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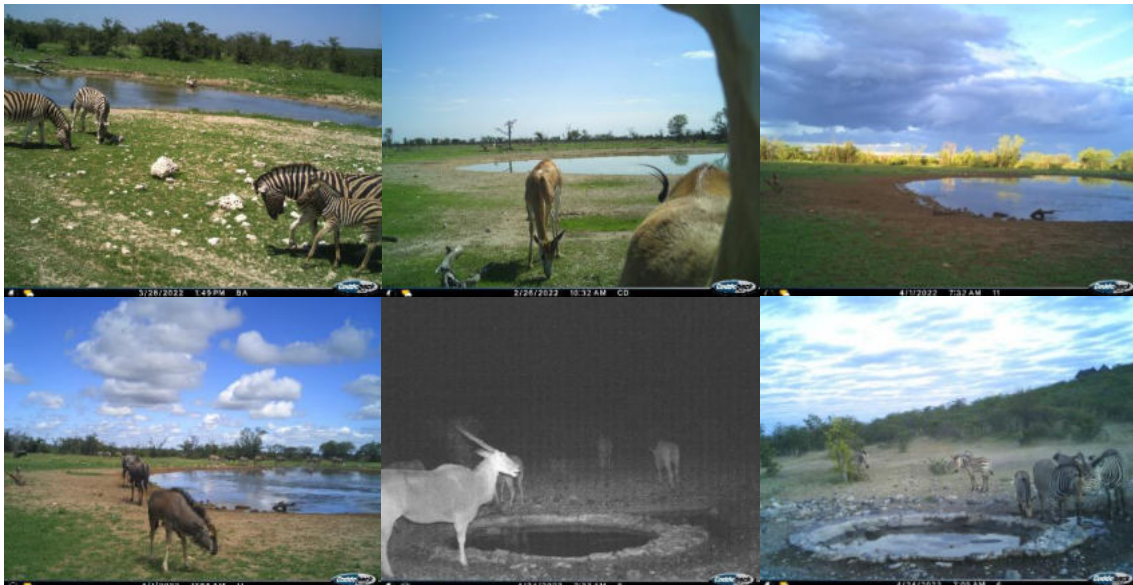
**Drinking activity patterns and interactions of mammalian herbivores and carnivores
at waterholes in Etosha Heights Private Reserve**

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Abstract

This study looked at the drinking activity patterns and interactions of mammalian herbivores and carnivores at six of the 23 active waterholes at Etosha Heights Private Reserve, Namibia. The study provided a better understanding of drinking patterns and behaviour, as well as the interactions between herbivores and their predators at waterholes. Camera traps and a 48 hour game count at one were used to collect data at the waterholes. The results should enable the management team of the reserve to get a better understanding on the drinking activities of both herbivores and carnivores at Etosha Heights and to see which herbivore species overlap with or avoid which carnivore species at the waterholes. The results showed at what time of day or night different species preferred drinking.

1. Introduction

Daily activity patterns are important to understand the behaviour of animals, that can be affected by feeding, drinking, temperature, humidity, predators, competitors, their biological cycle, and even the phases of the moon (Aschoff, 1964; Wakefield & Attum, 2006). In Africa, animals' water requirements and the availability of water especially in drier areas can greatly affect their daily activity patterns. Effective management of wildlife will depend on knowledge of such patterns, for example for some herbivores, drinking is a risky activity, as large predators often target waterholes (Crosmary et al., 2012). In addition to traditional observation of wildlife such as from hides at waterholes, camera trapping is now used more and more by ecologists to remotely watch animals, particularly mammals and to determine their abundance, distribution, and density, as well as to observe species interactions. Camera traps can provide a way to better understand previously challenging patterns of terrestrial mammals' ecology. This project focused on assessing daily activities of different animal species at the waterholes, in one of the larger private game reserves in Namibia, Etosha Heights Private Reserve. It is hoped that the findings will contribute to our knowledge about ways to effectively manage wildlife in Etosha Heights Private Reserve.

1.1 Study Area

As shown in Figure 1, Etosha Heights Private Reserve (EHPR), is one of the largest private reserves in Namibia, located on the south-western border of the Etosha National Park, covering an area of 60 000 ha. The vegetation types include mopane woodlands, riverine woodlands, savannah plains, grasslands, scattered salt pans and dolomite hills that provide habitats to a large variety of mammal species such as greater kudu (*Tragelaphus strepsiceros*), lions (*Panthera leo*) and Hartmann's mountain zebra (*Equus zebra hartmannae*). It is 450 km from Windhoek, and 150km from Outjo. EHPR can be considered a "buffer-zone" between the Etosha National Park and the main farming and tourism communities south of the park. (Jokisch, 2009; Nortjé, 2019).

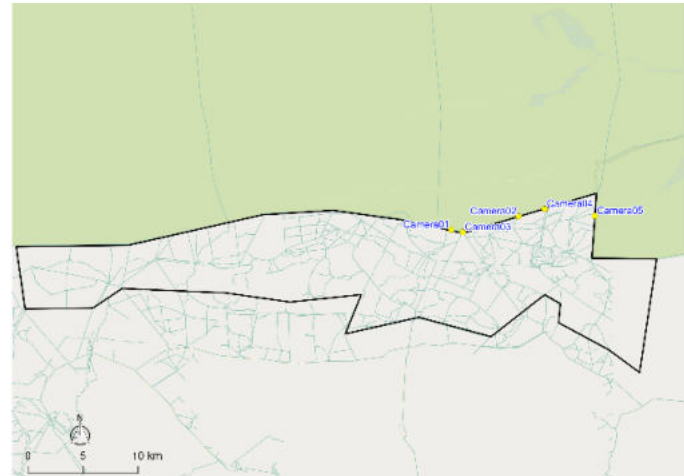


Figure 1 Map of Namibia to show location of Etosha Heights Private Reserve to show location relative to the Etosha National Park.

Source: Gerhard Nortjé and Jackson Hamutenya (MSc)

Etosha Heights Private Reserve is within the semi-arid part of Namibia and so it is extremely hot and dry, with a large temperature variation between day and night (Nortjé 2019). Although, as shown in Figure 2, there are 55 man-made waterholes scattered throughout the reserve to provide the game with water, only 23 waterholes are currently working.



Figure 2 All 55 the original man-made waterholes of Etosha Heights Private Reserve **Source:** Jackson Hamutenya (MSc)

1.2 Study Animals and their drinking behaviours

This study focused on the medium and large mammal species that rely on the waterholes in the EHPR. Species that have been noted at the waterholes, are African elephant (*Loxodonta africana*), Blue wildebeest (*Connochaetes taurinus*), Plains zebra (*Equus quagga*), Red hartebeest (*Alcephalus buselaphus caama*), Black rhino (*Diceros bicornis*), Hartmann's mountain zebra (*Equus zebra hartmannae*), Common eland (*Taurotragus oryx*), Greater kudu (*Tragelaphus strepsiceros*), Black-faced impala (*Aepyceros melampus petersi*), Black-backed jackal (*Canis mesomelas*), Spotted hyaena (*Crocuta crocuta*), Springbok (*Antidorcas marsupialis*), Brown hyaena (*Hyaena brunnea*), Gemsbok (*Oryx gazella*), Angolan giraffe (*Giraffa giraffa angolensis*), Lion (*Panthera leo*) and Cheetah (*Acinonyx jubatus*).

