Reserves (AVIGREF) Three years later in 1996, the Beninese government created the autonomous authority known as the National Centre for the Management of Wildlife Reserve (CENAGREF) that managed the protected area with AVIGREF members directly until August 2017. (Goad 2019) In 2017, the Government of Benin entered into a long-term agreement with African Parks Network (APN) to revitalise, rehabilitate and develop Pendjari. Pendjari was included as one of 45 flagship projects of the “Revealing Benin” national investment programme In January 2018 together with the Benin Government, the Wyss Foundation, National Geographic and the Wildcat Foundation, APN announced a commitment of $23M over 10 years, $6M of that amount was pledged by the Government. (African parks – Pendjari 2022)

## 3.2. Data collection

The data were collected by Ing. Zuzana Holubová. The data collection period took held during year 2020 from February to June. In total 56 camera traps (CT) were installed during period of 104 days in systematic grid (Figure 1). Distance between camera traps was 2.5 km with maximum deviation of 100 m from previously determined location. All camera traps were model Strike Force Pro X from Browning.

The CTs were placed on natural structures such as tree trunks. They were placed on trails and other places with higher probability of detection of animals and approximately 7.5-10 m from the target place. They were positioned 80-90 cm from the ground, facing north or south to avoid false triggers by sun. To avoid false triggers, also vegetation in front of and immediately around camera was cut, as the CTs are very sensible. The camera traps were also positioned at angle of 45°, while seeing 1/3 of horizon.

Each camera was set on Trail mode, with low picture size and detection distance 20-25 m from camera trap. It was set to work 24 hours per day and to take 2 pictures per trigger with 10 seconds delay with high sensitivity. At night, red glow infrared flash was used.

After placing of each camera trap, date, time, ID and state of cameras, GPS coordinates and information about the place were recorded and pictures of place were taken.

After approximately 30 days each camera was serviced. During the service all pictures from camera were downloaded on hard drive and then erased from the camera memory to create space. Condition of each camera was recorded and batteries and SD cards were replaced if needed. Also capture delay of most of the CTs was changed from 10 seconds to 1 minute.


**Figure 2:** Camera trap deployment in Pendjari NP

## 3.3. Data analysis

Obtained data were first analysed by eMammal, data management system and archive for camera trap research projects. In this system is possible to identify species, numbers of individuals, sex and age of individuals for each photograph. After this, data were uploaded into ZSL-CTAP (Camera Trap Analysis Package), created by Zoological Society of London, where most of the analyses were done.

As the analysis also compares different habitats, it was necessary to determine the habitat in which each camera trap was located. They were determined through photos of immediate surroundings of each camera trap taken after their installation. All camera traps were placed in one of subclasses of savannah classified according to Lopes et al. (2020), where he divided savannah into 4 subclasses: Grass savannah, Shrub savannah, Tree savannah and Woodland savannah. Only 3 classes of savannah: Grass, Shrub and Tree savannah, were identified according to these definitions: Grass savannah is grassland where no ligneous elements are present. Grass can grow up to 2 or 3 m. Shrub savannah is composed of grass and small ligneous elements such as shrubs and bushes that are not higher than 3 m. Tree savannah is composed of grass, shrubs and sparse trees (at least 3 m high) sufficiently spaced so that the leaves of different individuals do not touch each other. The Woodland savannah defined as savannah composed of grass, shrubs and denser tree cover than Tree savannah was not determined.

Data obtained from camera traps first needed to be sorted. They were sorted into deployments. Each camera was divided into 2 deployments according to dates. In the first one there were photos from time before service of camera trap and in the second one after the service of camera trap. Each person working on the project needed to create an account on eMammal webpage. Project manager, in this case Ing. Zuzana Holubová, created project and entered data about each deployment. The eMammal Desktop App was required to look through all images and to be able to tag them. All images were loaded through this app into its respective deployments. This program automatically groups bursts of photos into sequences if they are <1 min apart, so it is possible to tag whole sequence of images and not each image separately. After images were tagged, they were uploaded for review by project manager.

Working in eMammal required good cooperation between project manager and person tagging the images. Also, the Desktop App is rather intuitive, however extracting the results from whole system is not.

Most of the analyses were done ZSL-CTAP. The first step was to create new survey.

Creating survey required several tables, such as list of cameras with coordinates, time and date of setup, service and recovery of each camera, configuration of each camera trap or list of photos taken by each camera trap with species recognition. Unfortunately, tables from eMammal worked with sequences of images, thus having different names and different number of captures. The list of images from deployments was created through command line and tables were interconnected through capture time.

Once the survey was uploaded, the first basic analysis was performed according to set parameters. The important parameter was duration of independent event, defined as minimum time interval between photographs for new event to be recorded, which was set by default on 60 mins. It was necessary to install R software to execute other analyses.

For statistical analysis of data, software Statistica v.14 was used. Normal distribution of data was checked by Kolmogorov-Smirnov's test. This allowed to decide if further analysis require parametric or nonparametric methods for dataset comparisons. The Kruskal-Wallis test was used for data without normal distribution.

### 3.3.1. Diversity and species richness

Species richness is the simplest, most intuitive and most frequently used measure for characterizing the diversity of an assemblage. (Chao & Chiu 2016) However, it is also the most sensitive to the difference in sampling effort, since it weights all species equally independent from their relative abundances, i.e. rare species count equally to common species although they are more likely to be undetected. (Zelený 2022) Just as we can fail to detect a single species at a site at which it is present, when surveying for species richness, we may fail to detect a species in our survey even though it is part of the sampled community. (Sollmann 2018)

ZSL-CTAP program provides the species accumulation curves, and species richness estimate. A species accumulation curve records the total number of species revealed, during the process of data collection, as additional individuals are added to the pool of all previously observed individuals. (Gotelli & Colwell 2001) ZSL-CTAP also provides rarefaction curve, which show the expected number of species based on a number of possible combinations of samples from the survey data while ignoring imperfect detection of individual species, and Jacknife 1$^{st}$ order estimate curve which takes into account imperfect detection to estimate the total number of species. (Amin et al. 2017) First parameters like class, habitat or trophic level needed to be set. Then species richness was calculated within R package "rich".

The diversity indices were calculated by Past4.03 software, which offers wide variety of them. Species diversity is an expression or index of some relation between number of species and number of individuals. Several diversity indices are commonly used in literature. Probably the most used index is that referred to as 'Shannon's Index' or 'H'. In the literature, the 'Shannon Index' is sometimes referred to as the 'Shannon–Weaver' Index and sometimes as the 'Shannon–Wiener' Index. (Spellerberg & Fedor 2003) This index represents the uncertainty with which we can predict of which species will be one randomly selected individual in the community, the more species the community contains, the more uncertainty increases. However, if community has many species, but only one prevails (many individuals of one species), uncertainty will not be so high, since we have high probability that randomly selected individual will be the most abundant species. (Zelený 2022)

Other chosen index is Pielou's evenness also called Shannon's evenness or "J". Evenness is a synthetic measure describing pattern of relative species abundances in a community. The Pielou's evenness is calculated as a ratio of Shannon index calculated from real community. (Zelený 2022)

However, diversity indices are not themselves diversities. Also, they are not very intuitive interpretation of diversity. That is why it was proposed to use Effective numbers of species derived from diversity indices, as they behave as one would expect of a diversity and produce stable and easily interpreted similarity measures. The effective number of species derived from Shannon index was calculated as exponential of this index: $e^H$ , where e is Euler's number (2.71828). (Jost 2006)

The accumulation and rarefication curves as well as diversity indices were also calculated for every habitat: Grass savannah, Shrub savannah and Tree savannah individually.

### 3.3.2. Relative abundance and occupancy

Photographic trapping rate is very simple and intuitive index. It is defined as the number of independent records of a given species at a sampling location during some time interval. Dividing the number of records by the sampling effort at that location provides a photographic rate which we can also call relative abundance index (RAI). However photographic rates are influenced not only by species abundance, but also by many other factors such as movement patterns or habitat. Thus, when we compare RAIs across study areas or species, we do not know whether differences are in fact due to differences in abundance or due to differences in any of these other factors. (Sollmann 2018) Also uncorrected photographic capture rates yield overestimates of relative abundance. (Hofmeester et al. 2017)

The photographic trapping rate is also provided by ZSL-CTAP, here defined as the mean number of independent photographic events per trap day x 100. It is provided for each species individually.

