The function of “plant biltong” collected by bush Karoo rats (*Otomys unisulcatus*)

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A dissertation submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg in partial fulfilment of the requirements for the degree of Master of Science.

Johannesburg, 2024

Declaration

I declare that this dissertation is my own unaided work. It is being submitted for the degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other university.

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10/05/2024

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ACKNOWLEDGEMENTS

This study was made possible by the Succulent Karoo Research station board members (Dr Carsten Schradin, Prof Neville Pillay, Lindelani Makuya) and the University of the Witwatersrand. Thank you for providing funding, the research facilities and equipment. Specifically, I would like to thank Prof. Pillay, Lindelani Makuya and Dr Carsten Shradin for reading through my drafts and providing me with feedback, all our research assistants who have contributed with data collection. I would also like to thank Prof. Ganzhorn, Univ. Hamburg, and his lab for providing data on chemical contents of plants. This has been an opportunity of a lifetime to work under the supervision of Professor Neville Pillay and Dr Carsten Schradin which exposed me to both international and local collaborators within my field but most importantly for introducing me to different aspects of animal behavioural ecology.

This study was approved by the animal ethics screening committee of the University of the Witwatersrand (Ethical clearance no: **2022/09/01/B**).

ABSTRACT

Food storing is a commonly observed strategy in many rodents living in environments with seasonally fluctuating food availability. Stored food allows small mammals to survive through food restricted periods and has been extensively studied in the northern hemisphere, characterised by cold winters. It could also be adaptive in semi-deserts of the southern hemisphere, such as the Succulent Karoo, which experience winter rainfall and hot dry summers. Here I want to understand the function of food plants carried back by bush Karoo rats (*Otomys unisulcatus*) to the stick lodges they build in the Succulent Karoo. Some of the food plants carried back to their lodges dry out, forming what I refer to as “plant biltong” or ‘plantong.’ To date, the function of the plantong remains unknown. Plantong might function as food in the dry season, or it might just be left over from food eaten at the lodge, or it can aid in construction of the lodges. I studied which plant species were collected as plantong, and whether there were seasonal differences in collection and consumption of plantong. I observed 15 lodges over 12 months and recorded the fate of plant pieces carried back to each lodge by bush Karoo rats. I tested experimentally whether they do eat the plantong. Plant species that were collected and dried out to become plantong were mostly annual shrubs (*Zygophyllum retrofractum*, *Lycium cinereum*, *Salsola zeyheri*, *Helichrysum)*, grass species (*Schismus*) and perennials species (*Atriplex, Drosanthemum spec, Galenia sarcophylla, Hermannia, Mesembryanthemum, oxalis sp, Chlorophytum crassinerve, Psilocaulon sp.*). Most plant pieces were collected in winter and spring which is in the moist season. Plantong was consumed the most in the autumn (end of the dry season). Collected plant pieces were multifunctional. Most, 68%, of plant pieces carried back to the lodge were eaten green before they became plantong, Of the plant pieces that were collected, 12% were later eaten as plantong, 11% was incorporated into the structure of the lodge, while the fate of 9% was unknown. Experiments in captivity showed that bush Karoo rats indeed eat plantong. Plantong was not stored for months (from moist to dry season), but mostly days to weeks. Thus, I regard plantong as a food source derived from leftover food during collection and consumption but not as stored food for later consumption during harsh conditions.

INTRODUCTION

Collecting and storing food is an important adaptation of many small mammals, especially rodents living in seasonal environments. Red squirrels (*Tamiasciurus hudsonicus*) and European hamsters (*Cricetus cricetus*) store and hoard food for the winter (Hurly and Robertson, 1989), when seasonal cold greatly reduces food availability (Van Vuuren and Armitage, 1991). There are two ways in which rodents hoard food, namely scatter hoarding and larder-hoarding (Giulia et al., 2022; Jenkins and Breck, 1989). Scatter hoarding is when collected food is stored in small quantities over a large area, while larder hoarded food is stored in a central area and large quantities, typically near nests or burrows (Jenkins and Breck, 1989). Stored food enables small mammals to survive through the food-restricted winter (Olenev and Grigorkina, 2014), when conditions are energetically and nutritionally demanding (Day et al., 1999).

In semi-arid desert or desert environments, small mammals have unique adaptations to cope with limited water and food resources (Huntley, 2023; Fuller et al., 2021; Walsberg, 2000). While collecting and storing food is a common survival strategy among many small mammals, those inhabiting arid regions tend to face challenges that need special adaptations and behaviours. For example, *heteromyid* rodents, such as kangaroo rats (*Dipodomys merriami*) and white-footed mice (*Peromyscus spp.),* are known for their ability to thrive on a dry diet without regular access to water (Fuller et al., 2021; Walsberg, 2000). In the semi-arid Karoo region of South Africa, many rodent species (ground squirrels (*Spermophilus citellus*); Namaqua rock mouse (*Aethomys namaquensis);* South African gerbil *(Gerbilliscus leucogaster)*, and Namaqua dune mole rat (*Bathyergus janetta*)), along with the elephant shrews, Cape elephant shrew (*Elephantulus edwardii*), and Short-eared elephant shrew (*Macroscelides proboscideus*)), use different adaptations to survive in such habitats (Huntley, 2023; Fuller et al., 2021; Van Deventer and Nel, 2006). These adaptations include efficient water conservation mechanisms and selective foraging behaviours that prioritise collection of seeds, roots, tubers which overtime retain moisture allowing for longer storage (Huntley, 2023). However, when it comes to collecting and storing only succulent leaves or leaves that change texture over time due to hot climates, there is little to no evidence, indicating a gap in our understanding of collection and storing of dry food plant in arid environments (Fuller et al., 2021).

The main physiological advantage of stored food is that it allows small mammals to maintain homeostasis by avoiding allostatic overload in harsh, food-restricted environments (Hau et al., 2016). Allostasis describes the stability through a period of change and is a process that maintains important physiological processes, such as blood glucose levels, within a narrow range, referred to as homeostasis (McEwen and Wingfield, 2003). The associated costs are called allostatic load, and when these costs are higher than the energy available from food, this is called allostatic overload (McEwen and Wingfield, 2003). Some small mammals such as the forest-dwelling ground squirrel (*Spermophilus saturatus*) store food of high nutritional value, providing sugar and fat as energy sources, which are consumed when food is scarce to avoid allostatic overload (Cork and Kenagy, 1989).

Apart from sugars and fat providing energy, other chemical contents determine the quality of plants stored as food. These include chemical contents, such as plant toxins, neutral detergent fibre (NDF), and acid detergent fibre (ADF) (Touzani and Sclafani, 2007). NDFs form part of the plant cell wall that animals cannot digest without specialised digestive morphology and processes. ADF forms part of the plant cell wall which even animal species with specialised digestive systems cannot digest (Palo and Robbins 1991). One important content is protein, often measured as crude proteins, which are essential for growth, maintenance, and reproduction (Speakman, 2008). Protein and other chemical contents mentioned above are key in the nutritional ecology of animals and their availability is affected by climatic seasonality (Ortmann et al., 2006; Schradin and Pillay, 2006).

Climatic seasonality influences the availability of food plants and their nutritional value (Droescher et al., 2016). Winter in the northern hemisphere is associated with long, harsh, and often snowy conditions. During this time, plants either die off or stop growing (Banks and Dickman, 2000; Korslund and Steen, 2006). This does not only affect their chemical composition but also their availability, thus impacting the availability of energy and nutrients for many animal species, especially herbivores with fewer food plants available, small mammals, especially rodents, evolved strategies to survive winters. One such strategy is food hoarding (Li et al., 2021). Red squirrels (*Tamiasciurus hudsonicus*) hoard hundreds of hickory nuts and conifer cones (Hurly and Robertson 1987). Hoarding in Siberian hamsters (*Phodopus sungorus*) is influenced by energy needs and is higher in lactating females and increases in autumn to provide food reserves for the winter (Daya et al., 1999).