1.2.1 Black-backed jackal (*Canis mesomelas*)

Black-backed jackal are either solitary, live in small family groups, or in pairs that stay together for life. They prey on antelopes, and livestock and have been seen catching fish in drying pools, and drink water whenever they can but can go without prey if they eat fruits according to Apps (2000). When there are other animals at the waterhole, jackals are cautious. According to du Preez and Grobler (1977) they are most active in the mornings and evenings to avoid the heat, sleeping in burrows or in the shade, and their first activity on waking is to drink.

1.2.2 Spotted hyaena (*Crocuta crocuta*)

Spotted hyaena are social animals that lives in large clans with a dominant female, her daughters and some resident males. Immigrant males may join after a month of trying and but have to remain subordinate. The spotted hyaena are good scavengers that find carcasses by scent, the noise of other predators, and by watching vultures, and can displace most predators, even lions if they outnumbered them (Apps, 2000). According to du Preez and Grobler (1977) they are most active at dusk after eating they like to drink, immediately leaving the waterhole when done.

1.2.3 Brown hyaena (*Hyaena brunnea*)

Brown hyaena are usually solitary, although they, live in groups of two to ten that share a burrow or cave. They can smell carrion from a kilometre away, and they listen for sounds of other predators and scavengers at carcasses. Brown hyaenas do not need to drink as they get all their moisture from prey and wild melons according to Apps (2000). They are most active at dusk and drink after feeding and then immediately leave the waterhole as noted by du Preez and Grobler (1977).

1.2.4 Cheetah (*Acinonyx jubatus*)

Adult female cheetahs are usually solitary, unless they have cubs up to a year old. Males live in small stable groups. They are skilled hunters that stalk their prey and chase them at speeds of 100 to 120 km/h for up to 500 to 600 meters, before giving up according to Apps (2000)

1.2.5 Lion (*Panthera leo*)

Lions live in prides, either in groups 4 to 12 related lionesses and their cubs, or as 1 to 6 closely related males. Lionesses form the core of their prides. Lions often lie in wait near waterholes, as noted around Etosha Pan (du Preez & Grobler, 1977). According to Apps (2000) lions can find kills by smell, sound, or watching vultures, and displace any carnivores easily except if they are outnumbered. They sleep most of the day and become active around dusk, when they take a drink. If there are rhinos or elephants at the waterhole they are not afraid but are often chased away by these larger mammals. Lions often spend a long time near the water according to du Preez and Grobler (1977).

1.2.6 African Elephant (*Loxodonta africana*)

African elephants live in herds of closely related adult females and their young. Males only join when a female is in heat, otherwise young males form bachelor herds. Elephants are omnivorous bulk feeders, eating a variety of plants often damaging trees as they tear off branches. While grazing, elephants shake off soil from grass and roots. They have been seen picking up fruit and pods on the ground and even shaking trees to get more. They go to waterholes once a day to drink, bathe, and wallow, drinking from 70 to 90 litres to 150 litres a day. When their feeding areas and water sources are far apart, they visit waterholes less often (Apps, 2000). Elephants can either approach waterholes with care or in protected areas by strolling quickly directly to the water. They are often aggressive to other species at waterholes and sometimes prefer to drink later to avoid larger mammals like White and Black Rhinos. According to du Preez and Grobler (1977), Elephants prefer to drink from cemented reservoirs rather than earth dams, and cement troughs in Etosha National Park.

1.2.7 Hartmann's mountain zebra (*Equus zebra hartmannae*)

A dominant stallion controls up to six females and their foals. Because they digest even coarse grasses, they are unselective grazers. As the quality of the grass changes, they wander between grazing areas. When the herd is threatened, they run together, with the mares with the youngest foals running ahead, the stallion follows behind, kicking and biting any predators. According to Apps (2000), when Hartmann's mountain zebra herds meet at waterholes, the stallions approach

up to a few meters, then stand erect, drop their heads and continue to approach slowly until they sniff each other's genitals and rub their heads against the partner's rump (Apps, 2000).

1.2.8 Plains Zebra (*Equus quagga*)

Plains zebra live in herds of 1 – 12 female + their young and a stallion. Young stallions form bachelor herds. As they also prefer short grasses, plains zebra are often seen grazing with blue wildebeest. Plains zebras are always alert for predators and sound the alarm if one is seen. When attacked by predators, the mares and foals run ahead, followed by the other mares, with the stallion behind. They drink daily and live within 8 kilometres of water, often digging in dry riverbeds to find it (Apps, 2000). They approach a waterhole with great care, stopping every few seconds before going on once they feel comfortable. They sometimes walk into the water before drinking, standing close together. Plains zebra can become agitated to keep their drinking place at a waterhole. Plains zebra were observed to stand 1m apart at larger (du Preez & Grobler, 1977).

1.2.9 Black Rhinoceros (*Diceros bicornis*)

Black rhino are usually solitary, although the calf lives with its mother until it is two to four years old. Males may gather around a female in heat. Black rhinos are primarily browsers, but they will eat grass too. They use their dexterous top lip to nibble leaves, shoots, and twigs that are sliced off by the premolar teeth, pruning the bushes neatly. They eat thorns and twigs and swallow them whole, leaving half-digested bits in their dung, unlike White rhino (Apps, 2000). According to du Preez and Grobler (1977), Black Rhino in Etosha are aggressive toward smaller species at waterholes, and prefer to drink in the evening to avoid competition with larger mammals like elephants.

1.2.10 Angolan giraffe (*Giraffa giraffa angolensis*)

Angolan giraffe live in loose herds, although mature males are often solitary, only joining a herd when a female is in oestrous. They are browsers, able to reach leaves higher up than other herbivores can. Males often feed upwards to get to leaves 5 meters up, while females often bend down to feed on low bushes (Apps, 2000). They use their tongues and lips to nibble off leaves and avoid thorns and also eat bones for phosphate and calcium. They spend between 11 to 20 hours each day feeding. They splay their front legs and bend their knees to drink at waterholes, and need to constantly check to make sure there are no predators. According to Apps (2000) they can avoid blood pressure changes caused by bending their heads. They approach waterholes with care, first browsing nearby the water to check the area, then bend down to drink. They may leave without drinking if they are wary according to du Preez & Grobler (1977).

1.2.11 Common eland (*Taurotragus oryx*)

Common eland occurs in small herds that change with seasons. Breeding herds include all ages and both sexes. As calves get older they form mixed herds of juveniles and sub-adults. Cows and bulls separate in winter, but in spring, the females with calves and juveniles form nursery herds. Adult males later join them. Eland can remain in one area all year where food is available, otherwise they may follow the rains to find new grass. They are primarily browsers, but also graze. Eland can twist off branches with their horns to reach leaves. According to Apps (2000) Eland are capable of surviving without drinking, yet will drink together in large herds. They approach the water with care and leave as soon as they've finished drinking (du Preez & Grobler, 1977).