Other rather intuitive index of abundance is naïve occupancy defined as the number of cameras at which a species was detected divided by the total number of operational cameras. (Amin et al. 2017)

Species occupancy (ψ) can be used as surrogate for abundance. (Rovero et al. 2014) Occupancy is defined as the probability that the focal taxon occupies, or uses, a sample unit during a specified period of time during which the occupancy state is assumed to be static. The occupancy models also account for imperfect detection. As we already know, imperfect detection is, that we can fail to detect a single species at a site at which it is present. (Sollmann 2018)

However species occupancy heavily rely on model assumptions: a) above mentioned imperfect detection, b) closure, that means, that true occupancy status of a site—whether a site is occupied or not—does not change over the course of our study, c) independence of observations across sites and occasions.

The spatial independence of sampling units on each other, means that the observation in one location does not influence what we observe in a nearby location. For that we use "rule of thumb" to place stations at least approximately one home range diameter of the target species apart from each other.

To assume temporal independence, pictures taken within a short time interval at the same station are condensed into single independent detection. Threshold between independent detections can vary from 30 minutes to 1 day, but 60 minutes are the most common and are also used in this study. (Sollmann 2018)

Together with occupancy, detection probability (*p*) is calculated. It is defined as the likelihood of detecting an individual, or species, during a sampling occasion.

The ZSL-CTAP allows to calculate naïve occupancy and model occupancy estimates (ψ) and detection probability (*p*) with or without covariates. There were required parameters like duration of period for occupancy analysis (start and end dates of study) or length of occasion period (set on 5 by default), that had to be set. Then single season occupancy was modeled for each species by package "unmarked" in R software interface.

There are several criteria for calculating occupancy estimates, that needs to be fulfilled. First criteria is, that naïve occupancy has to be 0.1 or more, and the second, that number of events has to be 10 or more. If these criteria are not fulfilled, occupancy estimate will not be calculated for that species, to avoid unreliable estimates. (Amin et al. 2017)

In occupancy analyses we can explore influence of chosen covariate on occupancy estimates and detection probability. In this study the chosen covariate was habitat. The first modelled estimate is called null model. It assumes, that estimates are constant across study sites, so the covariate does not influence neither occupancy estimates nor detection probability. The other model assumes, that the covariates influence both, occupancy estimates and detection probability. Other 2 models assume, that covariates influence just occupancy estimates or just detection probability. To decide which model fits the most for each species, Akaike Information Criteria (AIC), calculated by ZSL-CTAP was used. The lowest AIC value for each species was found and then used to calculate ΔAIC for each model ($\Delta_i AIC = AIC_i - minAIC$). From these values Akaike weights (ω) were calculated as exp(-0.5 * ΔAIC for that model) divided by sum of these values for every model. The Akaike weights can be interpreted as the probability of that model to be the best one. (Burnham & Anderson 2002)

There were several criteria for selecting best fit model. The best model usually has the lowest AIC value. However raw AIC value has no statistical importance and cannot tell as the weight of evidence. So first step is to use “thumb rule" of Burnham & Anderson (2002), which indicate that the level of empirical support for a model is "substantial" if the value of its ΔAIC is lower than 2, so all models with ΔAIC lower than 2 are taken into consideration. If single model was not selected in first step, then we used Akaike weights to interpret, what model has the best probability to be the best model (the higher the weight, the better).

With the best model for each species selected, values of occupancy and detection probability for each species could be observed and compared across different habitats.

### 3.3.3. Activity patterns

The activity patterns were also created in ZSL-CTAP. The frequency of captures for every hour were than loaded into Orinana4 software for testing uniform distribution of data. Tests used were Rayleigh’s Uniformity Test (Z) and Rao’s Spacing Test (U). Both tests are testing if data are uniformly distributed, but each test does it in different way. The Rayleigh's Uniformity test calculates it from length of mean vector and number of observations. The Rao's Spacing test is calculating, if spacing between adjacent points is roughly equal around the circle. If data are uniformly distributed, than spacing between points should be around value of 360°/ number of observations. The more the spacing deviates from this, the bigger probability, that data are not uniformly distributed. (Kovach Computing Systems, 2011)

Both tests are performed because Rayleigh's Uniformity test is known to have very low power to detect multimodal departures from uniformity, that is situations with more than one concentration of data around the circle. That is why second test, Rao's Spacing test, is added as it can detect multimodal distribution. (Landler et al. 2018)

### 3.3.4. Comparison of large and small carnivorans

Analyses for large carnivorans were done in the same fashion as for small carnivorans. The accumulation, rarefaction curve and Jacknife 1$^{st}$ order estimator were created by ZSL-CTAP and diversity indices were calculated by Past4.03 software. Trapping rate, naïve occupancy, modelled occupancy and detection probability were also calculated by ZSL-CTAP software as well as activity patterns of individual species. Test of uniform distribution for activity patterns were again done in Oriana4 software.

# 4. Results

One Camera trap was excluded from analysis, because it did not capture any animal. In total 55 camera traps worked for 61.75 days each. The study resulted in 3396 of Camera operational days with 22,006 images. Just on 736 images (3.34 %) were carnivorans and 658 (3 %) of them were small carnivorans. Total of 4,642 of wildlife events were recorded with 31 species of mammals recognised with 342 events attributed to small carnivorans.

In the study 9 species of small carnivorans from 5 families was recognised (Table 1): Side-striped Jackal (*Canis adustus*), Caracal (*Caracal caracal*), African wildcat (*Felis silvestris lybica*), Serval (*Leptailurus serval*), Egyptian Mongoose (*Herpestes ichneumon*), White-tailed Mongoose (*Ichneumia albicauda*), Honey Badger (*Mellivora capensis*), African Civet (*Civettictis civetta*) and Genet spp. Most of the photos of genets were blurry, so the species were not recognisable. However, Rusty-spotted genet (*Genetta maculata*) and Common genet (*Genetta genetta*) were at least once identified.

| Family | Scientific Name | Local Name | IUCN Status | Population trend |
|---|---|---|---|---|
| Canidae | Canis adustus | Side-striped Jackal | LC | Stable |
| Felidae | Caracal caracal | Caracal | LC | Unknown |
| | Felis silvestris lybica | African wildcat | LC | Decreasing |
| | Leptailurus serval | Serval | LC | Stable |
| Herpestidae | Herpestes ichneumon | Egyptian Mongoose | LC | Stable |
| | Ichneumia albicauda | White-tailed Mongoose | LC | Stable |
| Mustelidae | Mellivora capensis | Honey Badger | LC | Decreasing |
| Viverridae | Civettictis civetta | African Civet | LC | Unknown |
| | Genett spp. | Genet spp. | LC | Unknown |

**Table 1:** List of species found in study area

## 4.1. Diversity and species richness

As we can see in Table 2, out of 9 species of small carnivorans detected in the whole area, most of them were distributed across all three habitats. 8 out of 9 species was present in Shrub and Tree savannah. Serval was not detected in Shrub savannah and African wildcat was not detected in Tree savannah. The Grass savannah was the only habitat were all species of small carnivorans were present.

| | Whole area | Grass savannah | Shrub savannah | Tree savannah |
|---|---|---|---|---|
| African civet | 30 | 7 | 11 | 12 |
| African wildcat | 3 | 2 | 1 | 0 |
| Caracal | 6 | 2 | 2 | 2 |
| Egyptian mongoose | 21 | 4 | 11 | 6 |
| Genett spp. | 56 | 1 | 25 | 30 |
| Honey badger | 13 | 4 | 4 | 5 |
| Serval | 8 | 7 | 0 | 1 |
| Side-striped jackal | 83 | 19 | 38 | 26 |
| White-tailed mongoose | 99 | 22 | 55 | 22 |
| Number of individuals | 315 | 68 | 147 | 104 |
| Number of species | 9 | 9 | 8 | 8 |
| Jacknife 1st Order estimator | 9 | 9.99 | 8.99 | 8.99 |
| Shannon Index (H) | 1.728 | 1.792 | 1.597 | 1.714 |
| Pielou's evenness (J) | 0.786 | 0.816 | 0.768 | 0.824 |
| Effective number of species | 5.63 | 6 | 4.94 | 5.55 |

**Table 2:** Number of individuals found in study area and within it with species richness estimates (Jacknife 1st order), diversity indices (H, J) and Effective number od species

Jacknife estimation of species for whole area suggests, that all species were detected, however estimations for each habitat suggest, that in every habitat we failed to detect 1 more species. In Shrub and Tree savannah, we know, that it is the case, as we did not detect african wildcat in Tree savannah and serval in Shrub savannah. However, in Grass savannah the estimation suggests, that one more species was not detected in the study.

According to number of species detected, the most diverse habitat is Grass savannah. This also support Shannon diversity index, that is the highest from all habitats (H=1.792) with evenness of species over 81 % and Effective number of species 6. The following habitat concerning Shannon diversity index is Tree savannah (H=1.714), but with the highest Pielou's evenness over 82 % and Effective number of species 5.55. The least diverse habitat according to Shannon diversity index (H=1.597) is Shrub savannah with evenness just under 77 % and Effective number of species 4.94.