Another seasonally food-restricted environments are semi-deserts, such as the Succulent Karoo in the southern hemisphere with rainy winters and hot dry summers (Jackson et al., 2002; Shradin C., 2005). Such seasonal climate variability here has an impact on the diversity and availability of food plants. Food availability increases in the moist winter, being at its maximum in spring, followed by very low food availability for several months in the hot and dry summer (Wolhuter et al., 2021). This might especially impact herbivorous animals. The Succulent Karoo is home to South Africa's smallest folivores of 100g body mass, the whistling rats (e.g., *Parotomys* spp) which feed primarily on leaves that are brought back to their burrows (Jackson et al., 2002). Another herbivorous rodent here is the closely related bush Karoo rat (*Otomys unisulcatus*), whose feeding behaviour is relatively poorly studied. Semi-deserts are characterised by seasonally high plant productivity, which could theoretically allow small mammals the opportunity to store food plants for the forthcoming food-restricted dry season. Whether such storage occurs is not known. My study focusses on the feeding and potential storage of busk Karoo rats in the Succulent Karoo.

The bush Karoo rat (*Otomys unisulcatus)*

- *Habitat and Ecology*

The bush Karoo rat is a member of the rodent subfamily Otomyinae. It is a diurnal species endemic to the Karoo (summer rainfall area) and the Succulent Karoo (winter rainfall area) of South Africa (Skinner and Smithers, 1994; Kerley and Erasmus, 1992). In the Succulent Karoo, it inhabits a semi-arid, highly seasonal environment, characterised by winter rainfall and a long food-restricted dry season with very high temperatures (Cowling et al., 1999). This habitat is dominated by leafy succulent plants with woody shrubs and ephemeral species that flower in spring (Jackson et al., 2002; Keller and Schradin, 2008). The adult body mass of the bush Karoo rat ranges between 70-135 g in weight in captivity (Pillay, 2001). Adults are brown grey with underparts that are whiter compared to neonates which are darker in colour at birth with naked ventral parts and pale fur (Pillay, 2001).

- *Nesting*

The habitat structure and environmental conditions influence small mammals, and they often build nests as refugees from variable and harsh environmental conditions. Members of the Otomyinae from both arid environments (i.e., *Parotomys brantsii, Parotomys littledalei* and *O. unisulcatus*) and mesic environments (i.e., *Otomys sloggeti*) typically build their nests in burrows (Deeming, 2022; Jackson et al., 2002). In contrast and very typical of bush Karoo rats (*O. unisulcatus*) is its extensive stick lodges built inside different shrub species (Brown and Willan, 1991; Jackson et al. 2002; Schradin, 2005), which offer good attachment for sticks to form lodges. The same shrubs have leaves that provide food (Brown and Willan 1991). The lodges are built up to 1 m high and 2.5m broad (Brown and Willan, 1991; Jackson et al. 2002), and are built using different materials such as sticks, grass, and animal dung (Deeming, 2022; Schradin, 2005).

The stick lodges provide protection against extreme climatic conditions, especially when temperatures reach above 400C in summer and during episodic cold fronts coupled with frosts and cold in winter (Brown and Willan, 1991; Schradin, 2005; Vermeulen and Nel, 1988). The lodges are well constructed such that they create a microclimate that is more stable than are outside conditions (Brown and Willan, 1991; Vermeulen and Nel, 1988). Inside the lodges, it is warmer in winter and cooler in summer than outside, and this reduces their thermoregulatory energy expenditure (Jackson et al., 2002). The bush Karoo rat is physiologically adapted to mesic environments and uses behavioural adaptations (lodge building, basking) to cope with semi-arid regions (Du Plessis et al., 1989; Jackson and Spinks, 1998).

- *Foraging behaviour and diet*

The bush Karoo rat is a generalist herbivore that feeds mainly on green plant pieces such as leaves, stems, flowers, and fruits (Brown and Willan, 1991; Pillay, 2001). They can slightly alter their diet depending on the season, habitat, and local availability of suitable food plants (Jackson and Spinks, 1998). Studies of the diet of small mammals have shown that their feeding patterns change seasonally to exploit available food, leading to changes in diet and migrating to areas of high abundance of food (Rymer et al., 2016; Du Plessis et al., 1991). For small mammals in harsh habitats (e.g.., bush Karoo rat in the arid Succulent Karoo) with the absence of free water, succulent plants also serve as water sources (Kerley 1989; Wolhuter et al., 2021). Foraging can be limited by the availability of plant cover which provides protection against predators and, as a result, bush Karoo rats forage closer to their lodges (Vermeulen and Nel, 1988). Thus, many interacting factors influence on foraging and diet patterns of the bush Karoo rat.

Central place foragers forage within close proximities to their defined shelters such that they can easily retreat into the shelter in case of any disturbance by a predator (Orians and Pearson, 1979). The bush Karoo rat can be considered as a central forager since it carries food plants back to its lodge and predominantly feeds and forages in close proximity to its lodge (Vermeulen and Nel, 1988). The bush Karoo can also be considered a larder hoarder since they collect food plants and place them in and on their lodges (i.e. larder hoarded food is stored in a central area and in large quantities, typically near nests or burrows (Jenkins and Breck, 1989)). Some of the food plants they put next to or on their lodges dries out forming what I refer to as 'plantong.' The common plant species collected include *Mesembryanthemum, Herpetalis,* and *Atriplex, Lycium*, *Psilocaulon,* and *Zygophyllum* (Hoepfl, 2013). Bush Karoo rats collect between 40 and 60 plant species, and most are known to form part of their diet (du Plessis et al., 1991; Jackson, 1989). The plantong might be stored for the dry season, or it could simply be left over from food taken to the lodge (i.e., the less nutritional parts of the plant piece carried back) or it might be carried there for lodge building. The function of plantong for bush Karoo rats is unknown.

Aim, objectives, and hypotheses

My study aimed to ascertain the function of plants collected by bush Karoo rats and especially of dried plants, the "plant biltong" or "plantong," derived from the Afrikaans combination of plant and tong, meaning a strip of dried plant, and related to the famous biltong, which refers to strips of dried meat. I addressed my aim through several questions and predictions summarized in Table 1. I studied which plant species are collected for feeding, which are stored as plantong, and which are used to build the lodge. I also studied the nutritional value of plantong and whether there is seasonality in plantong collection and consumption. For this, I monitored the fate of plantong over time. It is difficult to observe whether bush Karoo rats actually eat the plantong or it just disappears over time in nature and thus I also experimentally tested whether they do eat plantong in captivity.

Table 1: Questions and predictions based on the plant pieces brought to the nest by bush Karoo rats and the plant pieces that dry up and become plantong. The predictions are based on the hypothesis that bush Karoo rats store food in the form of plantong in the moist season to eat it in the food restricted dry season.

Questions	**Predictions**
What plant species are carried back to the lodge?	I predicted that plants carried back to the lodge are more often food plants than would be

	expected by chance (their abundance at the lodge being higher than in the field around the lodge).
Do plantong species have high nutritional value?	I predicted that the nutritional value of plant species collected for plantong is higher than the average nutritional value of all food plant species occurring on the field site.
Is there a difference between seasons in how much plantong bush Karoo rats collect?	I predicted that bush Karoo rats collect more plant pieces in spring (moist season) that will become plantong. I predicted that bush Karoo rats eat more plantong in the dry than in the moist season.
Plantong found in the dry season: Was it produced in spring (indicating hoarding food from spring for the dry season) or is it plant pieces collected a few days earlier that quickly dried in summer?	I predicted that the plantong found in the dry season is produced in spring. I predicted that the plant pieces collected will dry out quicker in summer (dry season) than in spring (moist season).
What happens to the plantong at a later time. Is it consumed, does it become part of the lodge, or does it decompose?	I predicted that plantong is eaten. I predicted that more plantong is eaten than used as lodge material.
If bush Karoo rats are presented with plantong in captivity for several hours, will they eat it?	I predicted that bush Karoo rats will eat plantong.