1.2.12 Greater kudu (*Tragelaphus strepsiceros*)

Greater kudu live in small herds of about 12 animals, but may congregate in large numbers at waterholes when it is dry. Males and females occur together in the mating season (May to August), but are mostly separate; females stay in herds with their young, while males live alone or in bachelor herds. Greater Kudu are solitary and spend nearly all of their time hiding in dense vegetation. They are anxious and quick to run when in the open. This has helped them to survive in bush encroached areas when other herbivores could not (Apps, 2000). They approach water very carefully and leave quickly after drinking, usually moving into nearby bushes to rest. According to du Preez & Grobler (1977) Greater kudu, Common eland and Red hartebeest may show aggression to each other at waterholes in Etosha.

1.2.13 Gemsbok (*Oryx gazella*)

Gemsbok live in small herds of about twenty or more especially if there is enough grazing. Males are territorial, but sometimes join mixed herds of adult females, their calves, and younger non-territorial males. Some males form bachelor herds while females and their calves form nursery herds. They prefer to graze, but if grass is scarce, they will browse. According to Apps (2000) they mostly graze at night when the water content is higher, they dig up roots and eat wild melons for the water. Thus a gemsbok can survive without drinking as it is able to concentrate its urine, and they allowing their body temperature to rise instead. They approach water without fear but usually stop a little distance away to check the area, unless there are other herbivores at the water and before drinking, Gemsbok often walk into the water to stand near each other. According to du Preez and Grobler (1977) gemsbok threaten with their horns to keep their drinking space and leave as soon as they are done with drinking.

1.2.14 Blue wildebeest (*Connochaetes taurinus*)

Blue wildebeest live in female herds, bachelor groups, or as lone territorial males. They need year-round access to water and short grass. They must drink water every day and are usually within 15 kilometres of water. When predators approach, they flee to the middle of the herd to

reduce their chances of being caught (Apps, 2000). Blue wildebeest prefer drinking in groups and approach water with care, by being very alert, especially when there are no other herbivores, they stop every few seconds to check before moving on. When there are other herbivores, they are more relaxed, grazing as they near the waterhole. De Preez and Grobler (1977) noted that when there are several other species at a waterhole, the wildebeest create a wedge to get to the water and then stand more sideways along the water's edge.

1.2.15 Red hartebeest (*Alcephalus buselaphus caama*)

Red hartebeest live in large herds of up to 30 animals which form much larger groups when feeding. A herd includes the females, foals, subordinate males, and the dominant bull. They like fresh grass and will even leave their area to find new growth after fire or rain. They form large aggregations to defend themselves from predators (Apps, 2000). They usually rest near the waterholes, when they feel comfortable. According to du Preez and Grobler (1977) solitary bulls move on as soon as they finish drinking and only relax if other species are present.

1.2.16 Black-faced impala (*Aepyceros melampus petersi*)

Black-faced impala form breeding herds of one or two adult males, adult females, and their young, or larger, year-round herds. Because they are grazers and browsers, they feed on whatever is available favouring *Acacia* pods and flowers. Black-faced impala give out a loud snort, to alert each other of danger once seen, they either move towards it or quickly retreat. When charged by a predator, they escape in all directions, into the bushes. They can leap up to 3 meters high covering 11 meters in one leap, confusing their predators (Apps, 2000).

1.2.17 Springbok (*Antidorcas marsupialis*)

Springbok live in mixed-herds of adults and young, bachelor groups or as single territorial males. Springboks are both browsers and grazers that eat whatever is available, including roots they dig up. Springbok will run in all directions when charged and can pronk 2m off the ground and covers 6m in a single leap to confuse their predators, which are mainly cheetah and leopard according to Apps (2000). They drink at waterholes in groups that approach the water slowly stopping every few seconds. Other herbivores at waterholes determine the caution they will use to approach the water. Springbok often wait to drink if other herbivorous are at the waterhole, which frequently making them wait hours according to du Preez and Grobler (1977).

1.3 Previous studies on animal behaviour at waterholes in Southern Africa

Over the past 50 years, many studies have been conducted on the behaviour, including drinking behaviour, and daily activity patterns of African mammals. Fifty years ago, an important study was conducted in Zimbabwe by Weir and Davison (1960) in what was then called the Wankie National Park, (now the Hwange National Park), on the daily occurrence and activities of game

species at waterholes during the dry season. They recorded over 11 000 animals during 27, 24-hour, observations over three years, (1958, 1959 and 1960) (Weir & Davison, 1960).

More recent research, in the same park in Zimbabwe by Crosmar, et al. (2012) focused on the drinking challenges faced by African ungulates, especially risks from hunters and predators that could prevent them drinking at waterholes. They found that some species avoid the waterholes at night to avoid being shot or preyed on, especially prey species adjusted their behaviour to avoid hunters and predators (Crosmar, et al., 2012).

In the same year, Cozzi, et al (2012) published on the nocturnal activity patterns of, and temporal partitioning by, 25 individual cheetah, wild dogs, lion and spotted hyena, fitted with radio collars that continuously recorded their activity in the Okavango Delta in Botswana. Their results revealed unexpectedly high time overlaps among the four species and showed how optimal hunting conditions shaped their daily activity patterns, especially of subdominant, large predators that were “starvation driven” and so made use of every opportunity to get food (Cozzi, et al., 2012).

In South Africa, Hayward and Hayward (2012) investigated the timing of waterhole use in the Kruger National Park and Pilanesberg National Park using webcams to determine if drinking was random through the day and if there was a difference in animal coalitions using the waterholes, over 16 months during which time they made 1 546 observations of 30 different species. They used this data to create a relative ranking of water dependency comparing waterhole use with relative species abundance and found that both elephant (*Loxodonta africana*) and Common impala (*Aepyceros melampus*) were most often seen and that the majority of larger predators were nocturnal, while their prey was always diurnal. The index of relative water use showed that warthog (*Phacochoerus africanus*), blue wildebeest (*Connochaetes taurinus*) and hippopotamus (*Hippopotamus amphibius*) were found to be very water-dependent whereas Greater kudu (*Tragelaphus strepsiceros*), lion (*Panthera leo*) and spotted hyaena (*Crocuta crocuta*) were found to be more water-independent (Hayward & Hayward, 2012).

