A camera-trap survey investigating the use of pools by terrestrial mammals in the non-perennial Prins River system

by

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Biodiversity and Conservation Biology

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I, **Ayesha Hargey**, having the student number **3650393**, do hereby declare that the following assignment entitled "**A camera-trap survey investigating the use of pools by terrestrial mammals in the non-perennial Prins River system**" is my own work and that all the sources I have quoted have been indicated and acknowledged by means of complete references.

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Signature: ....

Preface

This mini-thesis is submitted in partial fulfilment of the requirements for the degree Bachelor of Science (Honours) in Conservation Biology. It has been written and formatted in the style of a traditional thesis.

Acknowledgements

I wish to express my gratitude towards my supervisors Professor Jenny Day, Doctor Bryan Maritz and Doctor Michael Grenfell for their support, guidance and encouragement with regards to this thesis project. I further wish to thank the Department of Biodiversity and Conservation Biology at the University of the Western Cape for all resources and assistance. This thesis is a contribution to the multidisciplinary research project on non-perennial rivers being carried out by the Institute for Water Studies at the University of the Western Cape. Finally, I wish to thank the National Research Foundation for funding my studies.

Abstract

Non-perennial rivers account for more than half of the total river-length in South Africa. Despite their abundance, they are rarely studied due to their highly variable nature. Few studies focus on the faunal components of the non-perennial river habitat, and those are predominantly focused on the aquatic invertebrate assemblages that inhabit these areas. Using camera traps, a survey was performed along the non-perennial Prins River in the Klein Karoo, Western Cape, South Africa, to investigate the use of pools in the riverbed by terrestrial mammals. Camera stations were active for 1280 camera-trap days and spanned three different pools along the river. A total of 14 terrestrial mammal species were recorded, encompassing five orders (Primata, Carnivora, Rodentia, Ungulata and Lagomorpha). The most commonly photographed species were the Chacma baboon *(Papio ursinus*), steenbok (*Raphicerus campestris*) and cattle (*Bos taurus*). A total of 10% of photographs could not be identified. Detections were higher as a result of motion-triggered photography than hourly triggers by a factor of more than 12 and no unique species were detected solely through this. Detection rates were higher in summer than in winter. There is some variation in species detected between sites, suggesting there are microhabitats that certain species favour. Species accumulation curves showed that the community had been almost sampled to completion. No relationship was found between water availability and detection rate, but species richness and total detections were highest following a flood that recharged the pools. Variations in diurnal patterns of species were constant with their known behaviour. This study represented the first species inventory of the mammalian assemblage of the Prins River. Future investigations should be undertaken on other non-perennial rivers in South Africa with the goal of more sustainable management of these important environments.

Keywords: biodiversity, camera trap, terrestrial mammals, non-perennial, rivers, Klein Karoo

Introduction

Non-perennial rivers

River systems in arid landscapes across the world that undergo intermittent cessation of water flow are known as non-perennial rivers. There exists a deficit in research towards these systems despite their abundance, as rivers that dry up occasionally make up more than half the river-length in South Africa as well as globally (Raymond *et al.*, 2013, Day *et al.*, 2019). Terminology used to describe these river systems is inconsistent, some authors using ‘intermittent’ (Datry, Larned and Tockner, 2014) and others ‘ephemeral’ (Matthews, 1988), among other terms, but all are ‘non-perennial rivers’. Unlike their perennial counterparts which are associated with a predictable nature, non-perennial rivers are complex, highly variable aquatic ecosystems impacted by changes in a mixture of standing water, flowing water and dry terrestrial riverbed (Uys and O’Keeffe, 1997; Day *et al.*, 2019). This is because they are impacted by changes in flow regime that leave them periodically flooded or dry. Furthermore, they are affected by the pools of standing water which remain in them during dry periods (Day *et al.*, 2019). As a result of their variability, they are challenging systems for the terrestrial mammas dependent on the water contained within them (Jacobson, 1997) — as well as the researcher who studies this environment, leaving a noticeable gap in research to non-perennial rivers (Steward *et al.*, 2012). Yet, they are very important to both people and wildlife living in the vicinity, providing the scarce resource of water in the dry surroundings (Day *et al.*, 2019). In the same way that non-perennial rivers are difficult for certain mammalian species to live in, they are equally challenging to manage but this does not mean they should be underrepresented by policy-makers. Rivers that run dry should no longer be considered atypical, but rather, as being part of a global phenomenon.

Although non-perennial rivers in South Africa are significant in size and extent, these environments are largely ignored in research and in management (Uys and O'Keeffe, 1997; Datry, Arscott and Sabater, 2011). Climate change has adjusted flow regimes, and the lack of understanding regarding the ecological impacts of this has led to policies based on unverified assumptions (Uys and O'Keeffe, 1997). With an increase in predicted droughts as a result of the warming of the climate, an increase in the abundance of non-perennial rivers is expected as well as an increase in the duration over which they remain dry (Meehl *et al*., 2007). Consequently, this has the potential to heavily impact the fauna dependent on these rivers.

A river recharges itself with water, allowing the reconnection of populations of aquatic organisms in previously isolated pools, as well as flows of organic matter and nutrients (Steward *et al*., 2012). When the river dries up again, it can act as a corridor for the movement of terrestrial organisms (Sánchez-Montoya *et al*., 2016). Many dry riverbeds contain minimal trees, ensuring limited obstructions and making it favourable as a means of migration. Herbivorous mammals and many carnivores use dry rivers as means to trace remaining waterholes (Mills and Retief, 1984). Arid environments are typically associated with high daily temperatures and high evaporation rates. Compounded with water scarcity, this environment leaves a challenge for larger mammal species such as ungulates that cannot take refuge in shelters in the same way that smaller vertebrates can (Grenot, 1992). Furthermore, Grenot (1992) notes that evaporative heat loss is an essential component for the maintenance of homeothermy. This becomes relevant when considering the decrease in available water sources in arid areas. Many of the small-bodied vertebrate species found in this environment have limited potential to store body water and need to replenish their water intake frequently (Smit *et al*., 2019). Smit *et al*. (2019) also found that the probability of drinking is higher on hot days, and further predict that under climate change conditions, more species will rely on available surface water.

Non-perennial rivers have value to humanity. This environment has been described as a 'linear oasis' due to the vegetation inside these corridors being richer in retained organic matter than the surrounding habitat. In comparison to perennial rivers, there is no constant water flow which moves through the fertile soil (Kassas and Imam, 1954). Many carnivore species congregate along non-perennial river courses due to the higher density of herbivorous prey close to the river, and as a result some of these predators are considered residents of the area (Coetzee, 1970). Cattle have been observed frequently grazing on the plants along non-perennial river beds (Kassas and Girgis, 1964). Steward *et al*. (2012) states that there is a poorly researched but important ecotone represented by a river transcending from a habitat that is aquatic to one that is terrestrial and it is this ecotone is responsible for maintaining the diversity in species composition.

Of relevance to this study is the common trait of non-perennial rivers sustaining pools of water in the riverbed (Seaman *et al*., 2016). The pools tend to persist even when the rivers aren't flowing, and are important as often they are the sole water source. Romer (1958) has even theorized that it was the drying of pools in non-perennial rivers which caused sufficient environmental pressure that led to the evolution of water-independent movement traits in vertebrates, allowing them to venture onto land. Furthermore, it is also theorized that resistance to desiccation in aquatic vertebrates evolved as a response to the drying out of pools (Williams, 2005). Thus, they have importance both today and historically.

Non-perennial river research is uncommon despite their prevalence around the world, and the unique microhabitats contained within and around them (Datry, Arscott and Sabater, 2011). Previous studies on the faunal component of non-perennial rivers are vastly skewed towards invertebrates, and among those, studies such as Sánchez-Montoya *et al.* (2018) and Chester and Robson (2011) are skewed towards those that are aquatic. There is a major bias in research towards research involving perennial river networks, and this becomes even more concerning when dry rivers are expected to increase as water abstraction and land use alteration changes the environment (Datry, Larned and Tockner, 2014). Thus, there is a need for further studies pertaining specifically to mammals within this important environment.

Sampling animal communities

Worldwide, there is an increasing prevalence of camera trap usage to monitor and inventory terrestrial faunal assemblages, with particular emphasis on mammals (Cusack *et al*., 2015). Despite mammals being some of the most charismatic animals, it is difficult to study them in a non-invasive manner using traditional methods as they are frequently nocturnal, avoid human presence and are noted for their elusive nature (Gonthier and Castañeda, 2013). Furthermore, in the case of predators, physical handling can be difficult and their secretive habits and low densities can make detection difficult (Kauffman *et al.*, 2007). Despite the challenges associated with their observation, mammals play a significant role in the ecosystem. An example of such is their role in seed dispersal and predation, with grazers and browsers being important in the regulation of plant species populations (Redford, 1992). Their presence in the environment also mediates complex habitat dynamics (Terborgh *et al*., 2008). Camera traps can be seen as a valuable aid in documenting presence, assessing identity and estimating abundance of mammals, which are all factors to be considered in conservation actions (Cusack *et al.*, 2015). Remote camera traps can be used to inventory the presence of large mammals, frequently under environmental pressures such as habitat loss.

In an attempt to preserve the natural environment, there has been a consistent shift towards non-invasive sampling (Tobler *et al*., 2008). Camera traps can be used to collect data that would prove difficult to collect otherwise. Because past research involved time-consuming techniques (such as capturing live individuals) or resulted in detrimental environmental impacts (Kauffman *et al*., 2007), it is understandable that there is an effort to use methods that do not affect the natural habitat in a permanent capacity. Camera traps allow a remotely activated camera to take photographs of an area (Wong and Kachel, 2016). This technology has improved in quality and decreased in cost, and provides reliable evidence of species present (Tobler *et al*., 2008). For this reason, camera traps are seen as one of the best modern methods of data collection for many ecological disciplines. Photographs taken by camera traps can then be analyzed to calculate species richness in an area, which in turn can be used to compare diversity and, at a broader scale, used in conservation planning strategies, as the data obtained can be used to improve species distribution maps (Tobler *et al.*, 2008).