Aim: To investigate the function of "plantong" collected by bush Karoo rats (*O. unisulcatus*) by answering the following questions: Are the plant pieces that are left as plantong later used for consumption, does it contribute to lodge building, or does it disappear due to decomposition?

<u>Objective 1</u>: Ascertain whether plant species carried back to the lodge, either fresh or are identified at the lodge as plantong, are food plant species. Compare the abundance of plants carried back to the lodge with the abundance of plants in the field around the lodge.

I hypothesised that the abundance of food plants carried back to the lodge will be greater than the abundance in the field around the lodge.

H_O: There will be no difference in the relative abundance of food versus non-food plants carried back to the lodge.

H_{A1}: Food plants are carried back more often.

H_{A2}: Non-food plants are carried back more often.

<u>Objective 2</u>: To compare plant species collected for plantong with other species occurring around lodges regarding their nutritional value.

H_O: There will be no difference in the nutritional value of the surrounding plants compared to the plants collected for plantong.

H_{A1}: Plant species collected for plantong are of higher nutrition content compared to the surrounding plants.

HA2: Plant species collected for plantong are of lower nutritious compared to the surrounding plants.

<u>Objective 3</u>: To study seasonal collection and storage of plant pieces and consumption of plantong.

H_O: The amount of different plant species collected will not differ between the dry season and the wet season.

H_{A1}: There will be an increase in different plant species collected in the wet season than in the dry season.

H_{A2}: There will be a decrease in different plant species collected in the wet season than in the dry season.

H_O: The amount of plantong consumed will not differ between the dry season and the wet season.

H_{A1}: There will be a decrease in the amount of plantong consumed in the wet season compared to the dry season.

H_{A2}: There will be an increase in the amount of plantong consumed in the wet season compared to the dry season.

Objective 4: Establish what happens to plant pieces at the lodge over time Is it consumed fresh, dried (plantong), or it becomes part of the lodge?

While this is mostly descriptive part of my dissertation, I will test the outcomes against the following null hypothesis for the most common plant species collected by bush Karoo rats.

H_O: Most of the plant pieces will decompose over a 6-month sampling period.
H_{A1}: The plant pieces will be eaten fresh, so they will disappear before they decompose fully.
H_{A2}: The plant pieces will become part of the lodge and remain functional as lodge material over time.

Objective 5: To test whether bush Karoo rats eat plantong in captivity for 3 hours after trapping by presenting them with different plant pieces, both fresh and dry.

H_O: Bush Karoo rats will consume both fresh plants and plantong presented in captivity.
H_{A1}: The bush Karoo rats will eat plantong of known food species.

MATERIAL AND METHODS

Study site

The study was done at a field site of 5.5 ha next to the Succulent Karoo Research Station(SKRS) at Goegap Nature Reserve (10 km northeast of the town of Springbok) in the Northern Cape, South Africa. The area is arid and dominated by Succulent Karoo vegetation such as *Zygophyllum retrofractum* and *Lycium cinerum* (Jackson et al., 2002; Keller and Schradin, 2008, 2005). The area receives an average of 160 mm of rainfall a year (Jackson et al., 2002; Schradin, 2005) with temperatures ranging from -5 ℃ in winter to 42 ℃ in summer (Schradin, 2005). The study took place in all the seasons (spring, summer, autumn, and winter) with winter being the rainy season, and summer being the hot dry season.

Trapping

Adult bush Karoo rats were trapped with foldable Sherman traps and locally produced Sherman-like traps. Traps were baited with a mixture of bran flakes and sunflower oil and placed in the shade around stick lodges. Trapping was done both in the morning and afternoon for 1.5 hours. Traps were checked twice with an average interval of 30 minutes between rounds. There were five areas trapped in the field site in which two were trapped per week. The sex of trapped individuals was ascertained by examination of the ano-genital distance (shorter in females than males), and their body mass was recorded with a scale to one decimal place. For identification of trapped individuals, I attached metal ear tags with a unique code on each ear. I used even numbers for females and odd numbers for males. To allow for easy identification, especially during behavioural observations (below), I applied various colours of non-toxic hair dye (black, red, blonde) in different patterns onto the pelage of the rats (see Figure 1). Rats were released at their site of capture or taken to a nearby laboratory at SKRS which is about 5 min away from the field site for experiments in captivity (see below).

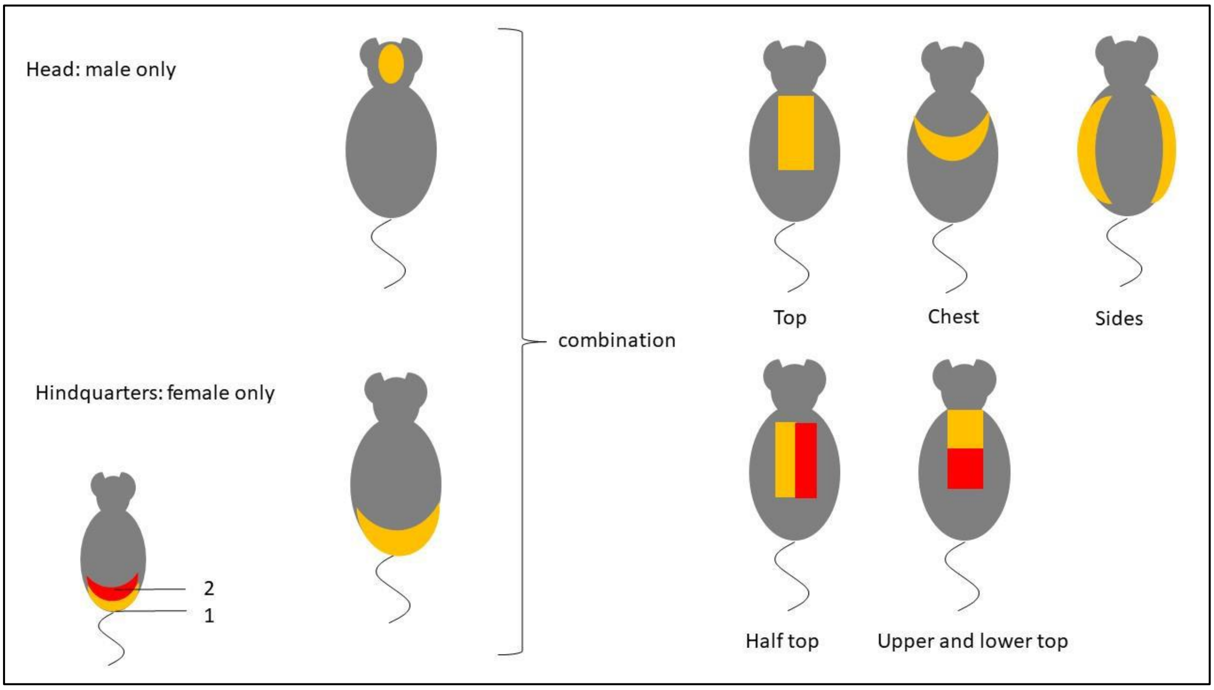


Figure 1: Representation of different non-toxic hair dye patterns and positions used to identify bush Karoo rats (*Source: Lindy Wolhuter*).

Behavioural observations

Behavioural observations were conducted to ascertain which plant species the bush Karoo rats feed on, which ones were carried back to the lodge, and which ones became plantong. This was done approximately five metres away from the lodge in the early morning at sunrise and in the late afternoon before sunset. Before observations started, all food plant pieces were identified on and around the lodge. The food plant pieces were characterised as fresh plant pieces (plant pieces collected on the same day), green plant pieces (plant pieces that looked older but not dry), or dry plantong (plant pieces completely dry). Behavioural observations involved focal animal sampling (Schradin, 2005), in which observations were done for 30 min and behavioural patterns were recorded every minute per individual rat. Recorded behaviours (Table 2) included whether the individual carried sticks or food plants, whether it was feeding, which plant species was eaten and to which category the plant belong: fresh, green, or plantong. Binoculars were used when it was unclear what the rat was doing and what plant species was collected. Following observations, I looked for the plant species collected around and on the lodge.