In Etosha National Park, some 33 000 observations of the drinking patterns and behaviour of game at waterholes were analysed and compared with similar studies conducted elsewhere in the mid-1970s (du Preez & Grobler, 1977), the findings revealed regional differences as well as peak drinking hours. When compared, the drinking times of common species found in both Etosha and Wankie (Zimbabwe) National parks, showed some fascinating discrepancies. More recently Kasiringua, et al (2017) conducted a study on the daily activity patterns of ungulates at waterholes during the dry season at Waterberg National Park, in Namibia. They observed the daily drinking activity of 12 herbivore species, which were Eland (*Tragelaphus oryx*), Buffalo (*Syncerus caffer*), Greater Kudu (*Tragelaphus strepsiceros*), Roan antelope (*Hippotragus equinus*), Sable antelope (*Hippotragus niger*), Common Warthog (*Phacochoerus africanus*), White rhino

(*Ceratotherium simum*), Black rhino (*Diceros bicornis*), Angolan Giraffe (*Giraffa giraffa angolensis*), Red hartebeest (*Alcephalus buselaphus*), Common duiker (*Sylvicapra grimmia*) and Gemsbok (*Oryx gazella*) at seven waterholes and one large carnivore, namely Leopard (*Panthera pardus*). Their results showed the busiest time for of drinking at the waterholes was between 18h00 and 19h00, when 15% of the animals were recorded drinking, however the majority of the species drank at night and were more active in the first half (18h00-00h00) than in the second half (00h00-06h00) of the night (Kasiringua, et al., 2017).

Another more recent study was conducted by Ndumbu (2020) on the waterhole use and behaviour of different wildlife species at three waterholes (Ganab, Gemsbok and Hotsas) near Ganab, in the Namib Naukluft National Park. She made use of camera traps at all three waterholes and conducted monthly direct observations for 24-hours, collecting data from 1 055 counts and observations for all three waterholes recording 14 species, namely Gemsbok (*Oryx gazelle*), Cheetah (*Acinonyx jubatus*), Angolan Giraffe (*Giraffa giraffe angolensis*), Mountain Zebra (*Equus zebra hartmannae*), Springbok (*Antidorcas marsupialis*), Common Warthog (*Phacochoerus aethiopicus*), Aardvark (*Orycteropus afer*), Porcupine (*Hystrix africae australis*), Black-backed Jackal (*Canis mesomelas*), Brown Hyaena (*Hyaena brunnea*), Meerkat (*Suricata suricatta*), Cape Hare (*Lepus capensis*), Aardwolf (*Proteles cristatus*) and Honey badger (*Ictonyx striatus*) (Ndumbu, 2020).

This brief literature review highlighted that various studies on daily activity patterns of wildlife had been conducted in Zimbabwe, South Africa and in Namibia over the last 50 years, showing that drinking activity can vary regionally and the presence of predators can influence when and even if mammals come to drink. This study at Etosha Heights offered an opportunity to look at and compare the drinking activity and interactions amongst and between 17 different species of herbivores and carnivores at waterholes in North-Central Namibia.

2. Aims and objectives

This project aimed to investigate the drinking activity patterns of mammalian herbivores and carnivores in an important conservation area, Etosha Heights and to understand the interaction between the herbivores and their predators, as well as to compare the results obtained from direct observations at one waterhole to those deduced from camera trap images at six waterholes in EHPR

2.1 Research questions

This research needs to answer the following:

1. What is the typical behaviour of mammals at waterholes in EHPR? E.g. how often does each species need to drink? How does each species approach the waterholes? How do

the herbivore species make sure no predators are waiting there for them? How do the carnivore species behave at the waterholes?

2. How do the different species interact with each other at the waterholes?
3. Are the results related to drinking behaviour and anti-predatory behaviour from direct observations any different from the results found when looking at camera trap images?

2.2 Objectives

To achieve the aim and answer the research questions, the following objectives need to be met:

1. To describe and if possible, quantify the drinking activity patterns of herbivores and carnivores at six waterholes in EHPR, particularly their preferred drinking times, approach to the water and any anti-predator behaviour
2. To investigate inter-species interactions particularly between the mammalian herbivores and their predators
3. To compare drinking and anti-predator activity patterns as well as mammal condition observed during a 48-hour waterhole direct observation with those deduced from the camera trap images.

3. Methods

3.1 The Study Sites

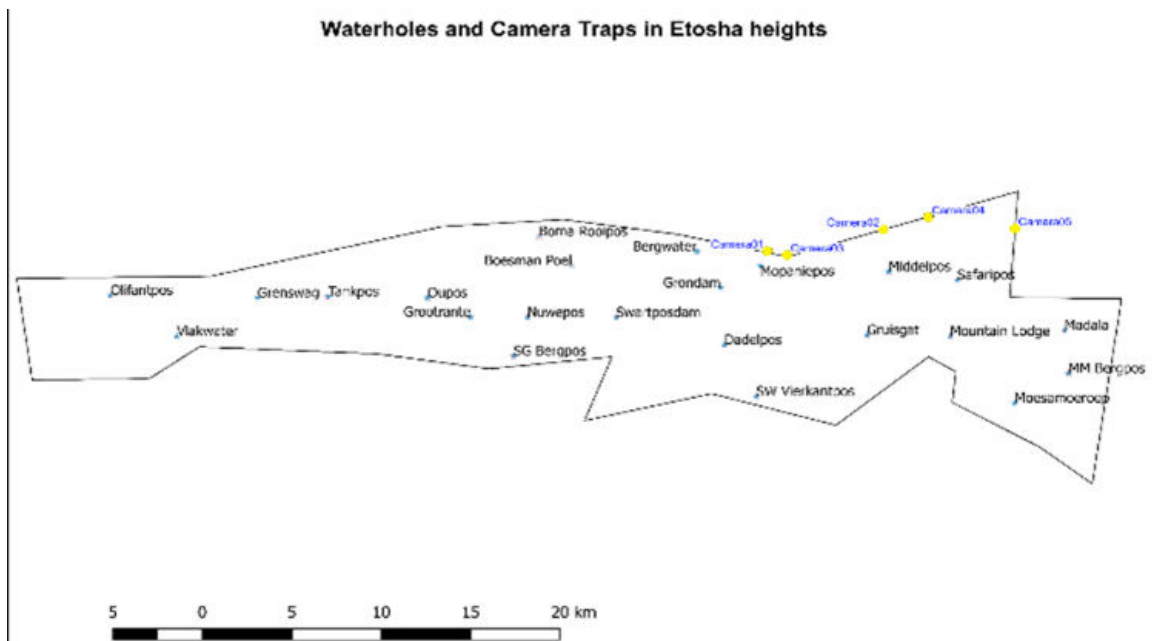


Figure 3 The 23 actively working waterholes of Etosha Heights **Source:** Jackson Hamutenya (MSc)

Figure 3 shows the locality of the 23 functioning man-made waterholes out of the original 55 in the Etosha Heights Private Reserve. Figure 4 shows the six waterholes that have been selected as the study sites for this research project in the north-western side of the reserve. These waterholes are: Witgat (S 19.21053 E 15.31600), Safaripos (S 19.23857 E 15.28556), Daddelpos (S 19.27479 E 15.16977), Middelpos (S 19.23379 E 15.25227), and both the Mountain Lodge upper (S 19.26629 E 15.28512) and lower (S 19.26898 E 15.28105) waterholes.