One of the ways in which camera trap surveys can be used is the process of capture-recapture. These techniques have been used to estimate population density of a target species, usually those that have individuals that can easily be identified, such as tigers (*Panthera tigris*) (Karanth and Nichols, 1998). This is useful, particularly in cases where the study species is elusive and would otherwise prove difficult to measure. Another use of the data gathered from camera trap surveys is species occupancy modelling which, along with estimating the probability of detection, uses presence-absence data to estimate the probability of occurrence, allowing estimation of the biodiversity of an area (Cove *et al*., 2013). These models have been continuously updated and refined, most notably by Tobler *et al*. (2015) who adjusted one to utilize data over multiple surveys, and was then able to estimate species presence with higher accuracy, as well as for species with minimal data. Models such as these are useful when camera trap effort is high, and can then be used to investigate patterns in community composition and distribution over long periods of time, an aspect that would be useful when attempting to investigate, as an example, the effects of climate change on a particular habitat. However, many camera trap studies cannot give absolute numbers of population of a given area. This is due to a limitation of camera trap data as it is difficult to distinguish between different individuals for many species. This would then affect the analysis as it would not be possible to discern between multiple or single visits by a particular organism (Kauffman *et al*., 2007). Tobler *et al*. (2008) investigated camera trap efficiency for rainforest mammals and found that the position of camera and area covered have little impact on survey results, as long as camera density is high and one accounts for variation in major habitat types.

In violation of traditional random sampling, camera traps are frequently placed at points that animals are thought to frequent, such as watering holes or trails (Cusack *et al.*, 2015). Thus, it is important to acknowledge the inherent bias in some studies. Cusack *et al.* (2015) did show, however, that given sufficient sampling activity, species richness can be ascertained and camera placement does not affect inferences made at a community level. This suggests that as long as a study encompasses a long enough time period, a level will reach at which the majority of the community will be accounted for, regardless of whether cameras were placed randomly or not.

Detection rates can vary between species (Mann *et al*., 2014). Camera trap placement is important when considering survey design, as different species favour different environments (Edwards, Gange and Wiesel, 2016). Designing camera trap surveys which increase probability of detection is ideal due to the naturally low populations of many species occurring in arid environments (Hayward, O'Brien and Kerley, 2007). While smaller mammals may prefer the safety of off-trail vegetation, it was found that certain carnivores are exclusively detected by cameras on trails (Edwards, Gange and Wiesel, 2016). If a particular species is targeted for study, placement is not the only factor that can influence detection. Certain surveys use bait, for example the use of a fish lure when detecting brown hyenas (*Hyaena brunnea*) (Thorn *et al.*, 2009). This technique is undesirable due to the risk of permanent habituation around the site, which would not reflect an accurate depiction of the environment (Balme, Hunter and Robinson, 2014). While baiting certainly has advantages in increasing detection, as well as individual identification, it is not without consequences. Those at the greatest risk are charismatic carnivores such as lions (*Panthera leo*), leaving them more vulnerable to activities that use bait stations, such as trophy hunting (Balme, Hunter and Robinson, 2014). However, Edwards *et al.* (2016) put forth the idea of water sources as “natural bait”, since typical arid environments lack this essential resource. An advantage of camera placement at natural water sources is that it comes with none of the detriments of introduced bait. Additionally Edwards *et al*. (2016) found that camera traps placed at a water source produced higher detection probabilities than cameras away from water sources, and that some animals, such as fox species (*Vulpes* and *Otocyon*), were not at all detected except at a water source. This shows the importance of including a water source when attempting to provide an inventory for an environment that includes one.

With this knowledge, the use of camera traps along a non-perennial river can provide a useful representation of the environment. There are, however, no known camera trap studies published on non-perennial rivers in South Africa.

The study site is within the Klein Karoo, and projections show that water demand will continue to increase for this area as well as South Africa as a whole (Maitre, Colvin and Maherry, 2009). This makes it an ideal location for one of the first studies on the mammalian wildlife component of a non-perennial river. The aim of this project is to investigate the use of pools by the terrestrial mammals of the Prins River. The objectives of this study are thus:

- Firstly, to establish an inventory of terrestrial mammals that occur along the Prins River
- Document the assemblages of terrestrial mammals that are directly and indirectly affected by the presence of pools
- Examining diurnal variation in detection of terrestrial mammals
- Furthermore, camera efficiency will be tested through the use of motion-triggered images and images taken at timed intervals
- Finally, the project aims to record the changes in fluctuations in surface-water availability and the effects of this on the detection of individual animals

This study will provide the first documented inventory of the mammals found at the non-perennial Prins River, taking place along three locations along the Prins River, along a gradient of pool water availability.

The study is a component of the research undertaken by the multidisciplinary Non-Perennial Rivers Research Programme, a project led by the Institute of Water Sciences that is concentrating on understanding the relationships between river flow, ecosystem characteristics and services provided by non-perennial rivers. This research can then be used to facilitate decision making and management of non-perennial rivers.

Methods and Materials

Study area

The area known as the Klein Karoo occurs in the Western Cape, South Africa (Figure 1). It is known for its semi-arid climate which is where three separate biomes (Fynbos, Succulent Karoo and Subtropical Thicket) meet (Mucina and Rutherford, 2011). This results in an ecosystem known for its ecological diversity and indeed, the Fynbos and Succulent Karoo biomes are recognized as global biodiversity hotspots (Driver *et al*., 2003). Despite the importance of this region, a legacy of mismanagement and poor agricultural practices has left the land exploited (Thompson *et al*., 2005). The nature of the arid environment means that water is a scarce resource, and indeed, important for further development (Thompson *et al*., 2005). Climate change is predicted to have an effect on the climate regime, with warmer temperatures predicted, as well as a predicted increase in rainfall in summer months and a decrease in winter months (Maitre, Colvin and Maherry, 2009).

The Prins River is a tributary of the Touws River, and is one that has persisting pools that are not frequently connected to the larger river network. There is a need to investigate the significance of these pools in supporting the faunal component as Jacobson (1997) noted that non-perennial water sources support certain animal species in arid environments. These pools subsist even when the river stops flowing, and are thus sources of water. The study site is known for variable summer rainfall, with major floods expected at unpredictable intervals. It has a low rainfall (100-250mm yr^{-1}), mean summer temperatures >30°C and mean winter temperature of 4-8°C (Maitre, Colvin and Maherry, 2009). As identified by Maitre *et al*. (2009), there is a lack of information on water systems in the Klein Karoo.

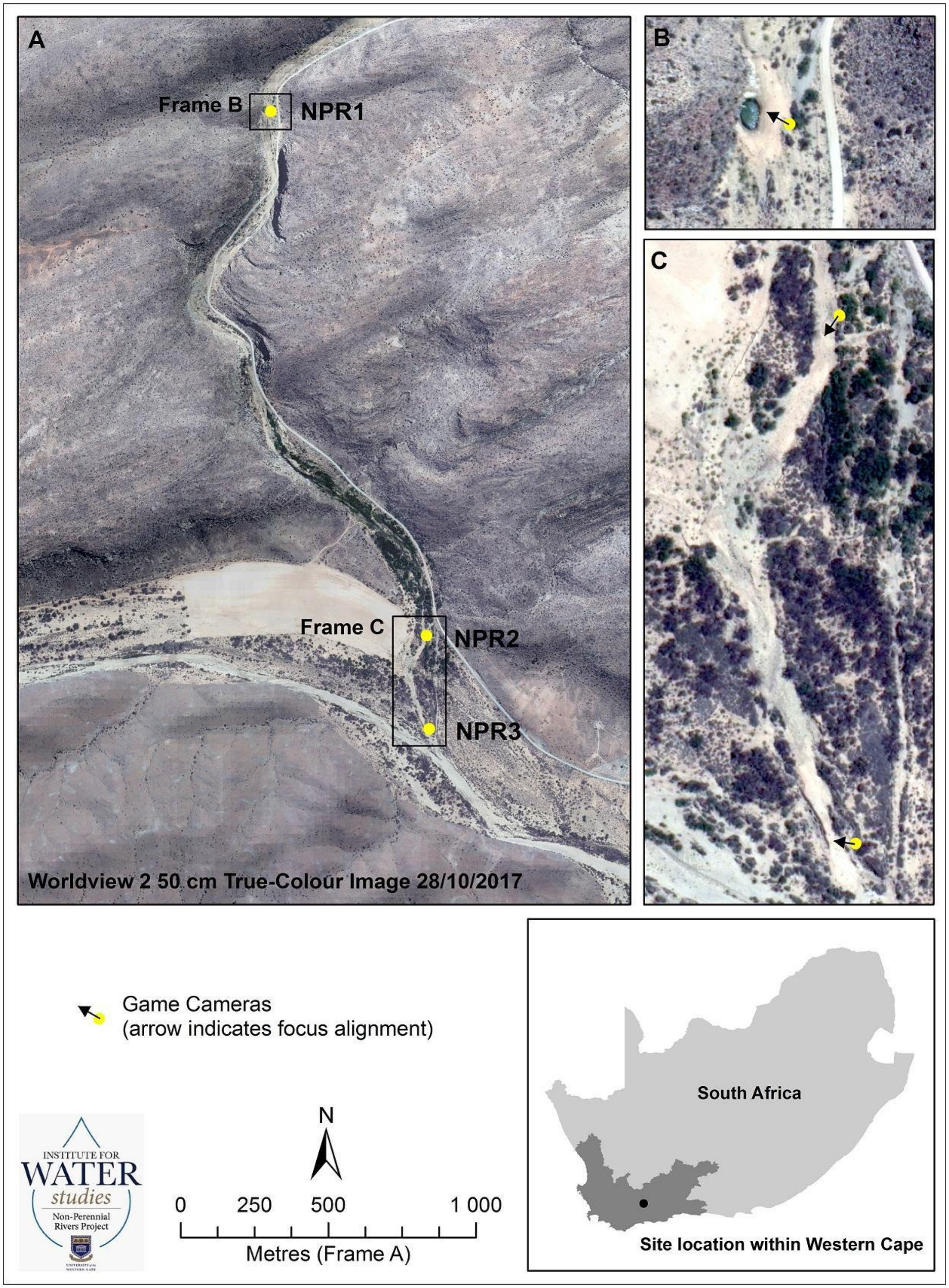

Figure 1: Study area and location of camera trap stations, located along the Prins River, a tributary of the Touws River and showing the location of the Klein Karoo in South Africa (inset) (Source: M Grenfell)