Data were collected from January 2022 to July 2023 by several researchers and students. In total, there were 998 observations done on 121 lodges with 164 bush Karoo rats (averaging to at least one individual per lodge). Lodges were selected randomly in areas not trapped on that particular day. From these data, I collected information on the plant species at the lodge, and whether they were fresh, green, and plantong. I ranked how commonly they were observed to generate frequency scores. This allowed me to generate the ratio of food plants to non-food plants at lodge. Furthermore, I used data collected during nest observations to analyse what plant species were consumed on site, stored as plantong, or carried for lodge building.

Table 2: Behaviours that were recorded and their descriptions during focal observations.

Behaviour	**Description**
Feeding	When the individual was actively eating a piece of plant.
Carrying stick	When the individual dragged a dry piece of stick to a focal lodge.
Carrying food	When the individual dragged a piece of food plants to the focal lodge.
Lodge building	When the individual manipulated the lodge through moving sticks or other material (e.g., dung) from one position to the next.

Plant species abundance around the lodges

Plant surveys were done around 12 occupied bush Karoo rat lodges, randomly selected at beginning of March 2023, June 2023, September 2022, and December 2022. A square area of 100m^2 with the lodge in the centre was marked using 4 iron rods(10x10m). Within the square, all plant species, and the percentage of the area they covered were recorded as metric of their abundance.

Nutritional value of plant species

Data on the nutritional content of plant species from the field site were available from the University of Hamburg (Ganzhorn et al., 2016). The plant samples were collected by Dr. Rebecca Rimbach and were then analysed in the laboratory of Prof. Ganzhorn. The data consisted of chemical contents for 31 plant species found within the field site (supplementary Table S4). I compared the nutritional value (see Table S3) of (1) food plants versus non-food plants for bush Karoo rats and (2) plant species that became plantong versus species that did not.

Marking of plant pieces

I used the same 12 lodges occupied by the bush Karoo rats which were used to ascertain the abundance of plant species around the lodge. For the lodges that were abandoned by the bush Karoo rats before data collection was finished, a new lodge was selected for study, and the unoccupied one was monitored for any changes should the inhabitant return. Lodges were separated into two groups of six, with one set of six lodges being checked on the same day, and the other six the next day. Lodges were monitored five days a week.

To follow the fate of fresh plant pieces observed at lodges (presumed to have been carried there by the rats), I marked 12 pieces of fresh plant pieces at each of the 12 lodges. Marking of plant pieces took place from July 2022 until August 2023 from the same lodges where plant surveys were done. I used a non-toxic food dye applied using a 250ml spray bottle. A pilot study in captivity showed that the non-toxic food dye did not influence plant selection and all dyed plant pieces presented were eaten during the experiment. From the 12 lodges if a piece of marked plant pieces disappeared, I chose a new fresh piece of the same species that was closest to the old plant pieces position that disappeared. Also, I recorded when a new plant species was collected. This was done to understand whether plant pieces met their fate (1) while they are fresh, green, or dry. (2) Fresh plants were chosen because they allowed me to follow their fate over time until they became part of the lodge or any other fate. (3) Disappeared implied ingestion but also the condition they were ingested was also important. (4) The same plant species was chosen to understand which plant species were used mainly for building, consumed fresh or green. "closest to the old plant pieces. This was not always possible in the dry season since plants in the field during this time were dry, especially the perennial plants; the annual shrubs i.e., *zygophylium, lycium* and *Salsola* were unaffected. As a result, there were less than 12 pieces marked at the lodges.

The condition of marked plant pieces was recorded three times a week as follows: 1) is it present or disappeared; 2) the state of the plant pieces (fresh, green or dry); 3) the position of plant pieces in relation to the shrub (base, middle or top); 4) the final fate of the plant, such as eaten green (bite marks and disappeared withing a day from being marked), eaten as plantong (dry plant piece with bite marks), became lodge building material (plant pieces stacked with new plant pieces or sticks), decomposed (plant piece does have any function nor eaten or building material) or unknown (plant pieces that were marked and not given final fate). From this, I calculated the number of days it took the plant to meet its fate. Bush Karoo rats collected plant pieces and stacked them in their lodges; as a result, some of the marked plant pieces were covered and thus not visible over time, plant pieces used were recorded as being part of the lodge. These processes were used to ascertain the final fate of plant pieces and when (after how many days) this happened.

Experimental plantong presentation

Plant preparation. Fresh plant pieces were collected within the Succulent Karoo Research Station without any impact on the field site. The plant pieces collected were from the three most abundant food plant species on my field site: *Galenia sarcophylla, Mesembryanthemum guerichianum,* and *Psilicaulon spp*. The plant pieces were cut into sizable pieces of 1.5g (fresh material) which is similar to the sizes selected and carried by the bush Karoo rat in the field. Half of the plant pieces were frozen, and the other half dried as plantong in a plastic box with holes placed into the sun to create a greenhouse effect. I preferred freezing the plant pieces over using fresh material since, during the trials in the dry season, no fresh plant pieces were available in the field. To test whether freezing had an effect, I also presented fresh plant pieces during trials in the moist season (see below).

Experimental procedure. Bush Karoo rats were trapped early in the morning. A total of 72 individuals were used throughout the study. Four individuals were captured and all four were tested individually in the tanks on the same day. The individuals were kept in captivity for three hours during the experiments. All experiment started at 9:00 AM in a field laboratory (6×3 metre Wendy house) at room temperature. The laboratory used LED fluorescent lighting to avoid adding significantly to the laboratory temperature (https://youtu.be/mJNtPmvJIOM). The rats were trapped for three different types of treatments, as indicated in Table 3:

Table 3: The three experiments, season, and time they were conducted and the type of experiments and conditions.

Experiment No.	Sample size	Period of experiment	Plant pieces condition
#1	24	Dry season (March 2023) Moist season (September – October 2023)	Frozen and dried plant pieces

#2	24	Moist season (November 2023)	Fresh and dried plant pieces
#3	24	Dry season (January 2023)	Fresh, dried, and frozen plant pieces

During the three hours in captivity, the rats were individually housed in tanks measuring 45x35x30 cm, furnished with wood shavings and provided with different food plant pieces, depending on the type of experiment. The food plant pieces were presented on a plastic tray at one side of the cage. Before the experiment, all plant pieces were weighed to approximately 1.5 g wet mass each. After the experiment, the remaining plant pieces were weighed to determine how much was eaten by the bush Karoo rats. Control plant pieces (previously frozen and fresh) placed outside but next to the cages were also weighed to account for loss of mass due to evaporation. Water was provided *ad libitum* during the experiments. The behaviour of the rats was video recorded using a Canon web camera during the three-hour feeding trial to minimize disturbance. The camera footage was later analysed using BORIS software to record the order (choice) in which the rats consumed different plant pieces. To record choice, a score of 1 represented the plant eaten first, 6 represented the last plant pieces eaten and 7 represented food plants that were not eaten (Experiment 1 and 2). To record choice in experiment 3, a score of 1 represents the plant eaten first and 9 represents the last plant pieces eaten and 10 represented food plants that were not eaten. At the end of the experiment, the bush Karoo rats were given bait consisting of a mixture of all-bran flakes, salt, and oil, provided *ad libitum* for 60 minutes. This compensated for any lost foraging opportunities. The bush Karoo rats were then released back to their lodges after the experiments.

Statistical analysis

All statistical analyses were conducted in R version 4.2.2 (R core team 2022) with the model significance set at 0.05. My first question was descriptive, for which I provided a list of all plant species collected at the lodges and ranked them according to how often they were observed. To analyse whether season influenced the abundance of food plants and plantong species around a 10x10 m area occupied bush Karoo rat lodges, I used an ANOVA with post-hoc test to compare seasons and pairwise combination, i.e. comparing spring vs autumn or autumn vs winter. Plant species around the lodges were categorized into four groups based on their usage: collected for plantong, not used as plantong, collected for food, and not collected as a food plant. To test whether bush Karoo rats were more likely to carry food than non-food plants to their lodge, I used a Wilcoxon matched pairs signed ranked test to compare the percentage food plants carried back to each lodge against the percentage of food plants occurring around the lodge. For plant pieces carried back to the lodge, I used Wilcoxon matched pairs signed ranked test to compare the percentage food plants at lodge relative to percentage of what was around the lodge, with each lodge having one data paint for each of the four seasons.