Figure 4 the six selected study sites for the research project **Source:** Jackson Hamutenya (MSc)

These six waterholes, five with camera traps served as the study sites and are located within different provisional vegetation types as shown in Figure 5: Middelpos, (mopane shrublands), Daddelpos, (*Terminalia* mountain shrubveld and *Enneapogon* grasslands), Witgat (*Enneapogon* grasslands), Safaripos (Mopane shrublands), Mountain Lodge Upper (*Terminalia* mountain shrubveld and Mopane riparian woodland) and Mountain Lodge Lower (*Enneapogon* grasslands).

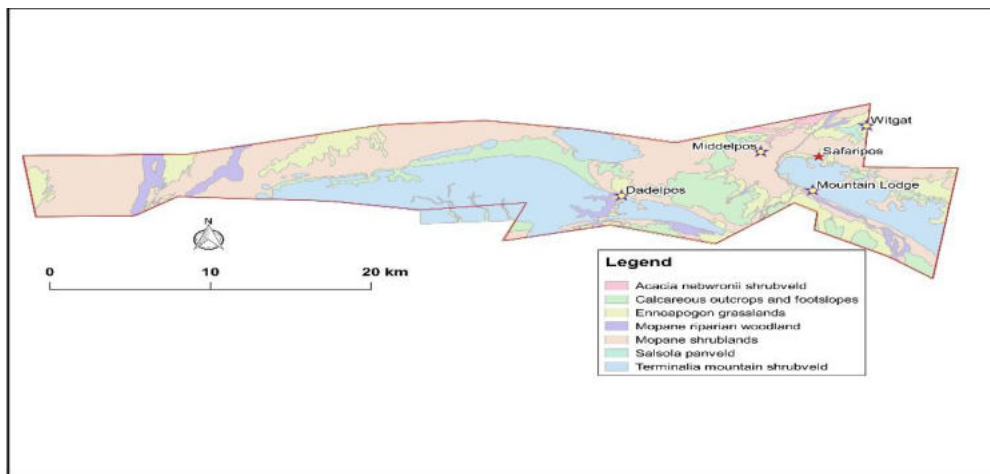


Figure 5 Provisional vegetation types where the study waterholes are found **Source:** Jackson Hamutenya (MSc)

The camera traps were set up on tree trunks at 5 of the 6 waterholes. Camera trap data was collected for analysis, using Digikam version 7.3.0 and the coded data was then typed into a Microsoft excel spreadsheet, and tables and graphs were made with the aid of pivot table. The SD cards that contained images from the camera traps were inserted into an Acer laptop for data analysis.

3.2 Direct 48-hour observation at Safaripos waterhole

Safaripos was where the 48 hour observation was conducted. There are artificial lights fixed at the waterhole that improved visibility. Each different mammal species or group of mammal animals that came to the waterhole were identified, recorded, timed, and counted. Whenever possible, each individual was also sexed and aged, and any identifying characteristics, tags or collars were noted to avoid double counts and their condition noted. Groups of the same species that came to drink together were identified by the size of the group, the number of young, sub-adults and adults and the sexes of the adults, which made it easier in identifying same groups that came to drink again.

3.3 Data analysis

3.3.1 Camera Trap Data analysis

Digikam version 7.3.0 was used to process the images from the camera traps. Image classification consists of tagging pictures according to different categories that fit the needs and goals of a particular study. The coded pictures were exported to Microsoft excel spreadsheet where tables and graphs was created with the aid of a pivot table.

The mammals recorded drinking were divided, depending on their drinking time preferences, into three main groups, 1. Diurnal drinkers, 2. Nocturnal drinkers (1 + 2 were further divided into two sub-groups each), and 3. Indiscriminate drinkers.

Group 1 – Diurnal (Daylight) drinkers (06:00 – 18:00)

- Sub-group 1 A Morning drinkers (06:01 – 12:00)
- Sub-group 1 B Afternoon drinkers (12:01 – 18:00)

Group 2 – Nocturnal drinkers (18.00 – 06.00)

- Sub-Group 2 A – Evening drinkers (18:01 – 00:00)
- Sub-Group 2 B – Pre-dawn drinkers (00:01 – 06:00)

Group 3 – Indiscriminate drinkers

The preferred drinking times within these 6-hour time intervals starting from 00:00 – 06:00, 06:00 – 12:00, and 12:00 – 18:00 to 18:00 – 00:00 is shown in a table that gave the total number of observed species at the waterholes during each time interval as was done by du Preez & Grobler (1977) in Etosha National Park. The cumulative data from the six waterholes was used to show the preferred drinking time for each species.

Other data attained from camera traps was presented as graphs to show daily drinking activities of each species. The data analysis for the 48-hour direct observations was analysed similarly.

The time when the herbivore and carnivore species came to drink was plotted to help assess the interaction between them. Interactions between herbivores and predators are described and presented in tables and graphs.

3.4 Materials

The main materials used for the research were:

4 × Cuddeback Digital Camera traps, 1 × UoVision Camera trap (Model: Glory LTE), Garmin eTrex 10 GPS and acer laptop

4. Results

During this study 17 mammal species were observed at the six waterholes and a total of 2 157 individual mammals were recorded. There were 5 carnivores and 12 herbivores that frequent the six waterholes as shown in Table 1. The table shows that the species seen most often at the six waterholes was the Plains Zebra, while only one cheetah was recorded at Safaripos waterhole during a 48-hour direct observation. The herbivores made up about 71% of animals recorded whilst the carnivores made up 29% of mammalian species observed at the waterholes.

Table 1: Mammal species observed at the six waterholes

Species	Total amount of individuals
Black-backed Jackal (<i>Canis mesomelas</i>)	12
Spotted Hyaena (<i>Crocuta crocuta</i>)	17
Brown Hyaena (<i>Hyaena brunnea</i>)	28
Cheetah (<i>Acinonyx jubatus</i>)	1
Lion (<i>Panthera leo</i>)	33
African Elephant (<i>Loxodonta africana</i>)	6
Hartmann's Mountain Zebra (<i>Equus zebra hartmannae</i>)	137
Plains Zebra (<i>Equus quagga</i>)	753
Black Rhino (<i>Diceros bicornis</i>)	46
Angolan Giraffe (<i>Giraffa giraffa angolensis</i>)	137
Common Eland (<i>Taurotragus oryx</i>)	40

Greater Kudu (<i>Tragelaphus strepsiceros</i>)	13
Gemsbok (<i>Oryx gazella</i>)	136
Blue Wildebeest (<i>Connochaetes taurinus</i>)	236
Red Hartebeest (<i>Alcephalus buselaphus caama</i>)	12
Black-faced Impala (<i>Aepyceros melampus petersi</i>)	52
Springbok (<i>Antidorcas marsupialis</i>)	498
Total	2157

Animals with excellent body condition that were recorded both from the camera trapping and 48-hour counts were the Black-backed Jackal, Black-faced Impala Cheetah, Common Eland, Lion and Springbok, while the rest were all in good condition. This was most likely due to good rains that provided good grazing and plenty of game for predators to eat. The condition scale ranges from 1 to 5 categories, 1 to 3 is for animals in poor to fair condition showing their ribcage and bony rump, weak posture and appearance, while 4 is for good condition meaning that the animal has a well-rounded rump and good posture, and 5 means the animal is in excellent condition. This data was collect through camera trap images and observations from February to the 2nd week of May when data collection came to an end. The condition of the animals seen at the waterholes was rated as seen in Table 2, the 17 species observed are quite healthy and in very good condition with majority of the species ranking in the 4th category.