Survey design

A camera trap survey was carried out from 20th April 2017 to 21st June 2018 along the Prins River. It spanned 2.4km in total. Locations chosen were specifically targeted at naturally-occurring pools in the river. The survey included three sites, selected by the project coordinators and therefore beyond the control of this thesis project. The first camera (NPR1) was placed at a pool filled with water for the duration of the study (Figure 1, Frame B), with the other two cameras (NPR2 & NPR3) situated at sites without perpetual water (Figure 1, Frame C). The distance between the first and second pool was 1.9km, and the distance between the second and third was 500m. The total duration of the survey was 427 days. Bushnell cameras (Bushnell Outdoor Products, Overland Park, KS, USA) were set to capture photographs every hour, as well as whenever they were triggered by motion. Date, time and temperature were automatically stamped onto each photograph. After the first interval (Table 2), the camera at the permanent pool was set only to take photographs by motion-trigger. Cameras were operating 24 hours a day and batteries were checked and replaced three times over the course of the study.

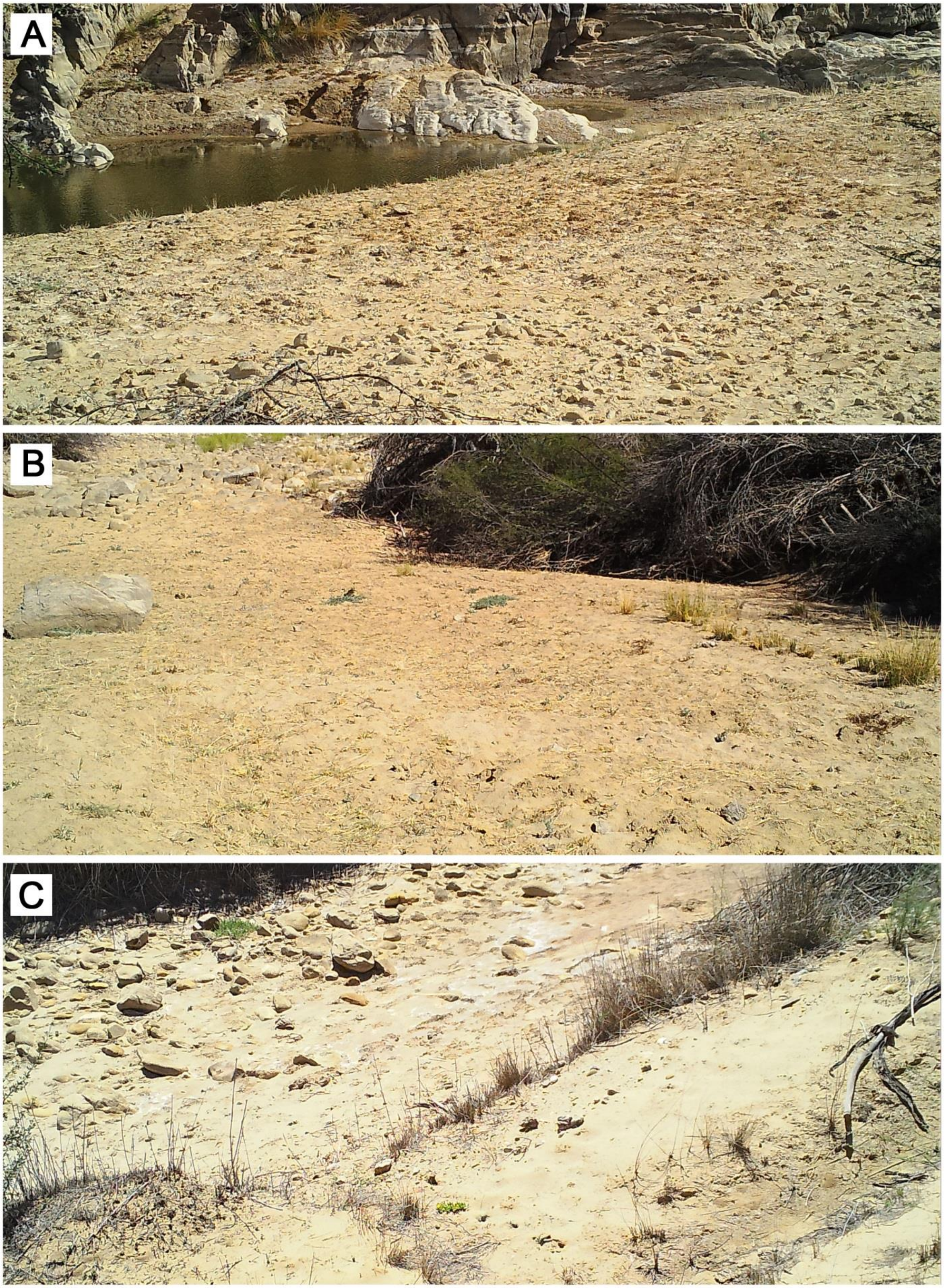

Figure 2: Study location of (A) Camera NPR1. (B) Camera NPR2. (C) Camera NPR3.

Camera NPR1 faced north across and slightly upstream of the confluence of the Prins River at a large deep pool, with an overhanging face of sandstone above (Figure 2a). There was sparse cover of *Vachellia karroo* on the left bank, according to camera placement. Camera NPR2 (Figure 2b) was placed at a downstream exit of the canyon at the confluence of the Prins and Touws River at a smaller pool. Dense cover of *Vachellia karroo* occured on both banks. Camera NPR3 (Figure 2c) was positioned upstream of the confluence of the Prins and Touws rivers, at a pool similar in size to NPR2. Directly facing the camera is dense cover of *Vachellia karroo* on the left bank, a reedbed of *Phragmites australis* at the lower right bank grading into the *Vachellia karroo*.

Data analysis

All images were downloaded from SD cards and entered into the software Timelapse2 (Greenberg, Godin and Whittington, 2019), designed for managing camera trap data while maximizing efficiency through rapid data-entry. For each photograph, the station, the temperature, the presence or absence of water, the date and time, and the species detected were recorded. Animals were identified down to species level through the use of Stuarts' Field Guide to Mammals of Southern Africa (Struik Nature, 2015). Images taken at night were enhanced in Adobe Photoshop (Adobe Systems, Mountain View, CA) through changes in brightness and contrast to better identify. If a species was unable to be discerned, it was left as unidentified. Images of animals not identified were taken into consideration only for detection-based analysis. A relative abundance index (RAI) was calculated as the number of detections per species divided by sampling effort and then multiplied by 100 (thus, a measure of detections per 100 days of camera trapping). It is a common component of many camera trap studies and used for comparable results due to its simple formula, and the way in which it can be used in studies where true abundance would be complex or difficult to calculate (Palmer *et al.*, 2018). RAIs can be used as a measure of population. Furthermore, Palmer *et al.* (2018) deduced that even under conditions with potential bias arising from imperfect detections, RAIs can predict relative abundance with accuracy.

Analyses were carried out in R version 3.5.0 (R Core Team, 2014). Species accumulation curves were plotted using the package vegan (Oksanen *et al.*, 2019). Additionally, a separate curve was calculated for the overall study. This is a measure of the total number of species against the total sampling effort and demonstrates the rate at which new species are being detected within the sampling site (Ugland, Gray and Ellingsen, 2003). It allows the comparison of diversity across sites and is able to predict whether an environment has been sampled to an acceptable level of detection.

Analysis of species richness was carried out only on the subset of data with identified species. Photographs taken by motion-trigger were compared with photographs taken at hourly intervals to determine which had a higher detection rate and thus was more efficient and this was done through the use of a *t*-test. In order to investigate the relationship between whether an increase in water availability would result in an increase in species detection, ANOVA was done of the time comparing detections during periods of water against detections during periods of water absence. A Chi square was done to examine if any difference in visitation occurred before and after a flooding event, such as that occurred in January 2018 (Figure 3). Diurnal variation in species detection was examined visually through the use of histograms generated using the package camtrapR (Niedballa *et al*., 2016).

Results

The overall number of terrestrial mammal species detected was 14, accumulated from a total of 1280 camera trap days across the three sites. There were 493 accounts of false triggers. Common causes for false triggers were movement of foliage and weather conditions such as rain. There were twenty cases of human activity recorded at the sites, and excluded from the analysis. While many bird species were captured (greater than five) on camera (N = 141), they were excluded from species analysis as this camera sensitivity is not designed for a robust study on birds. A total of 10% of photographs could not be identified due to poor image quality.

The fourteen mammal species detected were taxonomically diverse and span five orders: Primata, Carnivora, Rodentia, Ungulata and Lagomorpha (Table 1). Identification of individual animals was neither within the scope nor the objectives of this study. The mammal species most photographed were the Chacma baboon (*Papio ursinus*), steenbok (*Raphicerus campestris*) and cattle (*Bos taurus*). Of the felids, caracals (*Caracal caracal)* and African wild cats (*Felis silvestris cafra*) were both detected on six occasions. There were at least six unique individuals of greater kudu (*Tragelaphus strepsiceros*), both male and female, of varying ages. Figure 3 demonstrates the changes in water availability for the duration of the study. Most notably, water was present at site NPR1 throughout the study. Sites NPR2 and NPR3 were only filled with water for a short duration. Images from the study are shown in Figure 4 and 5.