My second question was about the nutritional value of plantong. I used an unpaired t-test to compare each chemical content between food- and non-food plants, and between plantong and non-plantong. I also used Spearman correlations to assess the strength and direction of the relationship between chemical content and abundance of plants collected for food and non-food species. For chemical components such as Dragendorff, Wagner, react with alkaloids which are secondary nonprotein nitrogen compounds that are present in plant as amino groups (-NH_2), imine groups (-C=N-), or aromatic rings, and I used a simple t-test comparing between plant species in which these values were positive (1) vs negative (0).

For my third question on seasonal difference on collection and consumption of plantong, I analysed the number of different plantong species found at the lodges in spring (September to November), summer (December to February), autumn (March to May), and winter (June to August) using a GLMM, using the formula: number of dry plant pieces at nest = season + lodge number as random factor. For consumption, I used Kruskal-Wallis tests with post-hoc test Mann-Whitney U tests to analyse whether the consumed plant pieces differed by season. I also analysed the number of plantong that had disappeared (assumed to be eaten) from the lodges in the four-season using a GLMM, using the formula: (number of plantong that disappeared from nest) = season + lodge number as random factor.

For my fourth question about what happens to the plantong over time. For each plant species, I analysed the most common outcome (eaten green) with the other outcomes combined compared to an outcome by chance (50:50) using a Fisher`s exact test. For example, if I marked 100 *Mesembryanthemum* pieces and found 90 to be eaten green, 4 to be eaten dry, 2 to be part of lodge building and 4 to be Unknown, the ratio of 90:10 was compared to the null ratio of

50:50. I also used a one-way ANOVA Kruskal-Walli's post-hoc test to compare all the season and combinations.

For my last question on whether bush Karoo rats ate plantong in captivity, for each of the experiments above I used a GLMM to analyse for the consumption and choice in food plant pieces, using these formulae: % consumption = plant species + condition (frozen, dry) + ID (bush Karoo rat (BKR)); and for choice = plant species + condition (frozen, dry) + ID (bush Karoo rat (BKR)). I also ran GLMM for intermediate season (in between the moist and dry season) where season was not a variable: % consumption = plant species + condition (fresh, frozen, dry) + ID (bush Karoo rat (BKR)), also for choice = plant species + condition (fresh, frozen, dry) + ID (bush Karoo rat (BKR)). I also used Fisher's exact tests per plant species, which analysed the ratio of plants eaten green versus the combined value eaten dry, building material and unknown.

RESULTS

<u>What plant species are carried back to the lodge?</u>

In total, 28 different plant species were identified at the field site, of which 21 species (75%) were observed around the lodges (10x10 m around the lodges) and at the lodges (Supplementary Table S1). At the lodges, 14 species (50% of all species) were fresh, 12 of which (57%) were also as green, and 11 (61%) were also as dry (plantong). In total, 2847 plant pieces were recorded at the lodges (data from behavioural observations), of which 615 were fresh, 954 green and 1278 dry plantong (Figure 2).

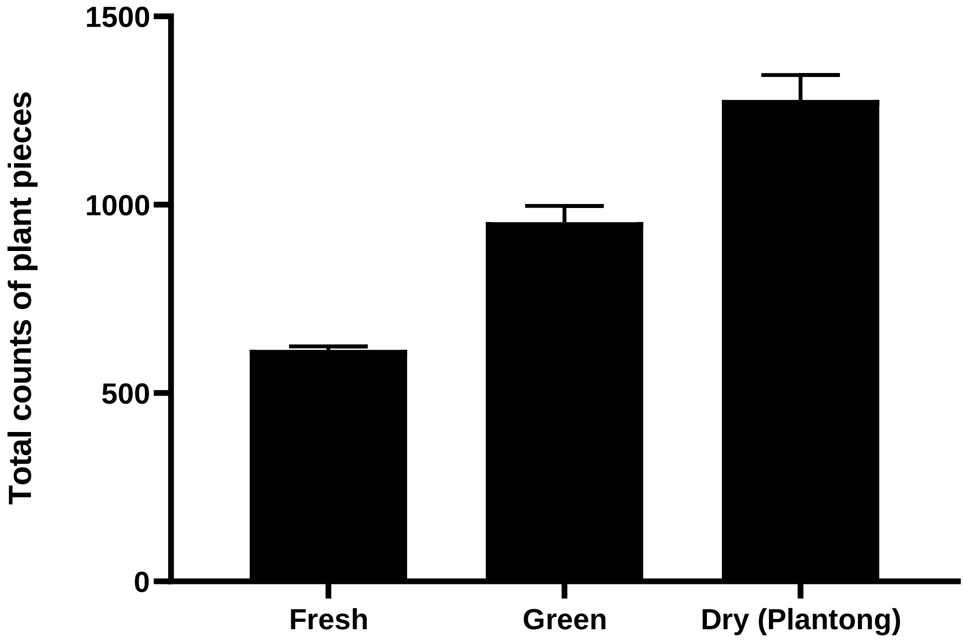


Figure 2: Total number of plant pieces recorded at lodges (data from behavioural observations).

Most plant species (17 of 22; 77%) carried back to the lodges were food species (data from 48 lodge surveys). The five plant species that were not used for food were mostly dry wood and other species, such dry reeds, *Chlorophytum crassinerve* and *Ornithogalum secundum*, which were not seen to be consumed by bush Karoo rats but used for lodge construction. In all four seasons, most plant species at the lodges were food plants: 92% in spring (11 of 12 species), 91% in summer (10 of 11 species), 80% in autumn (4 of 5 species), and 59% in winter (10 of 17 species). For plantong alone, the results were similar: 75% of dry plant species were food plants (9 of 12 species): 73% in summer (8 of 11 species), 80% in autumn (4 of 5 species), and 65% in winter (11 of 17 species; Supplementary Table S2).

The percentage 10 ×10 m area surveyed around lodges covered by all plants varied significantly over the seasons (repeated measures ANOVA, $F_3=4.240$, $p=0.036$; Figure 3), with spring being greater than autumn (Tukey-Kramer Multiple Comparison Test, $p<0.05$; Figure 3). Similar results were found around lodges covered by food plants, which varied significantly over the seasons (repeated measures ANOVA, $F_3=3.156$, $p=0.034$), and again spring being significantly different to autumn (Tukey-Kramer Multiple Comparison Test, $F_3=4.122$, $p<0.05$; Figure 3). The area covered by plantong was influenced by season (repeated measures ANOVA, F

$_3$=3.334, p=0.0344), being significantly greater in spring than autumn (Tukey-Kramer Multiple Comparison Test, F_3=4.264, p<0.05; Figure 3). Percentage of food plants carried back to the lodge plants was significantly higher compared to the percentage of food plants growing around the lodges (W= -67, p= 0.017, N=12 lodges, Wilcoxon matched pairs signed ranked test; Figure 4).