The Effective number of species follow trend of Shannon index, when Grass savannah is the most diverse and Shrub savannah the least diverse habitat. Results of Kruskal-Wallis test showed no significant difference between communities of small carnivorans in different habitats

The Figures 3 to 6 show accumulation and rarefaction curve for all habitats and for whole area. These graphs show the accumulation of species revealed, during the process of data collection (orange line), expected number of species with ignored imperfect detection of individual species (green line) and Jacknife 1st order estimate (pink line) which show expected number of species, while considering imperfect detection.

The graph for whole study area shown on Figure 3 shows, that all species were observed early in the study. The accumulation curve reaches the top in 2 weeks into the study as well as the rarefaction curve, which have very steep ascend at the start and reaches the value of 9 species very early. The Jacknife estimation reaches its peak of almost 14 species around the same time as the accumulation curve and then stabilizes on value 9 after day 30.

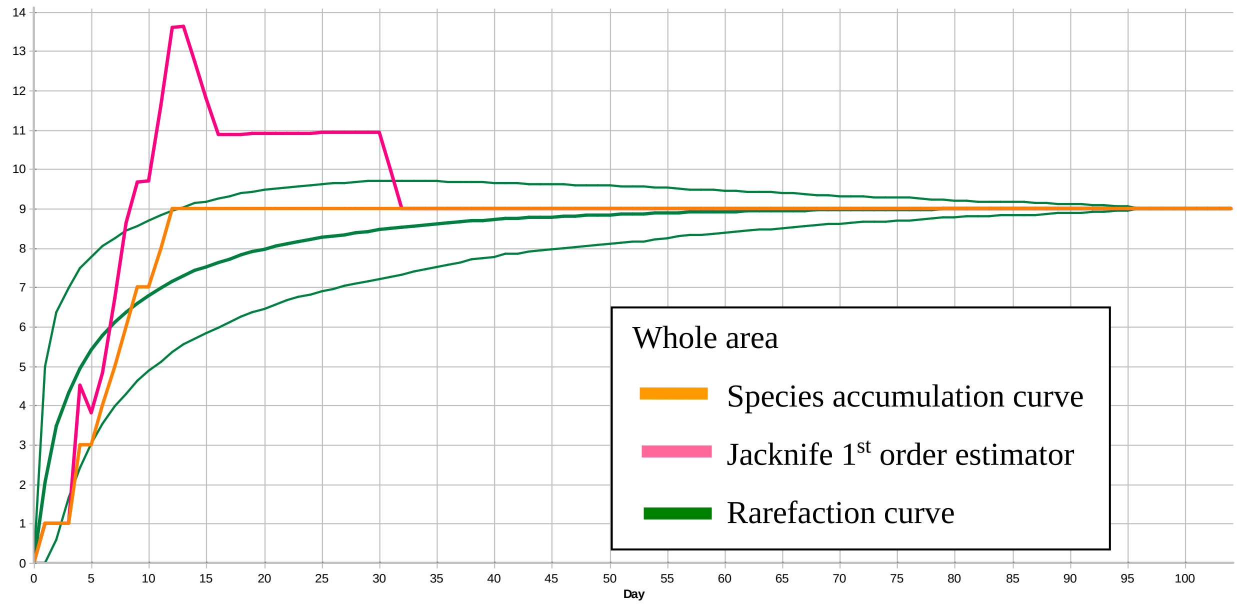


**Figure 3:** Accumulation curve, rarefaction curve and Jacknife 1st order estimator for whole area

On Figure 4 we can see graph for Grass savannah. This graph shows, that in this habitat, first species were not detected until day 6. After that, the accumulation curve and Jacknife estimate have very steep ascend, reaching value 8 on day 16. The last species was detected after 2 months, when the Jacknife estimator rose to value 10. The rarefaction curve has, compared to whole study area, quite slow ascend, probably because of no detection of species at the start and late detection of the last species.

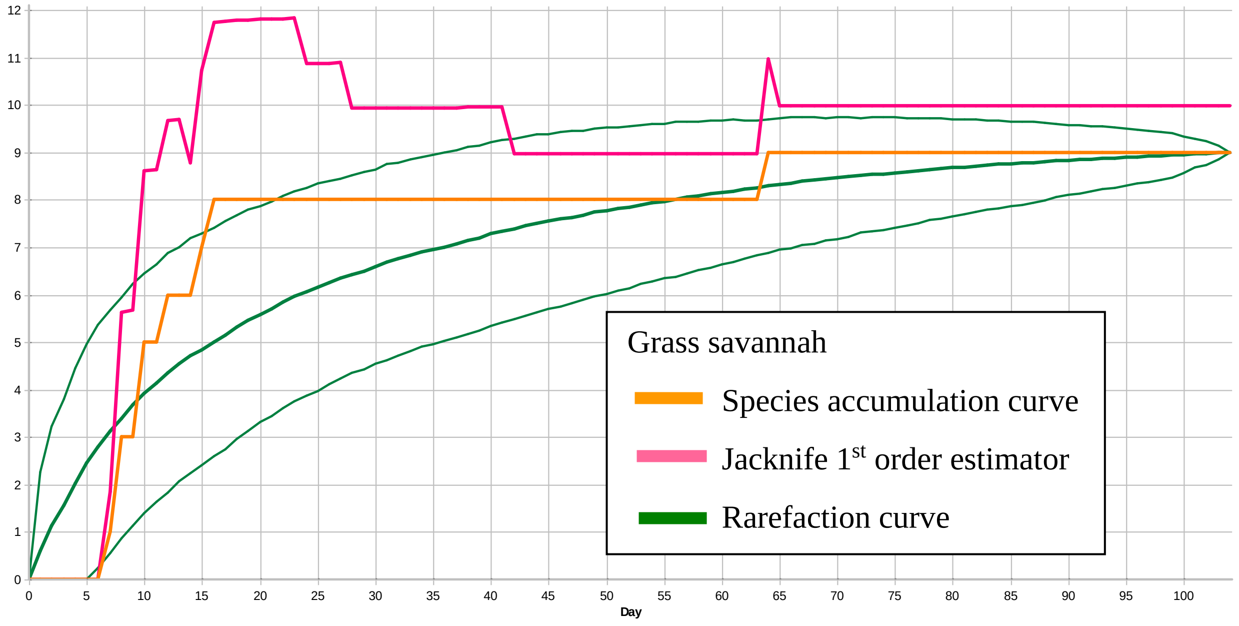


**Figure 4:** Accumulation curve, rarefaction curve and Jacknife 1st order estimator for Grass savannah

The graph for Shrub savannah (Figure 5) shows not very steep ascend of accumulation curve and the Jacknife estimator. The accumulation curve reaches value 8 after 35 days, when the Jacknife estimator is at its peak of almost 12 species. The Jacknife estimator than slowly descend to value 9 almost at the end of the study. The rarefaction curve has steeper ascend at the start, compared to Grass savannah and slow compared to the whole study area.

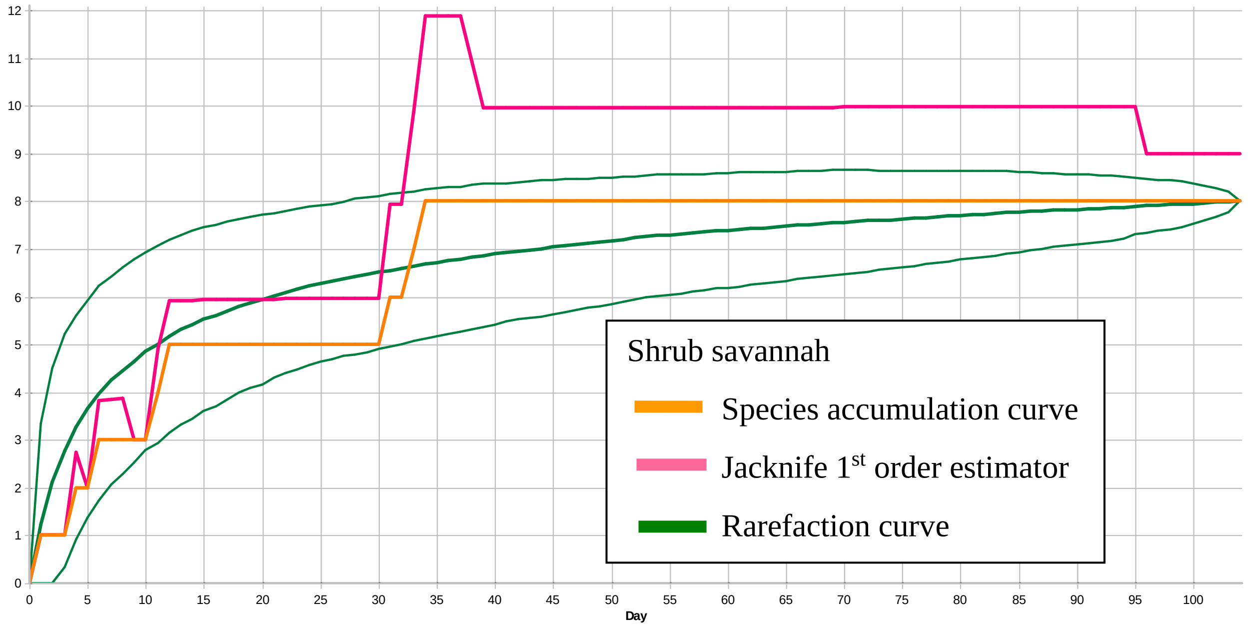


**Figure 5:** Accumulation curve, rarefaction curve and Jacknife 1st order estimator for Shrub savannah

The graph for Tree savannah (Figure 6) shows slower ascend. The accumulation and rarefaction curves reached the top values late in study compared to other habitats. However the rarefaction curve is still steeper than the rarefaction curve of Grass savannah. The Jacknife estimate is quite erratic, first rising almost to value 9, than descending, rising and descending again in similar fashion and then growing to final value of 9 species around day 60.