Table 2: Condition category of the species

Species	Condition Category				
	1	2	3	4	5
Black-backed Jackal (<i>Canis mesomelas</i>)					X
Spotted Hyaena (<i>Crocuta crocuta</i>)				X	
Brown Hyaena (<i>Hyaena brunnea</i>)				X	
Cheetah (<i>Acinonyx jubatus</i>)					X
Lion (<i>Panthera leo</i>)					X
African Elephant (<i>Loxodonta africana</i>)				X	
Hartmann's Mountain Zebra (<i>Equus zebra hartmannae</i>)				X	
Plains Zebra (<i>Equus quagga</i>)				X	
Black Rhino (<i>Diceros bicornis</i>)				X	
Angolan Giraffe (<i>Giraffa giraffa angolensis</i>)				X	
Common Eland (<i>Taurotragus oryx</i>)					X
Greater Kudu (<i>Tragelaphus strepsiceros</i>)				X	
Gemsbok (<i>Oryx gazella</i>)				X	
Blue Wildebeest (<i>Connochaetes taurinus</i>)				X	
Red Hartebeest (<i>Alcephalus buselaphus caama</i>)				X	
Black-faced Impala (<i>Aepyceros melampus petersi</i>)					X

Springbok (<i>Antidorcas marsupialis</i>)						X
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4.1 Preferred drinking times of mammalian herbivores and carnivores

As shown in Table 3 and Figure 7, the preferred drinking times were recorded for each species and further divided into different drinking time periods. The numbers in this table and graph are the amount of times from February until May 2022 this species visited the waterholes within those time intervals. The behaviour in which this species approached the waterholes was also observed to get a better understanding as to why this animals prefer coming and drinking at waterholes mostly within those specific times in Etosha Heights Private Reserve. As seen in the table 3, the Brown Hyaena only come out to the waterholes in the evening and was not seen through the camera trap images and direct observations coming to the waterholes in morning and afternoon.

Most species were at the waterholes in the mornings and afternoons, probably to avoid predators and other more dominant herbivores that exert their dominance such as the Black rhino and African Elephant that mostly frequent the waterholes in the evening or pre-dawn. The Angolan giraffe are known for being indiscriminate drinkers that can be observed at all hours of the day at waterholes but as seen in the Table 3, they too have their preferable time that they frequent the waterholes in the reserve. The spotted hyaena was most observed during the evening and pre-dawn periods at the waterholes and was not observed in the even at any of the six waterholes. Prey species such as the Blue Wildebeest, Black-faced Impala, Gemsbok, Greater Kudu and Springbok most preferred coming in the afternoon to drink as most of their predators mostly came to the waterholes in the evenings and pre-dawn.

Table 3: Mammalian species in the reserve drinking time preference.

Species	00h01-06h00	06h01-12h00	12h01-18h00	18h01-00h00	Time Preference
Black-backed Jackal	7	2	-	2	Pre-dawn
Brown Hyaena	1		-	7	Evening
Spotted Hyaena	7	1	-	7	Evening/Pre-dawn
Cheetah	-	-	-	1	Evening
Lion	6	3	-	1	Pre-dawn
African Elephant	-	-	3	2	Afternoon + Evening
Hartmann's Mountain Zebra	16	6	2	24	Evening + Pre-dawn
Plains Zebra	26	48	35	30	Anytime but mostly morning
Black Rhino	11	2	-	24	Evening + Pre-dawn
Angolan Giraffe	4	6	22	11	Anytime but mostly afternoon
Common Eland	4	1	-	6	Pre-dawn + Evening
Greater Kudu	2	1	4	-	Pre-dawn + Afternoon

Gemsbok	12	17	18	16	Anytime of day
Blue Wildebeest	1	25	14	11	Mostly morning
Red Hartebeest	3	4	-	2	Pre-dawn + morning
Black-faced Impala	-	2	3	2	Mostly afternoon + Evening
Springbok	1	10	13	1	Mostly morning and afternoon
Total	101	128	114	146	

Diurnal drinkers are Springboks, afternoon and evening are African Elephants, nocturnal – Brown Hyaenas, pre-dawn to Afternoon are Greater Kudus, at night and early morning are Lions, Spotted Hyaenas, Black-backed Jackals. Common Elands, Black Rhinos, and Red Hartebeest (Although mostly in morning), true diurnal are Springboks and the only nocturnal are Brown Hyaenas. In total there were 489 individuals that were recorded drinking. 20.6% of individuals preferred drinking in the hours of pre-dawn (00h01-06h00), 26.2% preferred drinking in the morning (06h01-12h00), 23.3% preferred the afternoon (12h01-18h00) and 29.9% preferred the evenings (18h01-00h00). The percentages shows that majority of the animals preferred drinking in the evenings and least in pre-dawn.