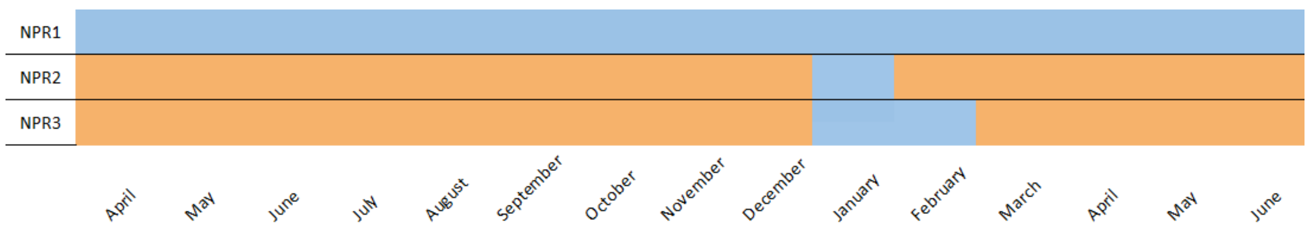

Figure 3: Presence (blue) or absence (orange) of water at the sites for the duration of the study

Table 1: Inventory of photographed species with number of captures and Relative Abundance Indices for all observed mammals during the camera trap survey in the Prins River

Taxonomic Group	Latin name	Common name	Site			Total	RAI
			NPR1	NPR2	NPR3		
Primata	*Papio ursinus*	Chacma baboon	76	132	42	250	19.3
Carnivora	*Canis mesomelas*	Black-backed jackal	45	13	10	68	5.31
	Galerella pulverulenta	Cape gray mongoose	0	1	0	1	0.08
	Felis silvestris cafra	African wild cat	1	3	2	6	0.47
	Caracal caracal	Caracal	1	3	2	6	0.47
	Canis lupus familiaris	Domestic dog	0	0	1	1	0.08
Rodentia	*Hystrix africaeaustralis*	Cape porcupine	3	0	0	3	0.23
Ungulata	*Tragelaphus strepsiceros*	Greater kudu	8	18	17	43	3.36
	Taurotragus oryx	Eland	12	1	4	17	1.33
	Raphicerus campestris	Steenbok	3	46	52	101	7.89
	Oreotragus oreotragus	Klipspringer	8	1	0	9	0.70
	Bos taurus	Cattle	27	38	39	104	8.13
	Oryx gazella	South African oryx	0	16	13	29	2.27
Lagomorpha	*Lepus saxatilis*	Scrub hare	0	1	0	1	0.08
Aves			4	11	126	141	11.02
Unidentified		Unidentified	27	33	25	85	6.64

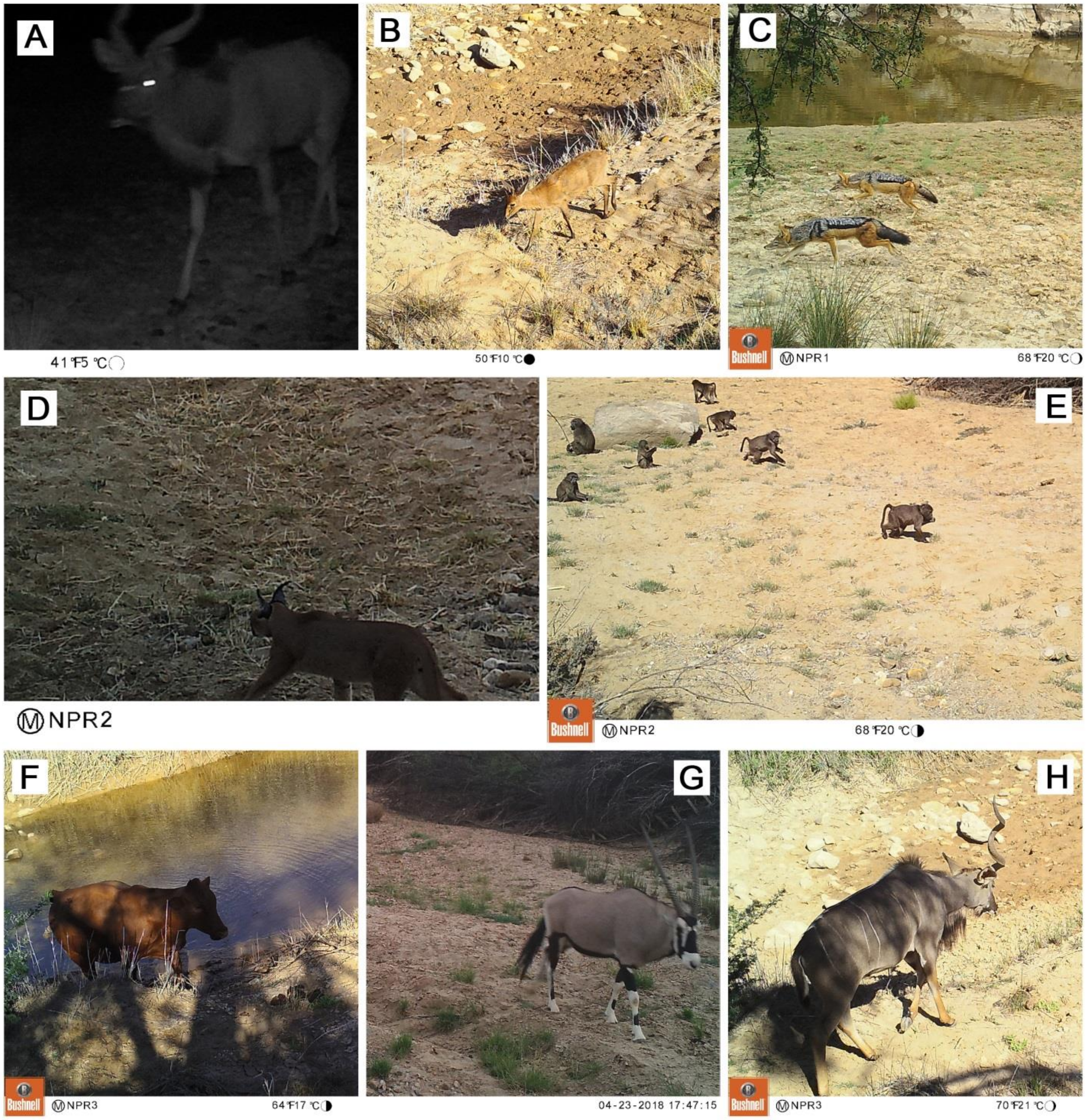

Figure 4: Camera trapping in the non-perennial Prins River. (A) Male greater kudu (*Tragelaphus strepsiceros*) during night-time. (B) Steenbok (*Raphicerus campestris*) in the dry channel. (C) Two black-backed jackals (*Canis mesomelas*). (D) Caracal (*Caracal caracal*) in the dry channel. (E) A troop of baboons (*Papio ursinus*) in the dry channel. (F) Cow (*Bos taurus*) in the water during the flood of January 2018. (G) South African oryx (*Oryx gazella*) (H) A single-horned male greater kudu (*Tragelaphus strepsiceros*).