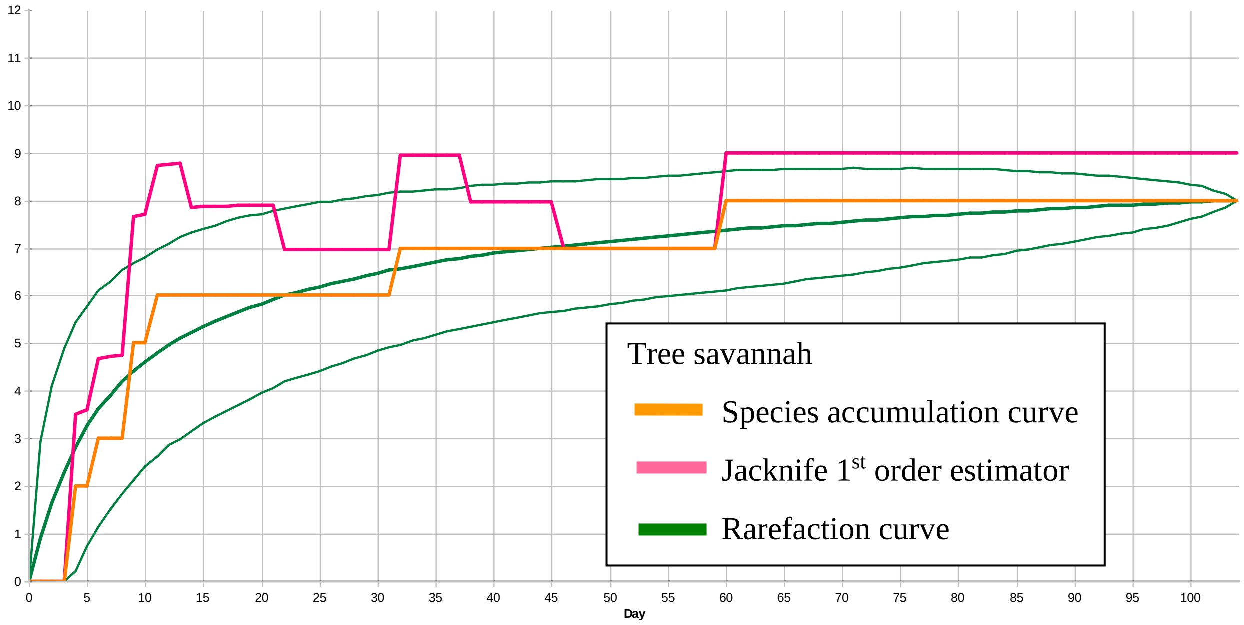


**Figure 6:** Accumulation curve, rarefaction curve and Jacknife 1st order estimator for Tree savannah

## 4.2. Relative abundance and occupancy

Camera trapping rates were calculated in period from 26th of February to 6th June 2020, that means for whole study period. In Table 3 we can see trapping rates for whole area and each habitat. The highest trapping rate had been observed in white-tailed mongoose closely followed by side-stripped jackal. The genet spp. had very high trapping rate in Tree savannah. According to Kruskal-Wallis test there where no significant differences between camera trapping rates of small mammals in different habitats.

| Species | Whole area | Grass savannah | Shrub savannah | Tree savannah |
|---|---|---|---|---|
| African Civet | 0.94 | 1.02 | 0.62 | 1.54 |
| Caracal | 0.18 | 0.26 | 0.11 | 0.24 |
| Genet spp. | 1.71 | 0.26 | 1.41 | 3.66 |
| Egyptian Mongoose | 0.62 | 0.13 | 0.62 | 0.71 |
| Honey Badger | 0.38 | 0.51 | 0.23 | 0.59 |
| Serval | 0.24 | 0.9 | X | 0.12 |
| Side-striped Jackal | 2.5 | 2.43 | 2.21 | 3.19 |
| White-tailed Mongoose | 3.09 | 2.94 | 3.28 | 2.84 |
| African wildcat | 0.09 | 0.26 | 0.06 | X |

**Table 3:** Camera trapping rates for small carnivorans

As first, we used naïve occupancy to visually compare different areas (Figure 7). We can see that generally highest naïve occupancy had side-striped jackal and white-tailed mongoose. Jackal had the highest value for whole area as well as for Shrub savannah and together with white tailed mongoose had the highest values also for Grass savannah (50 % of cameras both). However, the highest value for Tree savannah had Genet spp. in Tree savannah. The lowest value of naïve occupancy had African wildcat and caracal. the Genet spp. Were captured on 83 % of cameras even though that in whole area it was captured just in 41 % of cameras.

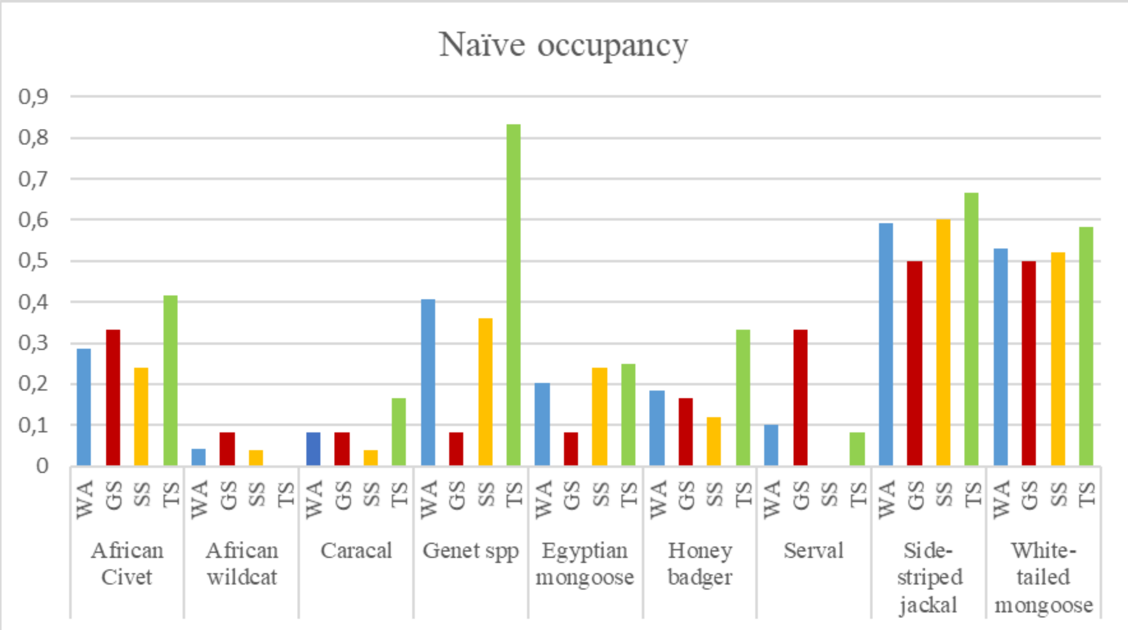


**Figure 7:** Naive occupancy for small carnivorans

For occupancy and detection probability modelling, 2 species were excluded, African wildcat and caracal. They were excluded because they did not meet the criteria set for occupancy modelling. Both, African wildcat and caracal had low number of detections (6 and 2 respectively) and low value of naïve occupancy (0,082 and 0,041 respectively)