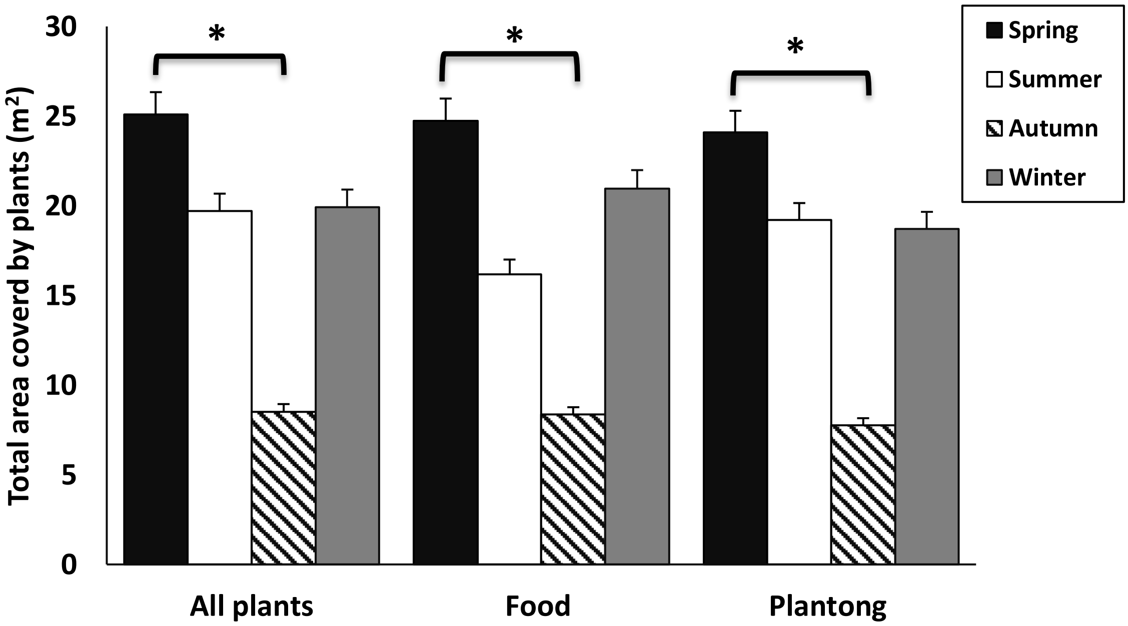


Figure 3: Mean ± StDev of how much food plants and plantong covered the 100m^2 area round occupied bush Karoo rat's lodges in the different seasons. N=12 lodges per season. Asterisks: 0.05 (*), 0.01 (**), and 0.001 (***).

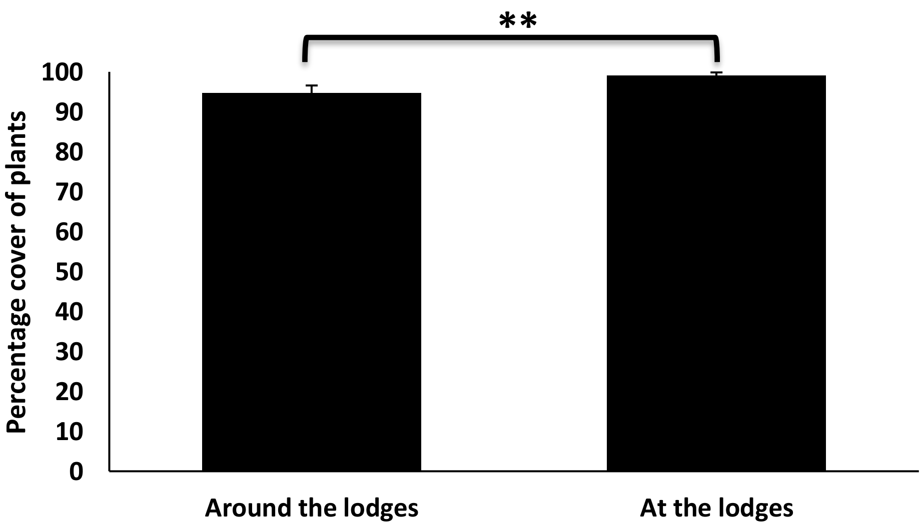


Figure 4: Percentage of food plants growing around the lodges (100m^2 area; N=12 lodges, with each lodge having one data paint for each of the four seasons) compared to the

percentage of food plants carried back to the lodge. Asterisks: 0.05 (*), 0.01 (**), and 0.001 (***).

Do plantong species have a high nutritional value?

The chemical composition of food and non-food plants showed notable differences in various chemical components measured (Figure 5). The crude protein content (14.01 ± 3.83, $t_{35} = 2.08$, p = 0.045), nitrogen (2.34 ± 0.61, $t_{35} = 2.08$, p = 0.045), and BioRad (soluble energy) (t_{35} = 2.05, p = 0.048) of food plants was significantly lower than those of non-food plants, while water content (71.94 ± 12.64, $t_{35} = 3.39$, p = 0.031) was high in food plants compared to non-food plants (Table 4). The remaining chemical components were not significantly different between food and non-food plants (Table 4). For the comparison of plantong versus non-plantong plants, the sugar content of plantong was half of that of non-plantong plants (Table 5). The ash content was almost two times higher in plantong than non-plantong species (collected green by us and then dried before measurements). The remaining chemical components did not differ significantly between plantong and non-plantong (see Table 5)

Most correlations between the abundance of plants found at lodges (collected by bush Karoo rats) and chemical contents were non-significant (Table 6). The exceptions were sugar content (r = -0.537; p < 0.001) and concentrated Polyphenol (r = -0.385; p = 0.0223), both of which decreased as the number of pieces increased at the lodges (Table 6).

Table 4: Chemical content of food and non-food species occurring around lodges. Analyses were done using the unpaired t-test between food and non-food-plants. Significant outcomes are indicated in bold. NA in chemical component such as Wagner, Mayer, and Dragendorff (these are reagents that react to alkaloids which are secondary nonprotein nitrogen compounds that are present in plant as amino groups (-NH2), imine groups (-C=N-), or aromatic rings) due to the measurement being positive (1) and negative (0). This is the proportion of samples (out of the total N) that had the relevant component, as such it's qualitatively different from the % of plant content (presumably per plant) that is fat %, BioRad %, or Sugar % etc.

Chemical content	**Food (N= 31 plant species)**	**Non-food (N= 4 plant species)**	**Test statistic**	***p***

Crude protein%	14.01 ± 3.83	19.45 ± 9.15	t_{35}=2.08	**0.045**
N%	2.34 ± 0.61	3.11 ± 1.46	t_{35}=2.08	**0.045**
BioRad %	5.30 ± 1.56	6.86 ± 3.10	t_{35}=2.05	**0.048**
NDF %	26.50 ± 16.21	25.94 ± 11.47	t_{35}=0.20	0.841
ADF %	14.88 ± 8.27	14.09 ± 9.07	t_{35}=0.18	0.860
Sugar %	16.65 ± 8.06	16.96 ± 4.84	t_{35}=0.66	0.498
Cons-Tann %	0.08 ± 0.25	0	NA	NA
Cons-Polyph%	1.51 ± 1.23	0.77 ± 0.15	t_{35}=0.73	0.471
Fat%	3.67 ± 1.64	2.12 ± 0.97	t_{35}=1.14	0.262
Ash %	16.27 ± 9.01	7.06 ± 0.18	t_{35}=1.84	0.074
		1±0		
Dragendorff (present/absent)	0.52 ± 0.51		NA	NA
Mayer(present/absent)	0.52 ± 0.51	1±0	NA	NA
Wagner(present/absent)	0.52 ± 0.51	1±0	NA	NA
Water%	71.94 ± 12.64	60.61 ± 9.03	t_{35}=3.39	**0.031**

Table 5: Chemical content of plantong and non-plantong species occurring around lodges Analyses were done using the unpaired t-test between food and non-food-plants. Significant outcomes are indicated in bold. NA in chemical component such as Wagner, Mayer, and Dragendorff (these are reagents that react to alkaloids which are secondary nonprotein nitrogen compounds that are present in plant as amino groups (-NH2), imine groups (-C=N-), or aromatic rings) is due to the measurement being positive (1) and negative (0). This is the proportion of samples (out of the total N) that had the relevant component, as such it's qualitatively different from the % of plant content (presumably per plant) that is fat %, BioRad %, or Sugar % etc.