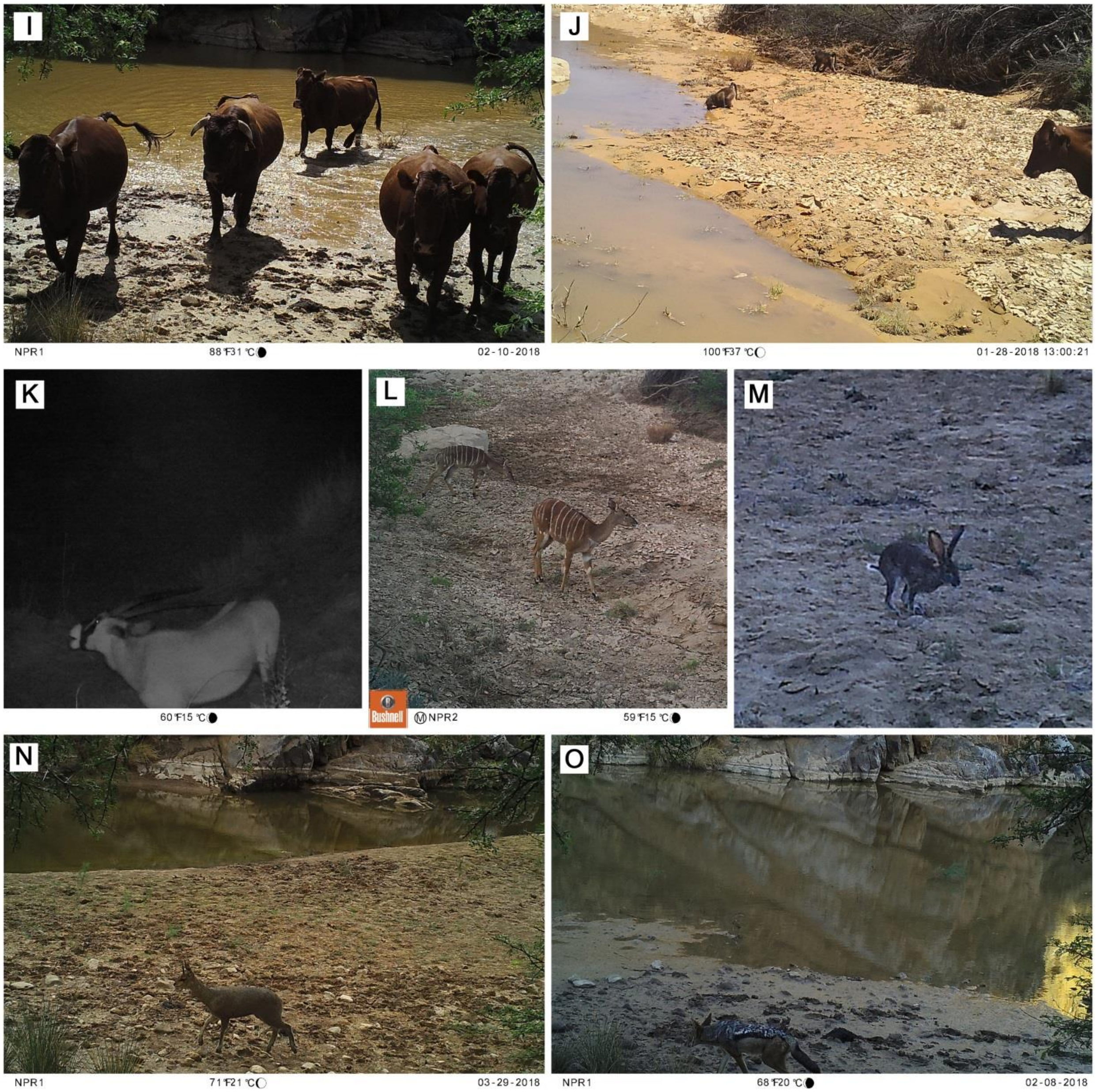

Figure 5: Camera trapping in the non-perennial Prins River. (I) Cows (*Bos taurus*) in the flooded pool (J) A cow (*Bos taurus*), and baboon (*Papio ursinus*) drinking from the rapidly drying river (K) South African oryx (*Oryx gazella*) at night. (L) Juvenile greater kudu (*Tragelaphus strepsiceros*). (M) Scrub hare at twilight (*Lepus saxatilis*). (N) Klipspringer (*Oreotragus oreotragus*) (O) Black-backed jackal at the recharged river (*Canis mesomelas*).

To see if more animals were detected using motion triggers than using timed photographs, the mean numbers of detections per interval were compared statistically using a two-tailed t-test. The intervals used are shown in Table 2, and represent each time the cameras were checked and batteries replaced. A significant difference was observed ($\text{t-test}_{t6} = 3.14$; $p = 0.02$). This demonstrates that detection rate is much higher when photographs are triggered by motion. The difference in detection is greater than a factor of more than twelve (comparing the mean values of 91 against 7.14). The only uncommon individual captured by the hourly photographs was a caracal *(Caracal caracal)*. This species, however, was also captured by motion-trigger images.

Table 2: Summary of total detections and method of triggering for a camera trap survey in the Prins River

Station	Start Date	End Date	Motion	Timed
NPR1				
Interval 1	21/04/2017	28/06/2017	33	4
Interval 2*	28/06/2017	21/11/2017	52	-
Interval 3*†	21/11/2017	20/06/2018	125	-
NPR2				
Interval 1	20/04/2017	28/06/2017	27	0
Interval 2	28/06/2017	21/11/2017	70	8
Interval 3†	21/11/2017	20/06/2018	196	16
NPR3				
Interval 1	20/04/2017	28/06/2017	21	0
Interval 2	28/06/2017	21/11/2017	85	1
Interval 3†	21/11/2017	20/06/2018	205	21

*Excluded from t-test analysis as camera only recorded motion-triggered detections

†Heavy rainfall in January 2018 resulted in a flood that recharged the river

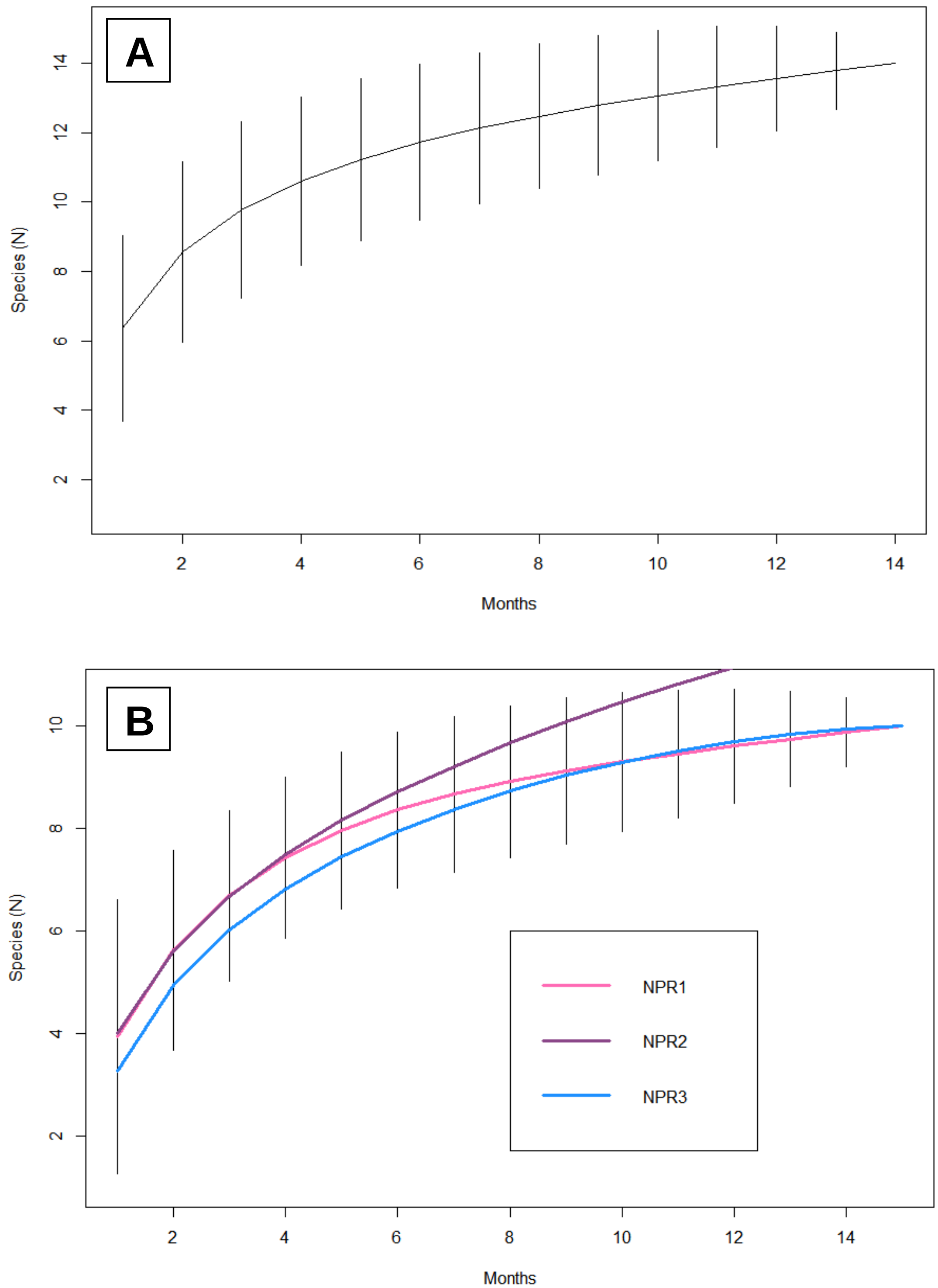

Figure 6: Sample-based species accumulation curve describing the terrestrial mammal community richness for the (A) overall study area, and (B) for the three sites. 95% confidence interval displayed as vertical lines.

The rarefied species accumulation curves (Figure 6b) for two of the three sites (NPR1 and NPR3) are similar in the number of species detected after the eighth month. While these two sites gradually reach an asymptote which suggests that the full species inventory has been reached, NPR2 continues to increase, suggesting that species are still being detected for the first time. Site-specific species richness saw a rapid increase within the first five months of study. The overall species accumulation curve (Figure 6a) levels off, suggesting that the environment is close to being sampled entirely, and that it would be only through multiple sites that all species could be detected. Most likely, any species not detected would be in NPR2 because the asymptote is not reached. While this does suggest it is more likely to encounter other species in NPR2, it is not impossible at NPR1 or NPR3. The site of highest species richness was NPR2 with 12 species detected in total. NPR1 and NPR3 both have a total of 10 detected.

A Jaccard dissimilarity index was done in order to quantify similarities in species composition among the sites. There was a strong association between the scrub hare (*Lepus saxatilis*) and Cape grey mongoose (*Galerella pulverulenta*). Most species were found in all three sites. The scrub hare (*Lepus saxatilis*), Cape porcupine (*Hystrix africaeaustralis*), Cape grey mongoose (*Galerella pulverulenta*) and a dog (*Canis lupus familiaris*) were unique to single sites.