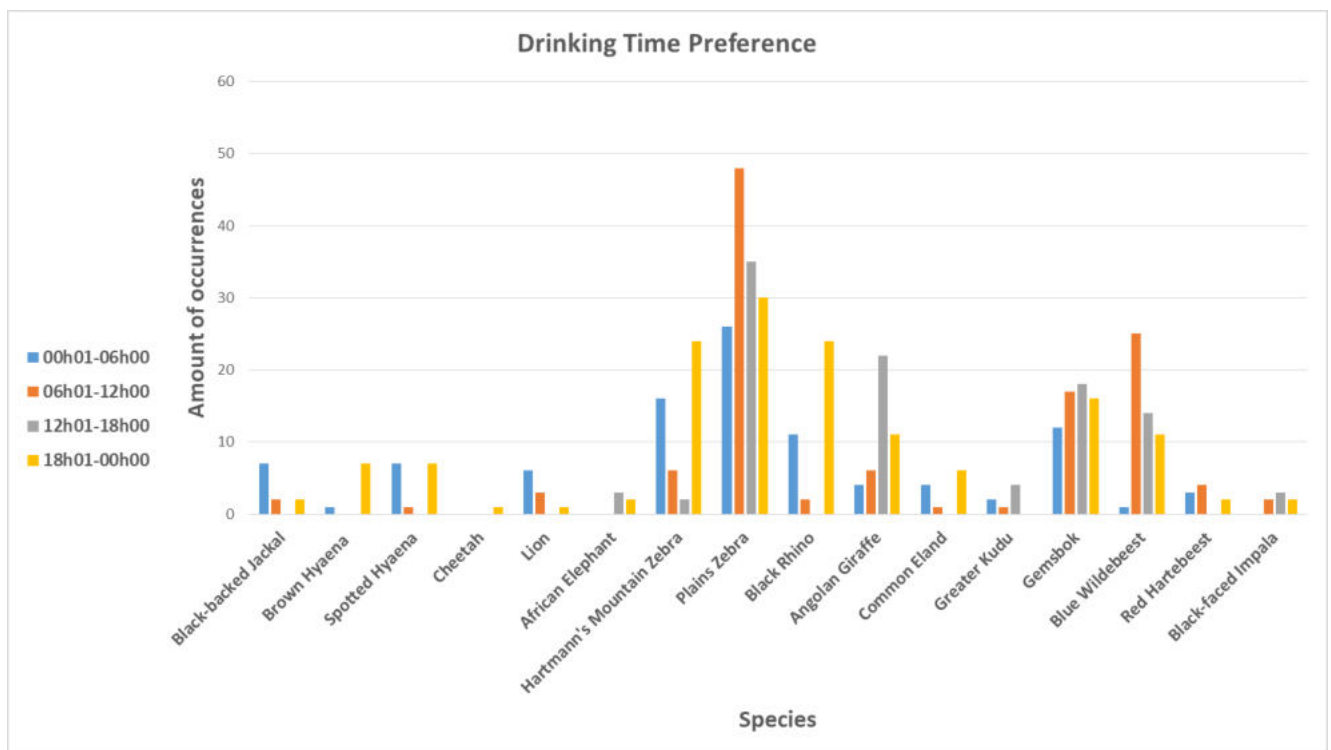


Figure 6: The species time preference that they can be spotted at the waterholes.

4.2 Behaviour observed at the six waterholes

Black-backed Jackal (*Canis mesomelas*) mostly came during pre-dawn hours and slowly approached the waterhole, stopping every few seconds and looked around for any signs of

danger before they came to the water and drank. They moved off as soon as they were done drinking back in the direction they came from.

Spotted Hyaena (*Crocuta crocuta*) were mostly observed as solitary, but on some occasion two were observed at the waterhole. They were very cautious when they approached the waterhole keeping a look out at any sudden danger, they will move off as soon as they were done drinking.

Brown Hyaena (*Hyaena brunnea*) mostly came and drank in the late evenings and moved off as soon as they are done drinking. They approached the waterholes with great caution.

Cheetah (*Acinonyx jubatus*) approached waterholes slowly, on high alert, paused at any sound, then waited a few moments before crouching down and drinking, leaving as soon as it finished.

Lion (*Panthera leo*) were mostly seen as prides at the waterholes and they showed no signs of cautiousness when they approached the water. They spent some time after drinking laying down, and cubs could be seen chasing each other and part taking in mock fights. And when lone lions approached the waterholes, they were observed to be cautious and moved off as soon as they were done drinking.

African Elephant (*Loxodonta africana*) were quite dominant species but can also be observed approaching the waterholes with great care, they tended to exert dominance on other species at waterhole. After drinking they would start browsing nearby the waterhole before they returned to the waterholes to bathe and soak in the water.

Hartmann's Mountain Zebra (*Equus zebra hartmannae*) with the dominant stallion leading, a herd, the herd approached the waterhole very alert, and did not drinking right away, but waited and looked around about before drinking, and then moved off after drinking. At Mountain Lodge Upper, the Hartmann's Mountain Zebra being the dominant species that frequent the waterhole was observed to spend hours at the waterholes and coming at all sorts of hours as the only carnivore recorded was the Spotted Hyaena.

Plains Zebra (*Equus quagga*) walked cautiously stopping every few seconds, grazed as they moved toward waterhole with the stallion leading the herd and looking out for danger. Stood for some time before drinking. When other herbivores were at the waterhole, they approached and drank just as quickly as they arrived at waterhole. Started to graze again after drinking. Mock fights between juveniles could also be observed and mating activities was also observed within some herds.

Black Rhino (*Diceros bicornis*) Aggressive behaviour towards smaller species was observed in Etosha Heights at the 3 of the 6 waterholes. The Black rhino approached the waterhole quickly, was aggressive towards other species (Common eland and Blue wildebeest), refused to allow other smaller species to drink, grazed on some *Datura ferox* (Large thorn apple), then after

drinking, scent marked by defecating and scraping it strongly with their back feet, disturbing the soil before moving off into the veld.

Angolan Giraffe (*Giraffa giraffa angolensis*): Angolan giraffes were quite a skittish and would take their time before finally drinking after spending time surveying the area to ensure that no predator comes out of nowhere and attack. They made some false attempts before finally drinking. They took turns to drink as the ones that were not drinking were on lookout duty. They were easily spooked by any sudden disturbances and moved away from water before attempting to drink again after a few moments. They started to browse as they walked away from the waterhole into the veld.

Common Eland (*Taurotragus oryx*) they were on high alert when they approached the waterholes and any sudden noise spooked them off. They eventually drank after numerous attempts, then moved away as soon as they were done drinking, it was interesting that we heard them clicking their hooves long before they got to the waterhole. They moved away from the waterhole when the Black Rhino was at the waterhole as it did not allow the elands to drink.

Greater Kudu (*Tragelaphus strepsiceros*) were mostly the most skittish amongst the 17 species recorded and ran off from the waterholes as soon as they heard any foreign sound that they were not used to. After drinking they would move off away from the waterhole and could be observed drinking in the thickets before they gradually move off into the veld.

Gemsbok (*Oryx gazella*) were seen approaching the water slowly and stopped every few seconds and grazed nearby before proceeding, they stopped at the waterhole for a while before drinking, knelt down to drink, and walked off as soon as they finished drinking. At Mountain Lodge Upper which is the smallest between the six waterholes, they were also seen exerting their dominance as they pushed away both the Plains and Hartmann's Mountain Zebra on several occasions by showing of their horns, but this only happened when they came a herd.

Blue Wildebeest (*Connochaetes taurinus*) mostly approached the waterhole in herds with the calves staying close to their mother's side but occasionally a lone bull can be seen on its own roaming around the waterhole. They were always on alert when approaching the waterholes and stopped every few seconds before moving forward, but when there were other species especially a herd of Plains zebra, they could be observed to be more at ease and will at times walk straight to the waterhole to drink. They did not drink immediate but instead stood or grazed close to the water until one/two initiated drinking. Mock fights between calves was observed at the waterholes. Territorial bulls have been observed chasing away other bulls that are were part of their herds. Marking territory via pawing ground and dung piles was also observed at the waterholes. Blue wildebeest, especially the lone bulls did not stay far from the waterhole and could be observed moving around the waterhole feeding on grasses close by after drinking.

Red Hartebeest (*Alcephalus buselaphus caama*) preferred approaching the waterhole in groups and was always on alert stopping every few seconds standing, scanning area and then proceeding forward. They stood and looked around before finally drinking after some time and walked off as soon as they finished drinking. Solitary Red hartebeest bulls observed during a 48-hour observation at Safaripos waterhole moved off as soon as they finished drinking in Etosha Heights Private Reserve.

Black-faced Impala (*Aepyceros melampus petersi*), two black-faced impalas seen at Safaripos waterhole in Etosha Heights did not drink, not even try to approach it, but simply grazed, lay down, and groomed each other. Most of the Black-faced Impala did not drink at the waterholes during the raining periods and only started drinking after the rain died down in the reserve. They mostly spent hours at the waterholes grazing and browsing (mostly grazing) near the waterholes during the raining seasons.