For remining 7 species ΔAIC was calculated. In Table 4 we can see that for 3 species only one model had ΔAIC < 2, so the model could be selected right away. For African civet it is null model as well as for Egyptian mongoose and side-striped jackal. For other 4 species the Akaike weight had to be calculated. None of the Akaike weights reached very high values, indicating that no single model approached reality of sampling. According to Akaike weights null model was best model for honey badger and white-tailed mongoose. Model where only occupancy (ψ) was influenced by habitat was best for genet spp. and model where only detection probability (*p*) was influenced was best fit for serval.

| Species | | null model | ψ, *p* | ψ | *p* |
|---|---|---|---|---|---|
| African Civet | AIC | 175.24 | 181 | 177.27 | 178.43 |
| | ΔAIC | 0 | 5.76 | 2.03 | 3.19 |
| | ω | **0.617** | 0.035 | 0.224 | 0.125 |
| Genet spp. | AIC | 290.87 | 282.12 | 280.74 | 283.61 |
| | ΔAIC | 10.13 | 1.38 | 0 | 2.87 |
| | ω | 0.003 | 0.287 | **0.572** | 0.136 |
| Egyptian Mongoose | AIC | 136.56 | 142.1 | 139.2 | 140.54 |
| | ΔAIC | 0 | 5.54 | 2.64 | 3.98 |
| | ω | **0.682** | 0.043 | 0.182 | 0.093 |
| Honey Badger | AIC | 105.76 | 109.42 | 107.78 | 107.53 |
| | ΔAIC | 0 | 3.66 | 2.02 | 1.77 |
| | ω | **0.516** | 0.083 | 0.188 | 0.213 |
| Serval | AIC | 69.634 | 66.412 | 62.626 | 62.416 |
| | ΔAIC | 7.218 | 3.996 | 0.21 | 0 |
| | ω | 0.013 | 0.066 | 0.436 | **0.485** |
| Side-striped Jackal | AIC | 407.9 | 414.07 | 411.35 | 410.94 |
| | ΔAIC | 0 | 6.17 | 3.45 | 3.04 |
| | ω | **0.693** | 0.032 | 0.124 | 0.152 |
| White-tailed Mongoose | AIC | 396.21 | 401.4 | 400.04 | 397.88 |
| | ΔAIC | 0 | 5.19 | 3.83 | 1.67 |
| | ω | **0.603** | 0.045 | 0.089 | 0.262 |

**Table 4:** AIC values and Akaike weights calculated for each species and each model. Highlited values are Akaike weights of selected models for each species.

For most of the species the best fit model was null model, which assumes, that species occupancy estimates and detection probability estimates are constant across sites, no matter the habitat they were located in. As we can see in Table 5, the 5 species with null model as the best fit have quite high occupancy estimates ranging from 0.301 in Egyptian mongoose to 0.868 in honey badger. On the other way, detection probability estimates for these species is very low with maximum of 0.193.

| Species (average home range) | best model | habitat | ψ | SE | *p* | SE |
|---|---|---|---|---|---|---|
| Genet spp. (2 km) | ψ model | Grass savannah | 0.105 | 0.1 | 0.991 | 0.025 |
| | | Shrub savannah | 0.43 | 0.12 | 0.991 | 0.025 |
| | | Tree savannah | 0.928 | 0.072 | 0.991 | 0.025 |
| Serval (20 km) | *p* model | Grass savannah | 0.91 | 0.759 | 0.042 | 0.042 |
| | | Shrub savannah | 0.91 | 0.759 | 0 | 0 |
| | | Tree savannah | 0.91 | 0.759 | 0.007 | 0.007 |
| African civet (8 km) | null model | Whole area | 0.473 | 0.147 | 0.073 | 0.026 |
| Egyptian mongoose (3 km) | null model | Whole area | 0.301 | 0.104 | 0.089 | 0.034 |
| Honey badger (400 km) | null model | Whole area | 0.868 | 0.782 | 0.019 | 0.018 |
| Side-striped jackal (1 km) | null model | Whole area | 0.671 | 0.082 | 0.169 | 0.022 |
| White-tailed mongoose (3 km) | null model | Whole area | 0.582 | 0.08 | 0.193 | 0.024 |

**Table 5:** Occupancy and detection probability of best models for each species

The species with other model than null model as the best fit are serval and genet spp. The different estimates values for these 2 species are displayed in Figure 8. The species with occupancy model (genet spp.) correspond to naïve occupancy as the highest occupancy of genet spp. was estimated in Tree savannah and the lowest in Grass savannah.

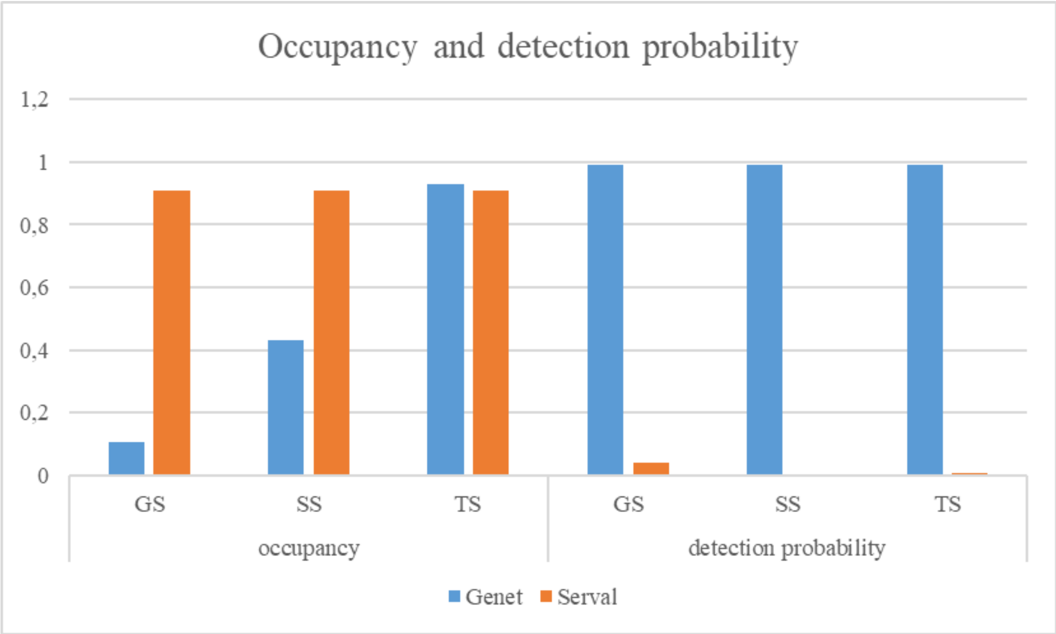


**Figure 8:** Occupancy and detection probability for genet spp. (ψ model) and serval (p model)

## 4.3. Activity patterns

The sunrise at the start of the study, means on 25th of February, was at 7:06 and sunset was at 19:01. Daylength at that time was almost 12 hours (11:54). At the end of the study, means on 6th of June, the sunrise was at 6:30, the sunset at 19:08 and the daylength was more than 12 and half hours (12:39). (Time and date 2020) as we can see on Figure 9, most of the species are nocturnal or crepuscular. The exceptions are caracal and serval, but they have low number of observations as well as African wildcat.