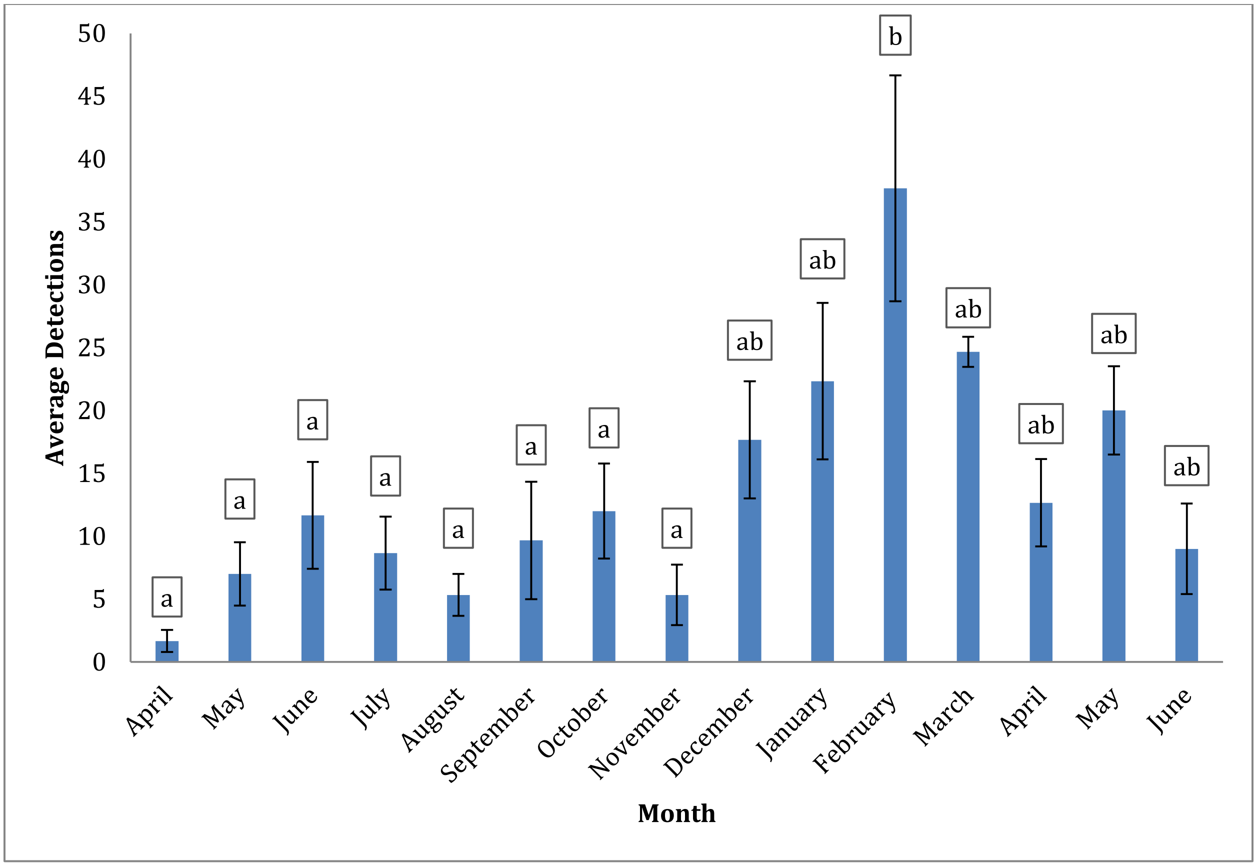

Figure 7: Average variation in detection frequency of camera traps across all sites for each month of the study duration. Error bars detonate standard error.

To investigate the relationship between seasonality and detection rates, mean monthly detections across sites were compared (Figure 7) and tested for significance using ANOVA. A significant difference was found (ANOVA: $F_{11} = 4.86$; $p < 0001$). This shows that detections vary dramatically across the study period. An ad-hoc Tukey HSD was done to determine the source of the difference. There were significant differences between the months April, May, June, July, August, September, October and November against February.

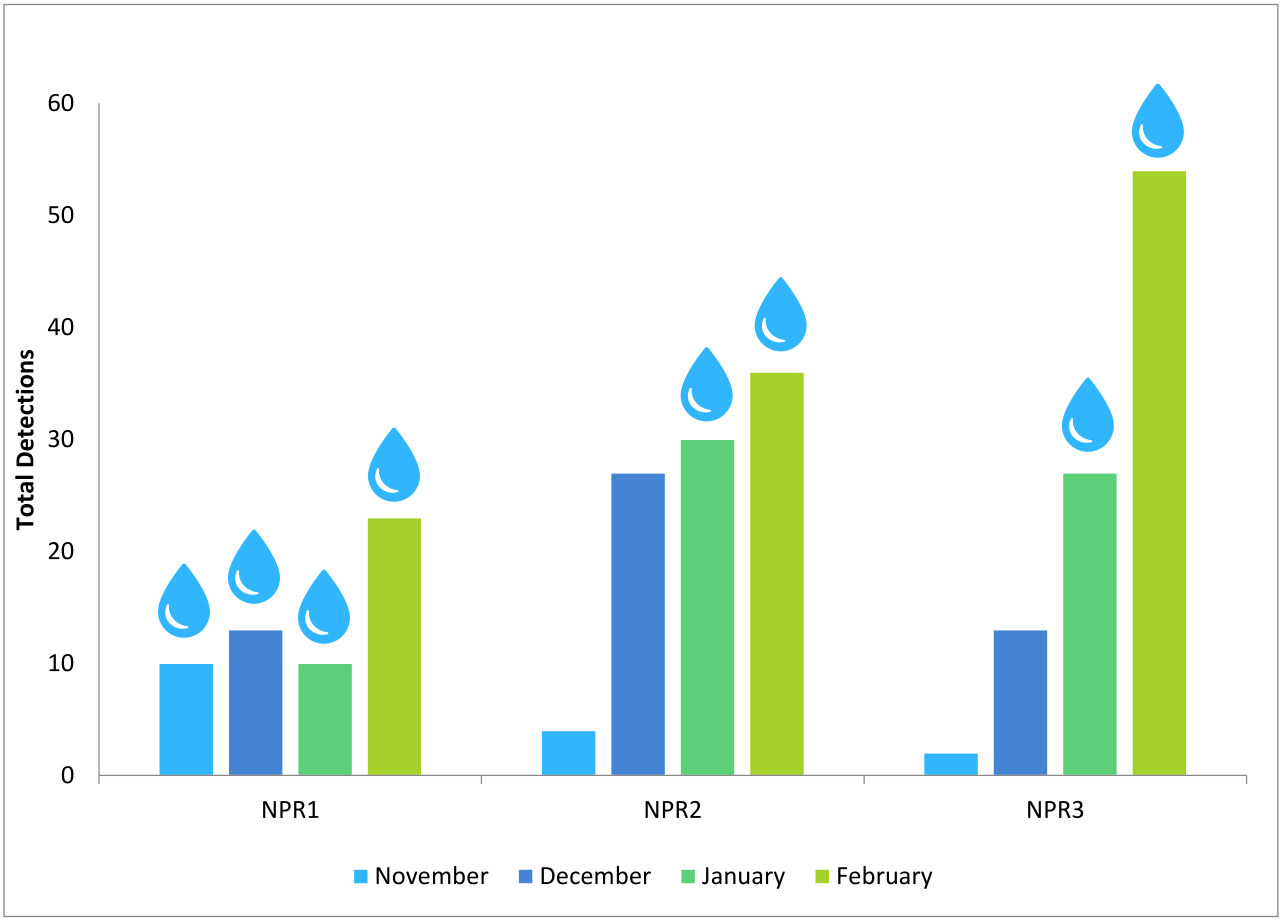

Figure 8: Total detections for the months preceding and following the flood that occurred in January of interval 3. This flood resulted in the river being recharged. Water droplets indicate water present at the pool.

In an attempt to answer the question if increased water availability increased the visitation rate at the sites, a subset of the total detection data was used for the months November, December, January and February (Figure 8) since during late January, a flood resulted in a flow of water into the pools (Figure 3). Using a Chi squared test, visitation rates at sites NPR1 ($x^2 = 10.67$, $p = 0.033$) and NPR3 ($x^2 = 31.48$, $p < 0.001$) were shown to be significantly different across these four months. The overall Chi squared was found to have a significant variation across all sites (x^2 = 19.046, p = 0.004). Detection increases immediately after a recharge event.