Chemical content	**Plantong (N= 10 plant species)**	**Non-plantong (N=25 plant species)**	**Test statistic**	***P***
Crude protein%	14.09 ± 3.79	15.34 ± 5.17	t_{32}=0.31	0.756
N%	2.25 ± 0.61	2.45 ± 0.83	t_{33}=0.69	0.496
BioRad %	4.85 ± 1.58	5.35 ± 1.93	t_{33}=0.72	0.474
NDF %	21.36 ± 11.10	26.85 ± 17.02	t_{33}=0.94	0.355
ADF %	9.82 ± 6.41	15.13 ± 8.49	t_{33}=1.78	0.084

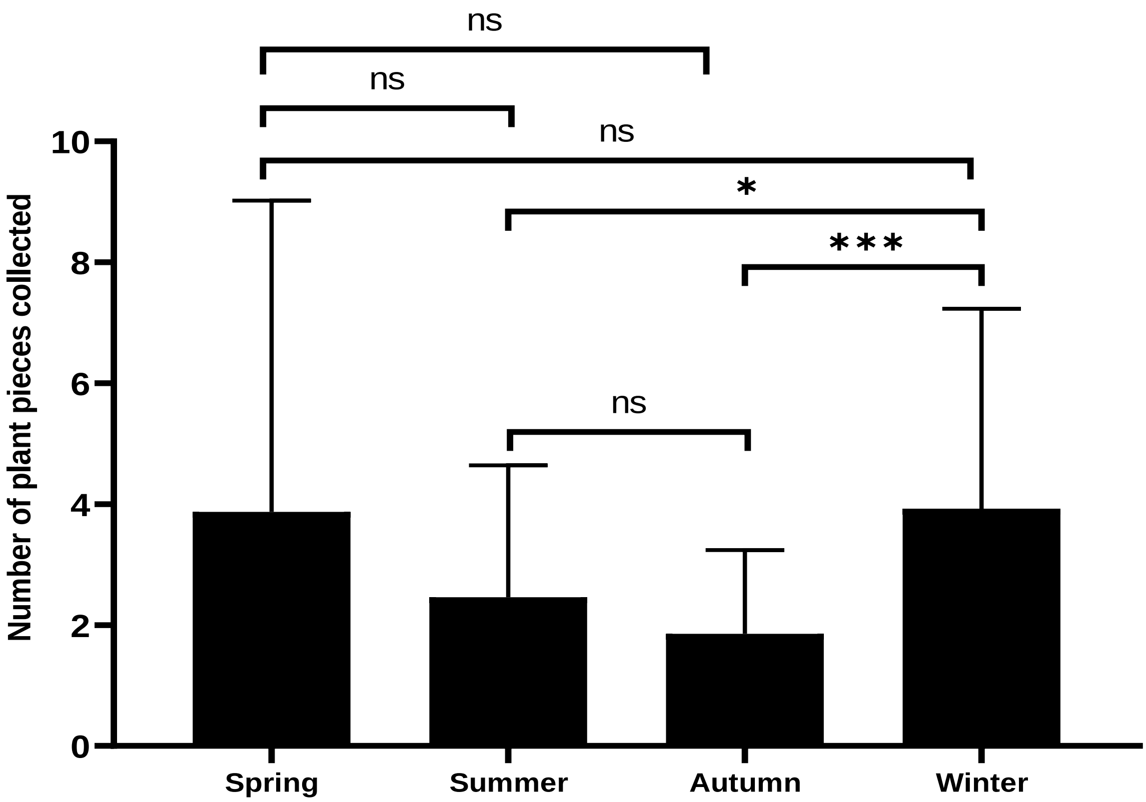
Sugar %	9.17 ± 5.59	17.22± 7.35	t_{33}=3.11	**0.004**
Cons-Tann %	0.16 ± 0.43	0.02 ± 0.08		0.612
Cons-Polyph%	1.39 ± 1.90	1.11 ± 0.74	t_{33}=0.63	0.535
Fat%	2.62 ± 1.18	3.31 ± 1.74	t_{33}=1.15	0.259
Ash %	21.08 ± 11.17	12.87 ± 6.87	t_{33}=2.65	**0.012**
Dragendorff (present/absent)	0.9±0.35	0.44±0.51	NA	NA
Mayer(present/absent)	0.9±0.35	0.44±0.51	NA	NA
Wagner(present/absent)	0.9±0.35	0.44±0.51	NA	NA
Water%	73.15 ± 14.66	69.64 ± 12.02	t_{33}=0.73	0.469

Table 6: Spearman correlations between chemical content and abundance of plants collected by bush Karoo rats and carried back to the lodge. Significant outcomes are indicated in bold.

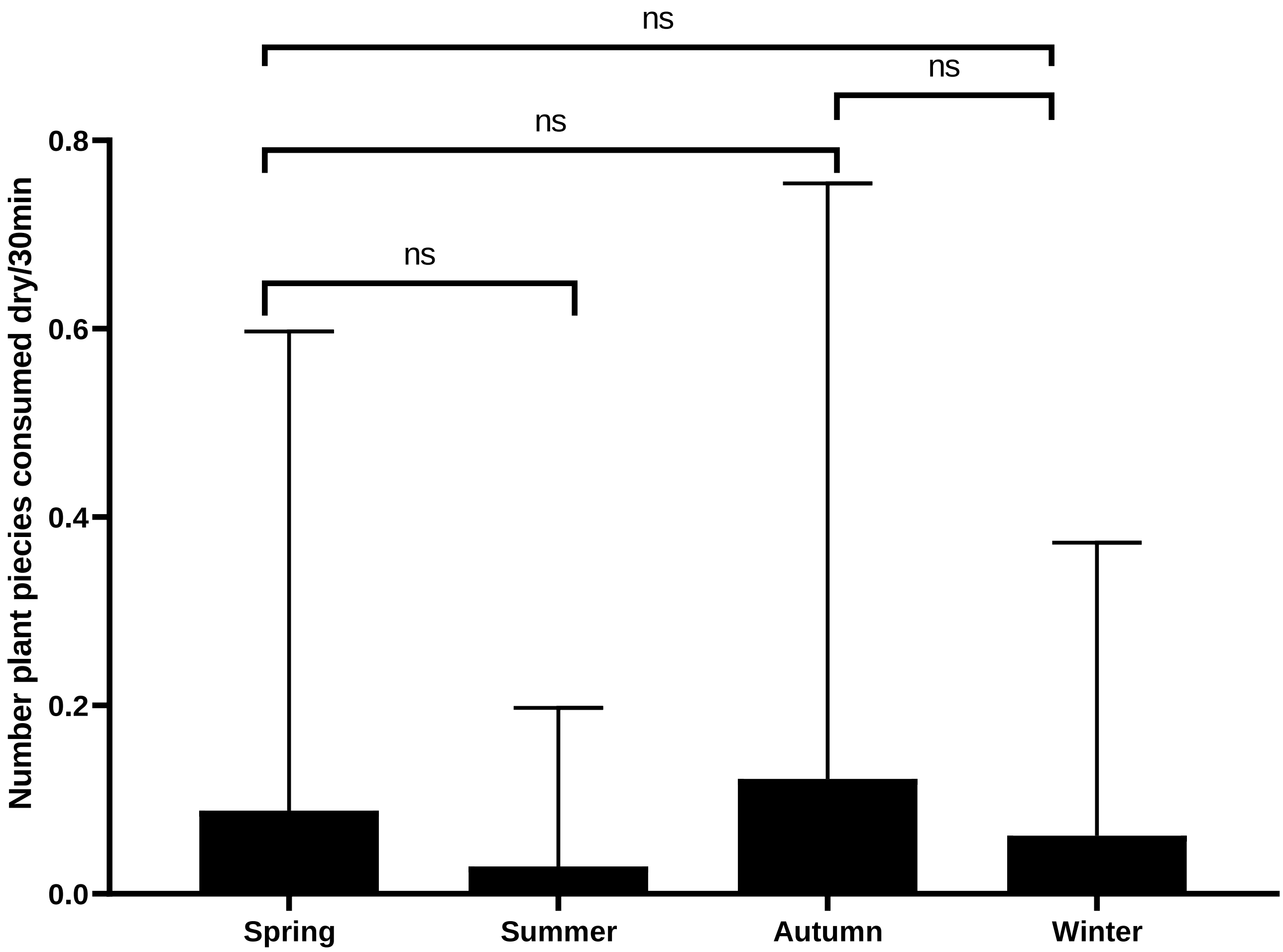
Chemical content	**Spearman (r)**	***P***
Crude protein%	-0.190	0.274
N%	-0.190	0.274
BioRad %	-0.295	0.085
NDF %	0.034	0.846
ADF %	-0.176	0.313
Sugar %	-0.537	**0.001**
Cons-Tann %	-0.010	0.956
Cons-Polyph%	-0.385	**0.022**
Fat%	-0.329	0.054
Ashes %	0.184	0.180
Water%	0.088	0.617

Is there a difference between seasons in how much plantong bush Karoo rats consume and collect?