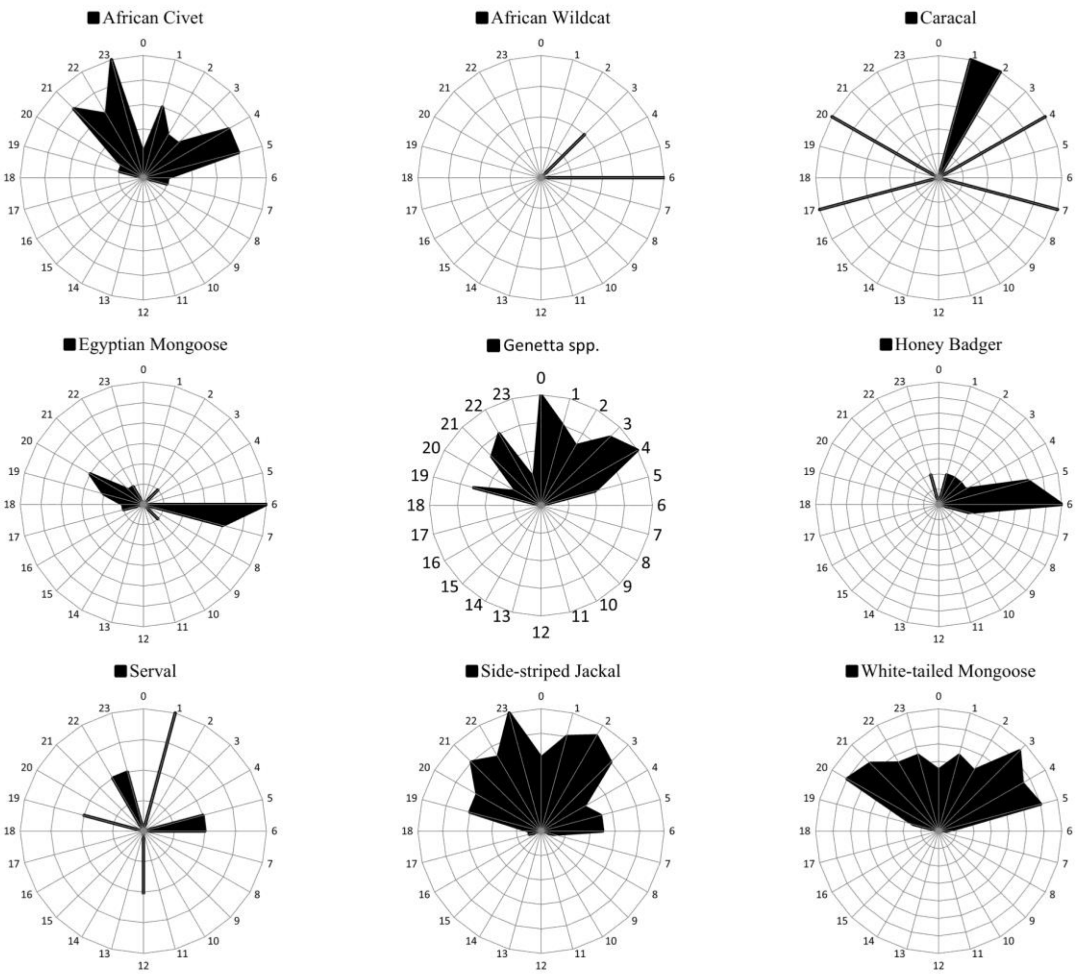


**Figure 9:** Activity patterns for small carnivorans

As we can see in Table 7, the low number of observation events in African wildcat, caracal and serval resulted in nonsignificant result in Rayleigh Test and null results in case of African wildcat or nonsignificant results for caracal and serval in case of Rao's Spacing Test. Otherwise we can see that most species have significant results, with exception of Egyptian mongoose in case of Rayleigh Test. As we know, this test fails to detect multimodal departures from uniformity. As we can see, the Rao's Spacing Test for Egyptian mongoose is significant, hence we can say, that Egyptian mongoose have bimodal activity.

| Species | Mean Vector (μ) | Circular Standard Deviation (CSD) | Rayleigh Test (Z) | Rayleigh Test (p) | Rao's Spacing Test (U) | Rao's Spacing Test (p) |
|---|---|---|---|---|---|---|
| African civet | 0:54 | 3:25 | 14.357 | <0.01 | 213.75 | < 0.01 |
| African wildcat | 5:01 | 1:25 | 2.609 | **0.061** | x | x |
| Caracal | 1:12 | 5:07 | 0.989 | **0.389** | 105 | **0.90** |
| Egyptian mongoose | 3:49 | 6:49 | 0.86 | **0.428** | 201.429 | < 0.01 |
| Genet spp. | 0:34 | 3:07 | 29.738 | <0.01 | 291.724 | < 0.01 |
| Honey badger | 4:22 | 2:15 | 9.169 | <0.01 | 214.615 | < 0.01 |
| Serval | 0:52 | 5:01 | 1.418 | **0.249** | 120 | **0.90** |
| Side-striped jackal | 0:07 | 3:29 | 36.782 | <0.01 | 296.471 | < 0.01 |
| White-tailed mongoose | 0:31 | 3:18 | 49.54 | <0.01 | 318.857 | < 0.01 |

x=result could not be calculated

**Table 6:** Tests of uniformity of activity patterns for small carnivorans

## 4.4. Comparison of large and small carnivorans

In study area only 4 species from 2 families of large carnivorans were detected. As we can see in Table 8, these species were critically endangered CR west african population of lion (*Panthera leo*), northwest african subspecies of cheetah (*Acinonyx jubatus hecki*) and leopard (Panthera pardus pardus) from family Felidae and spotted hyaena (*Crocuta crocuta*) from family Hyaenidae

| Family | Species | Latin name | IUCN status | Population status | Subspecies |
|---|---|---|---|---|---|
| Felidae | Cheetah | *Acinonyx jubatus* | VU | decreasing | *Acinonyx jubatus hecki* |
| | Leopard | *Panthera pardus* | VU | decreasing | *Panthera pardus pardus* |
| | Lion | *Panthera leo* | CR | decreasing | West Africa population |
| Hyaenidae | Spotted hyaena | *Crocuta crocuta* | LC | decreasing | x |

**Table 7:** List of large carnivorans in captured in study area

### 4.4.1. Species richness and diversity

On Figure 10 we can see, that species of large carnivorans were detected throughout the first half of the study. This also support rarefaction curve, which has very slow ascend and reaches the value of 4 species in the second half of the study. The Jacknife estimate is twice reaching value of 6 species but descends after 2 month to value of 5 species.

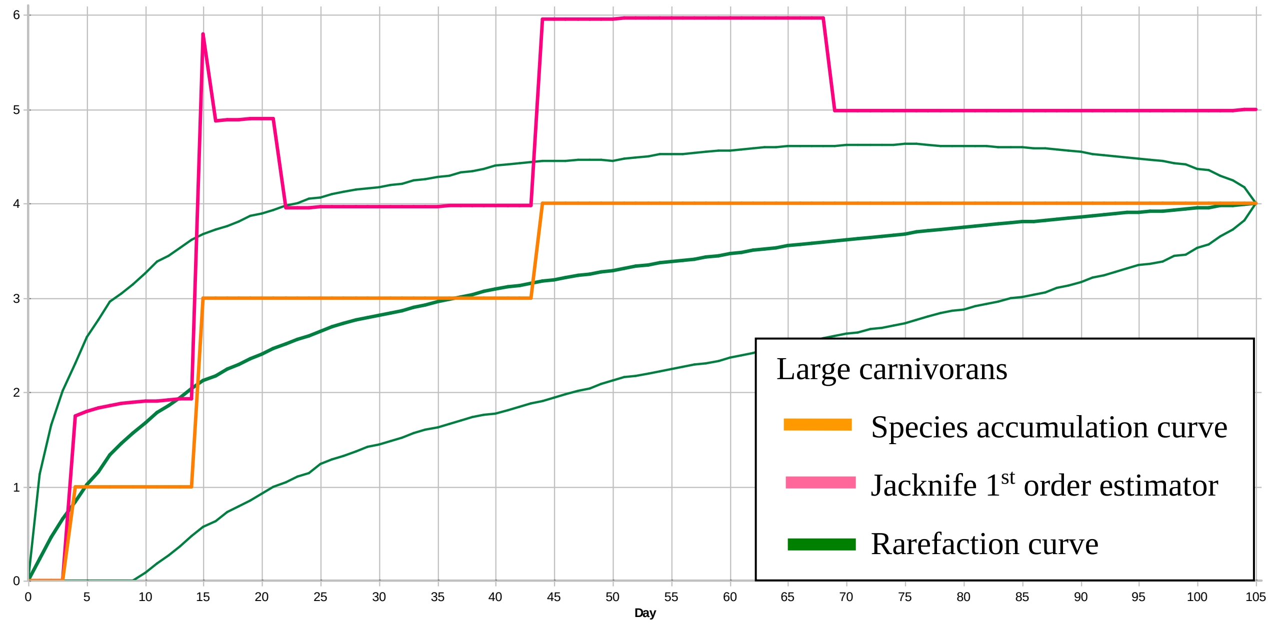


**Figure 10:** Accumulation curve, rarefaction curve and Jacknife 1st order estimator for large carnivorans

If we compare species richness and diversity of large and small carnivorans in Table 9, we can see, that there is fewer species of large carnivorans and more than twice as much species of small carnivorans. Also, there are comparably fewer species of large carnivorans, to the small ones.

The Jacknife estimate suggest, that there should be other species of large carnivoran, that was not detected. The Shannon diversity index is quite low, but with evenness of almost 75 % and the effective number of species of large carnivorans is almost 3.

| Small carnivorans | | Large carnivorans | |
|---|---|---|---|
| African civet | 30 | Cheetah | 3 |
| African wildcat | 3 | Leopard | 1 |
| Caracal | 2 | Lion | 8 |
| Egyptian mongoose | 21 | Spotted hyaena | 16 |
| Genett spp. | 56 | | |
| Honey badger | 13 | | |
| Serval | 8 | | |
| Side-striped jackal | 83 | | |
| White-tailed mongoose | 99 | | |
| Number of individuals | 315 | | 28 |
| Number of species | 9 | | 4 |
| Jackknife 1st Order | 9 | | 4.99 |
| Shannon Diversity Index (H) | 1.728 | | 1.036 |
| Pielou's evenness (J) | 0.786 | | 0.747 |
| Effective number of species | 5.63 | | 2.82 |

**Table 8:** Diversity of large and small carnivorans

### 4.4.2. Relative abundance and occupancy

Camera trapping rate of large carnivorans was low. The lowest value of camera trapping rate 0.03 had leopard with just 1 capture. Cheetah had also very low value, just 0.09. Lions had already a bit higher rate 0.24 and spotted hyaena had the highest capture rate of large carnivorans 0.47.