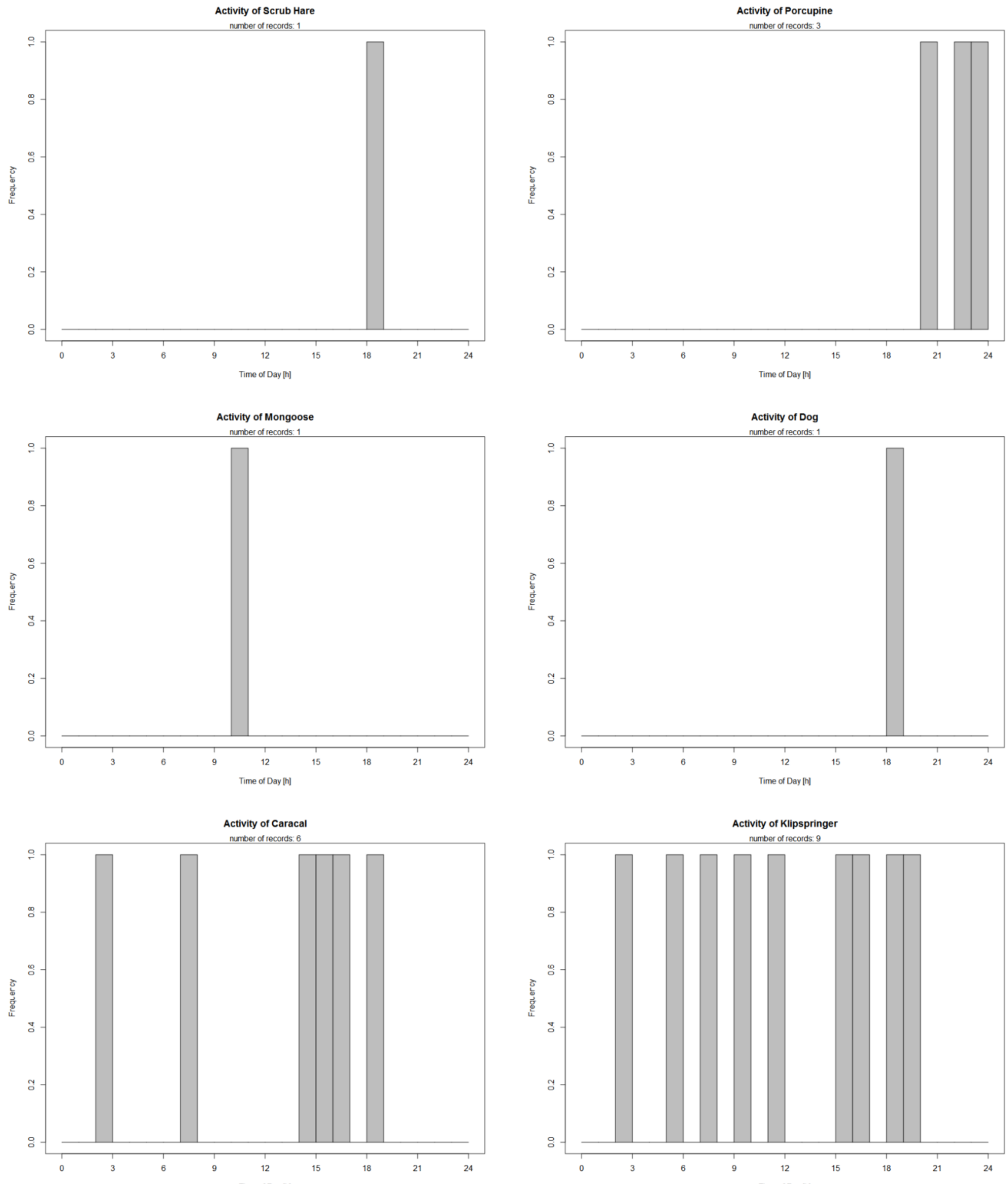

Figure 9: Histograms displaying the frequency over time for particular species, accumulated across all sites for species: scrub hare (*Lepus saxatilis*), Cape porcupine (*Hystrix africaeaustralis*), Cape grey mongoose (*Galerella pulverulenta*), dog (*Canis lupus familiaris*), caracal (*Caracal caracal*) and klipspringer (*Oreotragus oreotragus*).

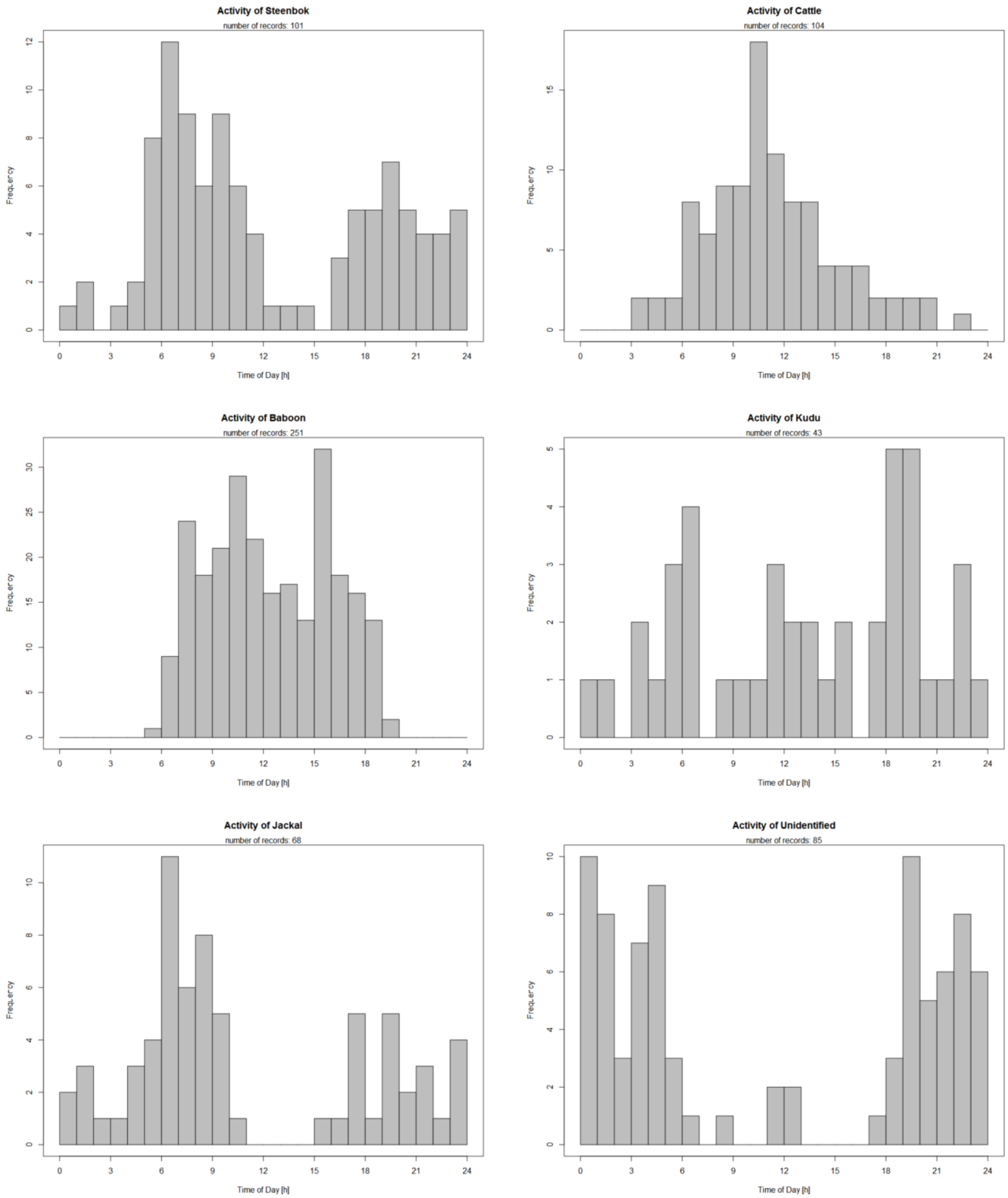

Figure 10: Histograms displaying the frequency over time for particular species, accumulated across all sites for species: steenbok (*Raphicerus campestris*), cattle (*Bos taurus*), baboon (*Papio ursinus*), greater kudu (*Tragelaphus strepsiceros*), black-backed jackal (*Canis mesomelas*) and detections of species that could not be identified. (Note that the scales on the *y* axes are different.)

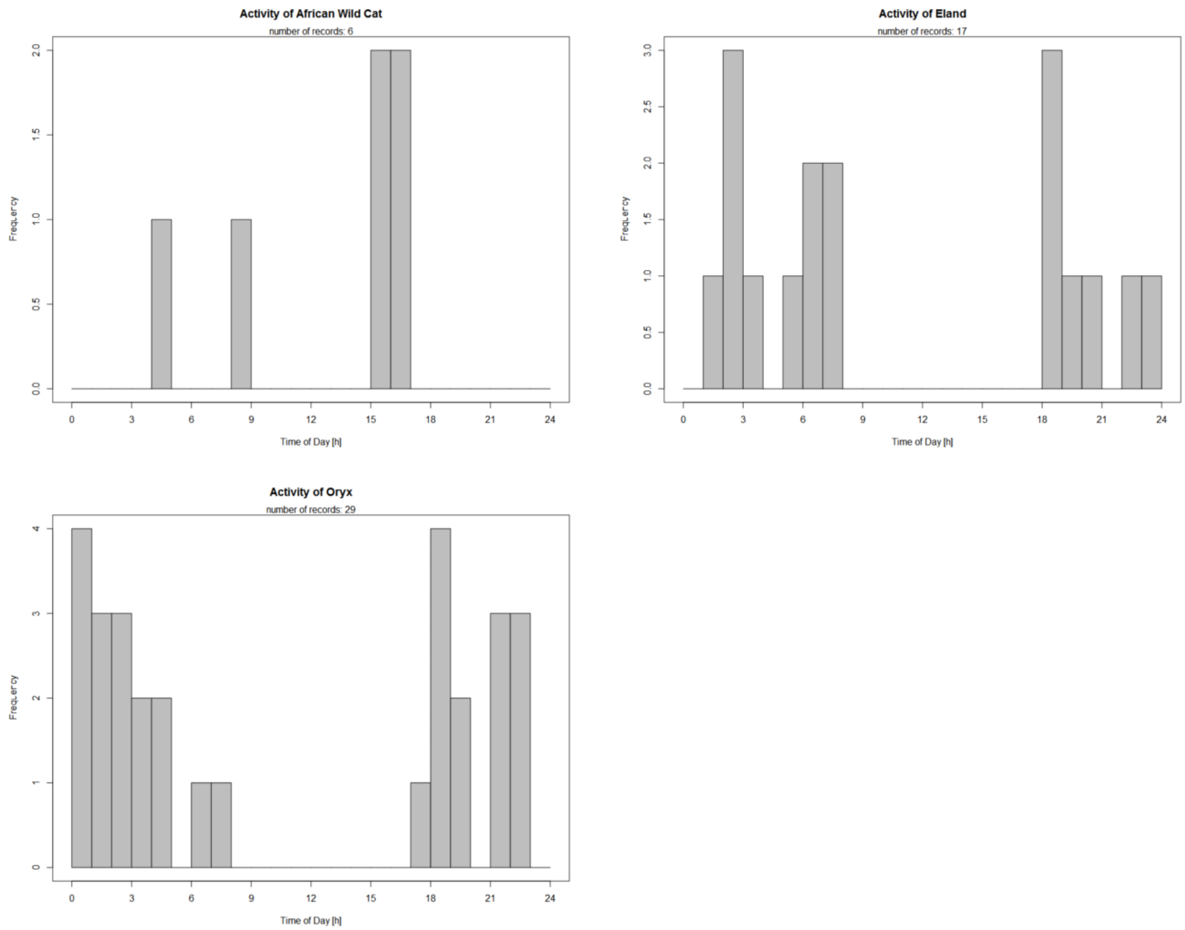

Figure 11: Histograms displaying the frequency over time for particular species, accumulated across all sites for species: African wild cat (*Felis silvestris cafra*), eland (*Taurotragus oryx*) and South African oryx (*Oryx gazelle*). (Note that the scales on the *y* axes are different.)