Springbok (*Antidorcas marsupialis*) drank every day, they may move off as soon as they were done but mostly remain to graze not far from the waterhole for several hours before they walk off into the veld. When the waterhole has salt licks, they will stay there for hours and will only move off before evening time.

4.3 Relationships between carnivore and herbivore

Figure 7 show the times in which the herbivores and carnivores mostly occur at the waterholes. At both 00h01-06h00 and 06h01-12h00 about 31% respectively, herbivores where observed at the waterholes, 56% of carnivores where recorded at 00h01-06h00 and about 13% carnivores were recorded at 06h01-12h00 and at 12h00-18h00 18% of species observed where herbivores as it was rare to spot any carnivore during this time interval. At 18h01-00h00, 21% of herbivores could be observed and only about 31% of carnivores where seen during this time interval. This is due to the huge population sizes of the herbivores in the reserve compared to that of the carnivores making the herbivores feel slightly at ease.

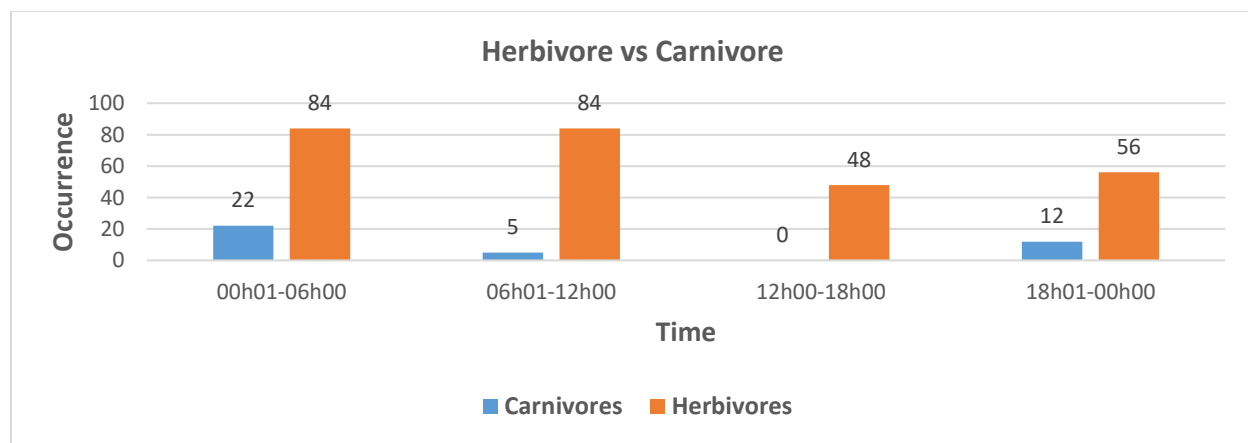


Figure 7: Herbivore vs Carnivore preferred times to frequent waterholes

Table 4: Carnivores and herbivores appeared within those time intervals from January to May

Time	Carnivores/5	Herbivores/12
00h01-06h00	3	10
06h01-12h00	4	11
12h01-18h00	0	9
18h01-00h00	5	11

Table 4 shows the time intervals in which each herbivore and carnivore individual came to all six waterholes. All five recorded carnivores were mostly active during the evenings (18h01-00h00) and none of them seems to be active during the afternoons (12h01-18h00) at all. The herbivores were active throughout all time intervals but they seem to be more active during the morning hours (06h01-12h00) and evenings (18h01-00h00), they are least active during the afternoons (12h01-18h00), but overall there isn't much differences between their time preferences.

5 .Discussion

5.1 Preferred drinking times

Blue Wildebeest and Red Hartebeest are morning drinkers and mostly frequent the waterholes in the mornings. Both of this species are prey species couldn't be observed late at night at waterholes such as Middelpoos that has a high count of carnivores. Regarding the drinking time, the afternoon drinkers were mainly observed to be the African Elephant, Angolan giraffe, Black-faced impala, Gemsbok, greater kudu and springboks. Elephants were quite dominant species but can also be observed approaching waterhole with great care, they tend to exert dominance on other species at waterhole. Evening drinkers, Black rhino, Brown hyaena, Common Eland, Hartmann's Mountain Zebra, Plains Zebra and the cheetah. Just like the elephant, Black rhinos exert their dominance on other species at the waterholes. Pre-dawn drinkers are predators, Lion and Black-backed Jackal, this is due to the fact that these two animals especially the lions spent

most of their time sleeping and when they wake up their first instinct is to drink water before they go and start hunting or scavenging. When approaching the waterhole, both species are quite careful and will look around their surrounding before approaching the waterhole. The jackals walk off into the veld after drinking but when a pride of lions come at a waterhole, they will spend some time there before walking off. The indiscriminate drinkers were the Angolan giraffe and Plains Zebra as they drank at all hours of the day (du Preez & Grobler, 1977; Apps, 2000; Ndumbu, 2020).

5.3 Relationship between Herbivores and Carnivores

The herbivores prefer open waterholes so that they can drink freely without disturbing other species or being chased away from waterhole by strong herbivores. When it comes to drinking, the animals seems to have a system whereby the most dominate and strongest drinks first as soon as it's done drinking, the next in line follows until to the smallest mammalian species. After the carnivores have drank and walked off, hours passes before herbivores start to return back to the waterhole in order to avoid coming in contact with their predators (Crosmar, et al., 2012).

6. Limitations

Sometimes data was missing from the SD cards For example when going through all the data collected, one of the waterholes camera data in the SD card was empty in, and one of the waterholes seems to be dry and only filled up when it rained heavily in Etosha Heights. When we conducted the 48-hour observation at Safaripos, we experienced limitations such as the noise coming from Safarihoek Lodge and disturbances due to the game drives at the waterholes. This was a hindrance in our observations as the animals we running away from the waterhole at any sudden movement or noise. The sensor of the camera trap at Daddelpoos damaged by a pride of lions. Time was also a factor as there were too much images to go through, and the time was short. Took some time to install and learn how to use Digikam

7. Conclusion and Recommendation

My research concluded that herbivores avoid carnivores and will only come to the waterholes hours after the carnivores have drank. Most herbivores especially the prey species often drink in the mornings and afternoons as a way of avoiding carnivores. The carnivores were mostly active during the evenings and pre-dawn. True Diurnal species was the Springbok and the only nocturnal was the Brown Hyaena. During the 48-hour direct observation, it seems like a lot of carnivores did not frequent Safaripos as there were only two carnivores recorded and this might be due to disturbances coming from Safarihoek Lodge, the only time the noises from the lodge settled down was when the tourists were off to their game drives or in their rooms around midnight. As for the objective, the third objective was not met because only one 48-hour observation was conducted.

Finally I would like to recommend:

1. Add more salt licks to as much waterholes as possible.
2. Try finding out why the population of carnivores is so much smaller than that of herbivores.
3. Carry on the study to see if it's a similar situation at all the waterholes that.

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