As we can see in Table 10, in comparison to small mammals the naïve occupancy for large carnivorans was also quite low. The naïve occupancy had similar trend as camera trapping rate. Leopard, that was detected just on 1 camera have naïve occupancy 0. The highest value had spotted hyaena which was captured on 20 % of cameras.

| Species | Naïve occupancy |
|---|---|
| Cheetah | 0.041 |
| Leopard | 0 |
| Lion | 0.143 |
| Spotted hyaena | 0.204 |

**Table 9:** Naive occupancy for large carnivorans

Occupancy and detection probability for large carnivorans was calculated only for lion and spotted hyaena. The other 2 species, leopard and cheetah, did not meet criteria of naïve occupancy 0.1 and more and number of detections 10 or more. The occupancy estimate for lion is 0.586 and detection probability 0.023. The estimates for spotted hyaena are $\psi$ = 0.35 and $p$ = 0.073. This does not correspond to naïve occupancy as lion had lower naïve occupancy than spotted hyaena.

### 4.4.3. Activity patterns

As we already know the sunrise during time of the study was 7:06 – 6:30, the sunset 19:01 – 19:08 and daylength around 12 hours. The large carnivorans in this study had very low number of observation events. The exceptions being spotted hyaena with 16 events and lion with 8 events. Spotted hyaena was active mostly at night or around sunrise, while lion was active throughout all day.

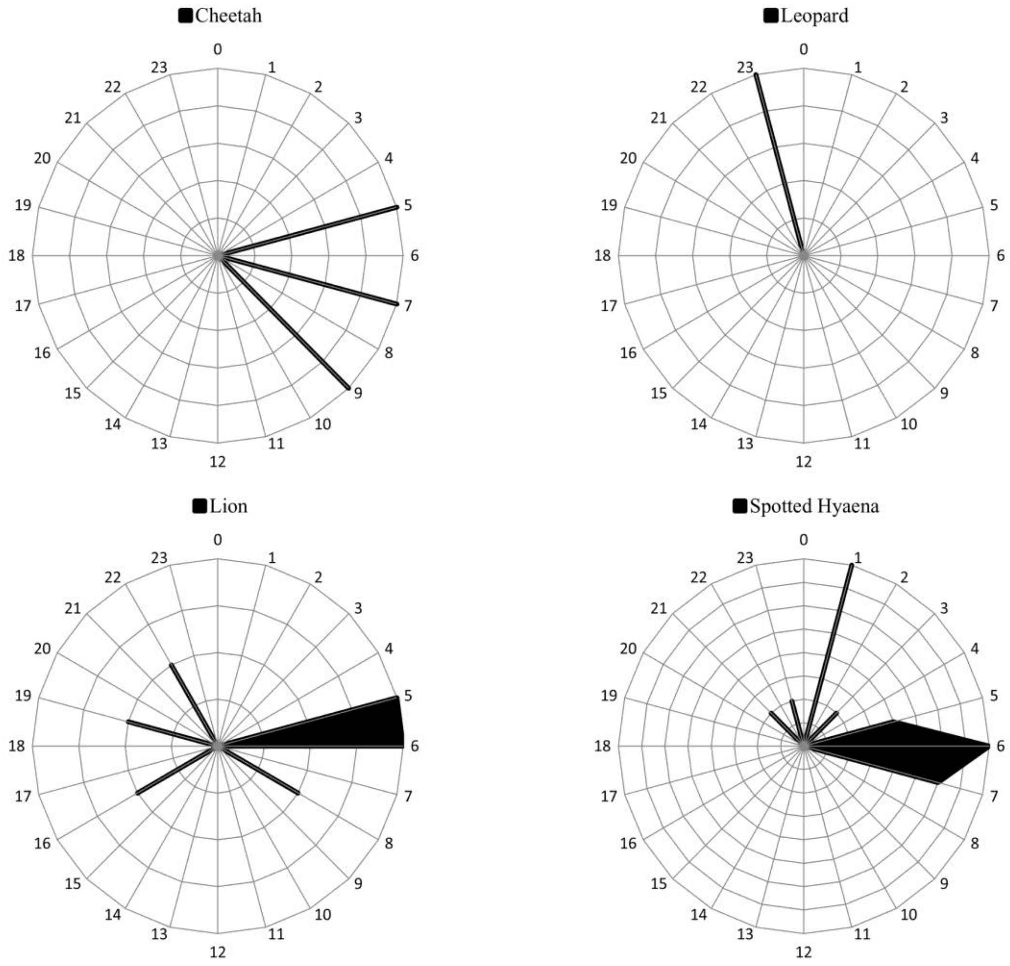


**Figure 11:** Activity patterns of large carnivorans

The uniformity tests (Table 11) support what we can see on the histograms (Figure 11). Low number of events for cheetah and leopard resulted in null results in Rao's Spacing Test and nonsignificant results in Rayleigh Test. Lion has nonsignificant results in both tests, confirming that it has uniform distribution throughout all day. Spotted hyaena has significant results in both tests.

| Species | Mean Vector (μ) | Circular Standard Deviation (CSD) | Rayleigh Test (Z) | Rayleigh Test (p) | Rao's Spacing Test (U) | Rao's Spacing Test (p) |
|---|---|---|---|---|---|---|
| Cheetah | 7:00 | 1:39 | 2.488 | **0.072** | x | x |
| Leopard | 23:00 | x | 1 | **0.512** | x | x |
| Lion | 5:01 | 5:46 | 0.812 | **0.458** | 135 | **0.50** |
| Spotted hyaena | 3:52 | 3:10 | 8.006 | <0.01 | 217.5 | <0.01 |

x=result could not be calculated

**Table 10:** Uniformity tests for activity patterns of large carnivorans

# 5. Discussion

In this study 9 species of small carnivorans were found in the study area. Sogbohossou & Aglissi (2017) found similar results when comparing Pendjari NP and its hunting zones. However, they found golden jackal (*Canis aureus*) (which was recently found out to be 2 species and golden jackals of Africa were renamed on African wolf (*Canis lupaster*)) and did not detect side-striped jackal. Also Djagoun et al. (2009) found that common slender mongoose (*Herpestes sanguineus*) was common in the area. According to them, there is possibility, that zorilla (*Ictonyx striatus*) also occurs in the area. However in 2009 it was not seen by locals for more than 10 years and Sogbohossou & Aglissi (2017) also did not find this species. From this we can say, that zorilla probably does not occur in study area anymore as well as African wolf as most of the evidence shows, that its range is more on north. From this we can say that we failed to detect at least 1 species of small carnivorans, the common slender mongoose.

Common slender mongoose is small species of mongoose with 500 to 1250 g. As camera traps in this study were placed 80 to 90 cm above ground, it is possible that the camera traps were not able to detect this species. The same reason goes also for zorilla, if it occurs in the area, even though it is a bit bigger than common slender mongoose.

Other species were also reported in the area in the past such as marsh mongoose (*Atilax paludinosus*), African clawless otter (*Aonyx capensis*), spotted-necked otter (*Hydrictis maculicollis*) or African palm civet (*Nandinia binotata*). However, these species are more dependent on aquatic environment or in case of African palm civet on more wooded habitats.

Results show that majority of small mammals in study area had quite uniform distribution between habitats. Out of 9 species, 7 were found in all of them. However, the 2 species not detected in all habitats (African wild cat and serval) had very low camera trapping rate, suggesting that that it could be caused by their low density. For both species together with caracal is open savannah typical habitat. However, it is also typical for them to have very diverse home range sizes. Home range of caracal can be from 5.5 to 220 $km^2$ large, for African wildcat 1.6 to 52 $km^2$ and for serval 9.5 to over 30 $km^2$. (ASCaRIs 2022) So the low camera trapping rate can be caused by low density of these species. Also, serval can be found in variety of habitats usually associated with well-watered environment. (IUCN) Even though habitats in this study are not much associated with water, detection probability of this species was influenced by habitat.

The most common species across all habitats is white-tailed mongoose closely followed by side-stripped jackal. According to IUCN side-striped jackal tends to avoid very open savannah. Number of captures of this species were indeed lowest in Grass savannah, however results for occupancy show, that habitat does not play very big role in occupancy of this species. White-tailed mongoose has similar tendencies – she is most common in more woody areas. (Admasu et al. 2004) Camera trapping rates of this species were highest in Shrub savannah; however our results did not find significant differences in occurrence of this species between habitats.