In order to investigate diurnal variation in occurrence, detection data was pooled to examine patterns in the frequency at which a particular species would visit any of the sites (Figure 9, Figure 10, Figure 11). Certain species of order Ungulata, such as the eland (*Taurotragus oryx*) and South African oryx (*Oryx gazelle*) occur only after early evening and typically leave before 09:00.

Black-backed jackals (*Canis mesomelas*), predominantly nocturnal, were seen during most of the day besides early afternoon. Although Cape porcupines (*Hystrix africaeaustralis*) had a low occurrence in this study (N = 3), all these detections took place at night, consistent with their known behaviour. Chacma baboons (*Papio ursinus*) were seen at all hours of the day but never late at night. Most unidentifiable sightings occurred at night.

Discussion

Non-perennial rivers are known for their dry appearance and despite the common assumption that these areas are barren (Steward *et al*., 2012), the results of this study have shown that a diverse assemblage of species occurs within the vicinity of the Prins River. Camera trap photography revealed that the Prins River was home to an array of vertebrate species, including 14 terrestrial mammal taxa across five different orders. Detectability of species varied across sites and also varied across months of the year, with the majority of photographs being taken during summer. Moreover, it was found that time-triggered photographs captured drastically less detection than motion triggered photographs.

The effect of variances in water availability on species detections was not expected. While it would be assumed that species richness would be higher at sites with constant water availability, the reality was not so. The total length that spanned from NPR1 to NPR3 was a distance from 2.4km suggesting that these pools are isolated. NPR2, a site which only contained water during the flood in January 2018 (Figure 3), was found to have the highest number of detections as well as the highest species richness. It was found that visitation appeared to increase with water availability but that ultimately the patterns seen were idiosyncratic, suggesting that species visitation could not be explained simply by the presence or absence of water. As stated by Steward *et al*. (2012), the soil in dry riverbeds is highly retentive of organic matter and nutrients, thus enriching the surrounding vegetation. This makes it favourable to many species, including grazers such as cattle, which have been observed to feed in these habitats (Kassas and Imam, 1954). Furthermore, after a river dries up, species of terrestrial animals will consume any stranded matter such as dead fish or invertebrates (Williams, 2005). This could be another explanation for the highest visitation occurring in the month of February, immediately after the flood.

The sites show slight variation in species composition, and a greater variation in detection rate. The larger members of order Ungulata are associated together at occurring at similar places. Ungulata also made up the highest proportion of species found at 25%. The African wild cat (*Felis silvestris cafra*) and caracal (*Caracal caracal*) displayed the exact same detections across all three sites and all intervals (6 in total). Mann *et al*. (2014) undertook a camera trap survey in the Klein Karoo as well and recorded a total of 23 mammal species. Their study took place across three distinct biomes within the Klein Karoo, and consequently, higher species diversity is expected in their study than in the present study, which sampled only Succulent Karoo.

It is worth noting that the species accumulation curve showed relatively complete sampling of the medium-sized and large mammal community. Each site had a minimum of one species that was not detected in the others. The large number of unidentified triggers (which represented 10% of the total) bring forth the possibility that any species remaining may have already been detected but could not be identified. It is likely that undetected species include those found in similar studies and are difficult to detect, such as carnivores with low population densities like the aardwolf (*Proteles cristatus*), small-spotted genet (*Genetta genetta*) and striped polecat (*Ictonyx striatus*) (Mann *et al*., 2015).

Alternatively, smaller, typically-nocturnal mammals also prove difficult to detect, and species known to live around the study area include other members of the order Rodentia, Lagomorpha and certain members of Carnivora (such as the Cape fox, *Vulpes chama)* (Mann *et al*., 2015). Furthermore, it is possible any species that remain undetected may have large home ranges, or occur in the area only seasonally, and consequently have an extremely low detection probability.

Periodic natural floods are characteristic of this environment and visible effects are seen in the vegetation surrounding the river, with the vegetation becoming greener and more abundant. This was observed in the months following the flood of January 2018 (Figure 3). Considering that cattle often feed on the vegetation present, this is relevant for the agricultural practices of the area (Steward *et al*., 2012). Particularly in the Klein Karoo, there is a reliance on cattle and sheep farming (Maitre, Colvin and Maherry, 2009) and, as explained by Kassas and Imam (1954), cattle typically graze in dry riverbeds. February has the highest monthly temperature of the year. This increased heat could be another factor to explain the increased visitation rates in summer. It is unlikely that the increase in visitation rates in February was due to recruitment of juveniles to the population, as there was no noticeable increase in the number of juveniles observed of the larger mammals. Particularly in species of order Ungulata, there are clear morphological differences between juveniles and adults, thus identification is relatively straightforward.

There are independent associations of predator and prey species occurring. The appearance of caracal (*Caracal caracal*) in only six detections is expected because of their naturally low densities (Melville and Bothma, 2006). They were seen at all three sites, as were some species of their natural prey, such as birds and steenbok (*Raphicerus campestris*) (Avenant and Nel, 2002).

Variations in diurnal patterns of species were observed. Black-backed jackals are usually scarce when in an area with strong human presence, although they are known to appear more frequently where there is no such danger (Stuart and Stuart, 2015). As observed in this study, the remote nature of the location has led to an increased activity of jackals in daylight hours, frequently in pairs. The presence of certain ungulate species such as the eland (*Taurotragus oryx*) and South African oryx (*Oryx gazelle*) only at night is consistent with their behaviour, as typically these animals avoid the heat of the day, and forage at night when humidity is greater and vegetation is more hydrated (Grenot, 1992). Furthermore, the South African oryx (*Oryx gazelle*) in particular, does not require access to drinking water (Stuart and Stuart, 2015). This could account for why this species was not found in NPR1 which had perpetual water within the pool. Foliage was thicker in NPR2 and NPR3 as well.

Unidentified images occurred mostly during the night. Causes for an image being unidentified are typically the animal moving too fast against the sensor, or being too far away. This is a factor worth noting as flash photography may result in clearer images at night, but at the disadvantage of affecting animal behaviour, scaring certain species away from the area (Wegge, Pokheral and Jnawali, 2004).

While none of the mammals detected are endangered, certain species, such as the scrub hare (*Lepus saxatilis*), have decreasing populations (Robinson *et al*., 2019). This suggests that their presence in non-perennial rivers may grow in importance.

The inherent constraint of this study was the limited number of cameras which consequently affected sampling activity and restricted the scope of the study. Ideally, cameras should be implemented at comparable non-perennial rivers in the area to investigate similarities and differences in faunal assemblages. While sampling time was longer than in most other studies (e.g. Gonthier and Castañeda, 2013; Mann *et al*., 2014; Edwards, Gange and Wiesel, 2016), in order to accurately represent the surrounding environment, more sampling time would be valuable. For instance, Cusack *et al*. (2015) found that after 1400 camera trap days, placement choices are not likely to affect inferences made about the composition of communities. Most likely any mammals still undetected would be small, as identification is easier with bigger animals, and typically requires less refined studying. Examples of such taxa that may have been overlooked by the camera traps include shrews, hares, and small rodents. However, many such species have low water requirements and thus would not derive as much benefit from the water source as the bigger mammals seen in this study.

Further research should focus on motion-triggered photographs, as time-lapse photography typically generates lower detection rates coupled with a high output. This makes data analysis inefficient, as most photographs are discarded. This does come with its own drawbacks, as animals that would not trigger by motion (such as by being too far away from the camera, or being too small) would not be detected at all. This suggests that animals that surpass motion detection are more likely to be elusive in nature, such as carnivores. This is an explanation as to why one of the time-triggered detections was of a caracal (*Caracal caracal*) walking in the distance.

Overall, the camera traps were successful in their purpose for this study, and were able to capture the assemblage of medium- and large-sized mammal species of the area and was a valuable tool in this context. Such camera traps are less suitable for surveys that concentrate on other types of animals, such as small mammals or birds.

A species list of the mammals occurring along the non-perennial Prins River has been generated, representing the first of its kind for South Africa. None of the species are of current conservation priority, but may become so in future due to dwindling populations. Recharge events, as a result of heavy rainfall, are an important and natural part of the ecosystem. Visitation is higher immediately after such a recharge event, but the extent of this variation is site-specific, suggesting that the microhabitats that occur within a non-perennial river are diverse. Furthermore, non-perennial rivers have direct value in providing drinking water to animals as well as indirect benefits, such an enriching the surrounding vegetation. Non-perennial rivers differ widely from each other, and for this reason it is often recommended that these systems are studied on a case by case basis (Day *et al*., 2019). Future studies done on the faunal component of non-perennial rivers are objective dependent, but in order to have a robust comparison of community composition, more rivers need to be investigated.

The limited quantity of water that may persist within non-perennial rivers is often thought of as insignificant and not capable for attracting a diverse array of species (Gómez *et al*., 2005). As such, non-perennial rivers tend to be inadequately managed and are often abused and exploited (Steward *et al*., 2012). Moreover, current policies do not place any importance or value onto these systems in many parts of the world (Datry, Larned and Tockner, 2014), an example of which includes their lack of representation in European water policy (European Union Water Framework Directive, 2000). This way of thinking is inaccurate and the lack of protection given to these ecosystems will result in continued degradation. No mention is made of non-perennial rivers in South African water law and they are currently managed, inappropriately, as poorly-functional perennial rivers (Day, pers. comm). Non-perennial rivers represent an important resource for local animal communities. Sustainable conservation policy making and management should highlight non-perennial rivers as biologically relevant elements of the environment (Sánchez-Montoya *et al*., 2016). The objective of this study was to demonstrate that even in areas as seemingly 'lifeless' as the beds of a dry river, it is associated with a variety of species, and there are direct and indirect benefits for its perpetuated existence. While it may be assumed that non-perennial rivers are devoid of biodiversity, the reality is more complex.

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