Other very common species in this study are genet spp. which were captured mostly in Tree savannah. 2 species of genets were identified in this study. Common genet prefers wooded habitats. Large-spotted genet occur in variety of habitats from rainforest to grassy savannah. However, it is not only terrestrial but also arboreal species, which seeks shelter in trees or other elevated areas. (Roux et al. 2016) Also results of this study show, that habitat played role in occupancy estimates of genet spp. and its preferred habitat is Tree savannah.

African civet and Egyptian mongoose both live in wide variety of habitats. Egyptian mongoose seeks habitats with understorey vegetation and termitaries. (IUCN) For both of this species habitat did not play a role in estimation of their occupancy or detection probability.

Even though honey badger has big geographic range, it has low densities, as it is solitary and have home ranges up to 500 km. (ASCaRIs) It can live in wide variety of home ranges and distribution of this species was not influenced by habitat in this study.

Most of the species detected were nocturnal with exception of Egyptian mongoose and honey badger, which were crepuscular. However, Monterroso et al. (2014) found, that Egyptian mongoose is strictly diurnal in Southwestern Europe. Allen et al. (2018) found out that honey badgers exhibited seasonal variation in activity patterns. They were active at all times with peak in crepuscular hours in wet season and in dry season they were active mostly at night. This study occurred in dry season and honey badger showed strictly crepuscular activity.

There were found 4 large carnivorans in this study. According to literature, we were able to detect all species occurring in study area. Some authors (Aristide 2008) indicate, that also African wild dog (*Lycaon pictus*) could be present in Pendjari NP, however if so it is definitely declining. There are no recent records about African wild dogs in Pendjari, so it was assumed, that they are not present in study area, thus we were able to record all present species of large carnivorans.

Large carnivorans have big territories that can go from tens to hundreds of $km^2$ and leopards and cheetah are mostly solitary, thus lowering the probability of capturing them. Lion pride territory can vary from 20 to 700 $km^2$ with West African lion subpopulation probably having larger home ranges than lions in South and East Africa. (Sogbohossou 2011) Spotted hyaenas live in fission – fusion clans and their density can be around 8 hyaenas on 100 $km^2$. (Stratford et al. 2020) Results of this study suggest, that densities of leopard and cheetah in area are low. Also, the study area probably overlapped with home range of 1 lion pride and hyaena clan.

For occupancy analysis sampling units should be arranged so they would be spatially independent. Rule of thumb is used to estimate distance between cameras, using 1 home range size of target species as wanted distance. (Sollmann 2018) As multispecies study, the distance that should be for this analysis between cameras is not very clear, but half of the species is recorded to have mean home range sizes up to 3 $km^2$ so spacing between cameras was appropriate. However, Rovero et al. (2010) suggested, that distance between cameras for small carnivorans survey should be up to 2 km. Also, Cameras should not be so high, but design of this study was focused on antelopes, thus having cameras 80 to 90 cm above ground. Number of cameras and duration seems to be also appropriate according to Kays et al. (2020) who suggested that there should be at least 35 camera traps for studies with spacing between cameras >1 km and duration of study should be at least 3 weeks. For precise estimates more cameras and at least 1 month are needed.

This study was first study focused on small carnivorans in the area after change of management. There was only one other camera trap study focused on small carnivorans. (Sogbohossou & Aglissi 2017) However this study goes deeper into the topic and the results are more complex than the ones of the previous study. Small carnivorans are generally understudied and especially in this area. However, with changing environment and decreasing populations of large carnivorans, studies on small carnivorans have great potential. The importance of studies focused on small carnivorans, and their ecological role will continue to grow in near future.

# 6. Conclusions

Findings of this study provided information about 9 species of small carnivorans living within Pendjari National Park. All these species are not endangered and are common in the area.

This study is pioneering work in comparing habitats of Pendjari NP. Savannah is dominating habitat of this area and the subclasses Grass, Shrub and Tree savannah are quite interconnected, so it was expected, that diversity of species between these habitats will be similar. The statistical analysis confirmed that there was no significant difference between communities of small carnivorans of different habitats. Majority of species was found in all habitats with some exceptions, like serval and African wild cat. In comparison, Grass savannah was the most diverse habitat and Shrub savannah the least diverse.

Every species was tested, what occupancy model fit the best. For most of the species null model was chosen, so habitat did not influence the occupancy for these species. The exception is genet spp. where model suggests that habitat influenced its occupancy. The other exception is serval where model suggests that habitat influenced its detection probability. It seems that all assumptions of occupancy model were met.

The small mammals of Pendjari NP had nocturnal or crepuscular activity. Also, from resalts of Rao's Spacing Test we can say, that Egyptian mongoose have bimodal activity.

Because of bigger sizes of home ranges, species richness and density of large carnivorans is lower than of smaller carnivorans. We were able to detect 4 species previously detected in Pendjari NP. 3 of these species are considered threatened by IUCN Red list. The Jacknife estimator results suggest, that there could be other not detected species. This might be correct, as African wild dog was reported several times in recent years in area of W and Pendjari NP. This species was considered extinct in this area until year 2000.

These species had very low capture rates and occupancy estimates, with exception of spotted hyaena, as they have big home ranges. Study design was not very suitable for carnivorans.

Small carnivorans are generally understudied in West Africa as well as in Pendjari NP. None of the found species is considered threatened, but small carnivorans have big impact on environment in which they live. The group contains large number of species that are tolerant of significant human-induced changes in habitat, so as the environment is changing and populations of large carnivorans are decreasing, research about small carnivorans is more and more needed.

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# Appendices

## List of the Appendices:

# Appendix 1: List of species

| Family | Common name | Latin name | IUCN status | Population trend |
|---|---|---|---|---|
| **Carnivora** | | | | |
| Canidae | Side-striped Jackal | *Canis adustus* | LC | Stable |
| Felidae | Caracal | *Caracal caracal* | LC | Unknown |
| Felidae | African wildcat | *Felis silvestris lubica* | LC | Decreasing |
| Felidae | Serval | *Leptailurus serval* | LC | Stable |
| Felidae | Cheetah | *Acinonyx jubatus* | VU | Decreasing |
| Felidae | Leopard | *Panthera pardus* | VU | Decreasing |
| Felidae | Lion | *Panthera leo* | CR | Decreasing |
| Herpestidae | Egyptian Mongoose | *Herpestes ichneumon* | LC | Stable |
| Herpestidae | White-tailed Mongoose | *Ichneumia albicauda* | LC | Stable |
| Hyaenidae | Spotted hyaena | *Crocuta crocuta* | LC | Decreasing |
| Mustelidae | Honey Badger | *Mellivora capensis* | LC | Decreasing |
| Viverridae | African Civet | *Civettictis civetta* | LC | Unknown |
| Viverridae | Hausa Genet | *Genetta thierryi* | LC | Unknown |
| Viverridae | Rusty spotted genet | *Genetta maculata* | LC | Unknown |
| **Cetartiodactyla** | | | | |
| Bovidae | Topi | *Damaliscus lunatus* | LC | Decreasing |
| Bovidae | African buffalo | *Syncerus caffer* | NT | Decreasing |
| Bovidae | Bohor reedbuck | *Redunca redunca* | LC | Decreasing |
| Bovidae | Bushbuck | *Tragelaphus scriptus* | LC | Stable |
| Bovidae | Common duiker | *Sylvicapra grimmia* | LC | Decreasing |
| Bovidae | Hartebeest | *Alcelaphus buselaphus* | LC | Decreasing |
| Bovidae | Kob | *Kobus kob* | LC | Decreasing |
| Bovidae | Oribi | *Ourebia ourebi* | LC | Decreasing |
| Bovidae | Roan antelope | *Hippotragus equinus* | LC | Decreasing |
| Suidae | Common warthog | *Phacochoerus africanus* | LC | Decreasing |
| **Primates** | | | | |
| Cercopithecidae | Olive baboon | *Papio anubis* | LC | Stable |
| Cercopithecidae | Patas monkey | *Erythrocebus patas* | NT | Decreasing |
| Cercopithecidae | Tantalus monkey | *Chlorocebus tantalus* | LC | Stable |
| **Proboscidea** | | | | |
| Elephantidae | African Savanna elephant | *Loxodonta africana* | EN | Decreasing |
| **Rodentia** | | | | |
| Hystricidae | Crested porcupine | *Hystrix cristata* | LC | Unknown |
| **Tubulidentata** | | | | |
| Orycteropodidae | Aardwark | *Orycteropus afer* | LC | Unknown |