Plant pieces that were observed at the lodge were significantly lower in summer than winter (KW=22.311, p = 0.025) and lower in autumn than winter (KW=22.311, p = <0.001) (Figure 5). No significant difference was observed in other seasonal comparisons (Figure 5). The consumption of plantong was higher in autumn but no significant difference was observed across the seasons (Figure 6). A generalized linear mixed model indicated that the number of different plantong species at a lodge was significantly influenced by the season. To test how the number of dry plant pieces collected by the bush Karoo rat differed between seasons, I used a generalised linear mixed models which showed a significant difference only between spring and autumn with $t_3 = -2.777$, $p = 0.033$ and not in the other comparisons (Table 7).



<u>Figure 5</u>: Mean ± StDev of plant pieces observed being collected by the bush Karoo rat in the various seasons at the lodge during 30 min observations. In total, 210 observations were done in spring, 169 in summer, 166 in autumn, and 260 in winter. Statistical significance using multiple comparison (Kruskal-Wallis test with subsequent Mann-Whitney-U test) is represented as 0.05 (*), 0.001 (***).



<u>Figure 6</u>: Mean ± StDev of plantong pieces observed to being consumed by bush Karoo rats in the various seasons at the lodge during 30min observations. In total, 136 observations were done in spring, 310 in summer, 336 in autumn, and 210 in winter. Statistical significance is represented as 0.01 (**), 0.001 (***) with non-significant as (ns) generated using Kruskal-Wallis test with subsequent Mann-Whitney-U test.

<u>Table 7:</u> Results of the generalised linear mixed models to test how the number of dry plant pieces collected by the bush Karoo rat differed between seasons. Significant outcomes indicated in bold.

Predictors	**Estimates**	**t-ratio**	***p***
Autumn *Spring	-7.213	-2.777	**0.033**
Autumn *Summer	-4.671	-1.799	0.281
Autumn *Winter	-7.459	-2.995	0.183
Spring *Summer	2.542	0.962	0.771

Spring *Winter	-0.246	-0.094	0.999
Summer *Winter	-2.788	-1.067	0.711

Is there a difference in how much plantong bush Karoo rats collect seasonally? (Results from marked plant pieces)

I marked plant pieces across the four seasons at 12 focal lodges to follow their fate. Results from this dataset confirm the previous results of focal observations: Bush Karoo rats collected most plants in winter, followed by spring, autumn and summer (spring vs summer, t_3=8.52, p = <0.001; (spring vs autumn, t_3=6.72, p = <0.001; spring vs winter, t_3=15.90, p = <0.001; summer vs autumn, t_3=5.02, p = 0.01; summer vs winter, t_3=15.12, p = <0.001; autumn vs winter, t_3=21.08, p = <0.001; Figure 7).

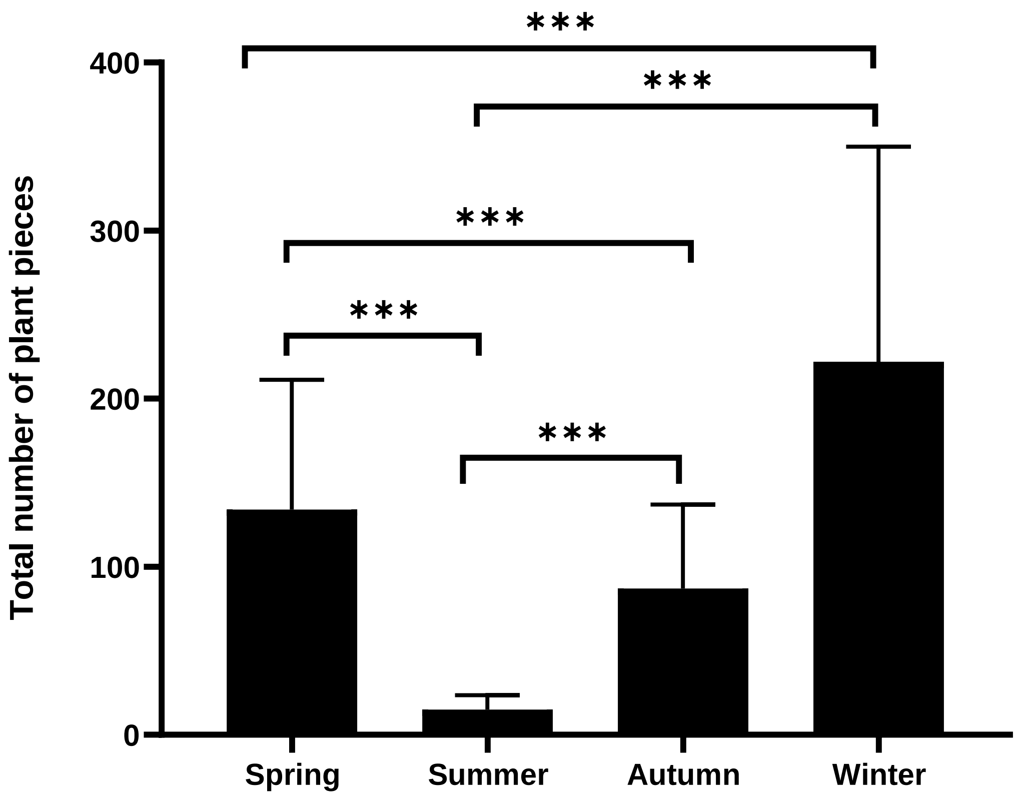


Figure 7: Total number with StDev of (marked) plant pieces collected by bush Karoo rats in the varying seasons. Data are from marked plant pieces around and at lodges and not from observations. Statistical significance using one way ANOVA post-hoc test represented as 0.01 (**), 0.001 (***).

What happens to the plantong over time: is it consumed, does it become part of the lodge, or does it decompose?

From all marked plant pieces carried back to the lodge, 68% was eaten green before it became plantong, 12% was later eaten dry (as plantong), 11% was incorporated into the structure of the lodge, and the fate of 9% was unknown (Supplementary Table S5).

I investigated how the bush Karoo rats utilised the different plant species. In total, there were N=12 different plant species at the lodges (Supplementary Table S5). All 12 plant species were eaten green, and all plant species except *Helichrysum*, *Hermannia,* and *Lycium cinereum* were eaten as plantong. All plant species, except *Drosanthemum hispidum*, *Helichrysum* and *Hermannia* were used as lodge building material (Figure 9). Plant pieces eaten green were consumed in 4±2 (mean ±SD) days, plantong was eaten in 6±5 days, and the remaining plant pieces formed part of lodge building material after 16±11 days (Figure 8). Fisher`s Exact tests used to analyse the number of plants eaten green versus the combined total of eaten dry, used for building material and unknown, showed that significantly more of the following species were eaten green: *Atriplex lindleyi*, *Drosanthemum hispidum*, *Mesembryanthemum*, *Psilocaulon sp.*, *Salsola zeyheri*, *Zygophyllum retrofractum*, *Lycium cinereum* and *Loranthus* (Table 8 and Figure 9). In contrast, *Senecio arenarius*, *Helichrysum*, and *Juncus acutus* had similar consumption patterns across categories (Table 8).

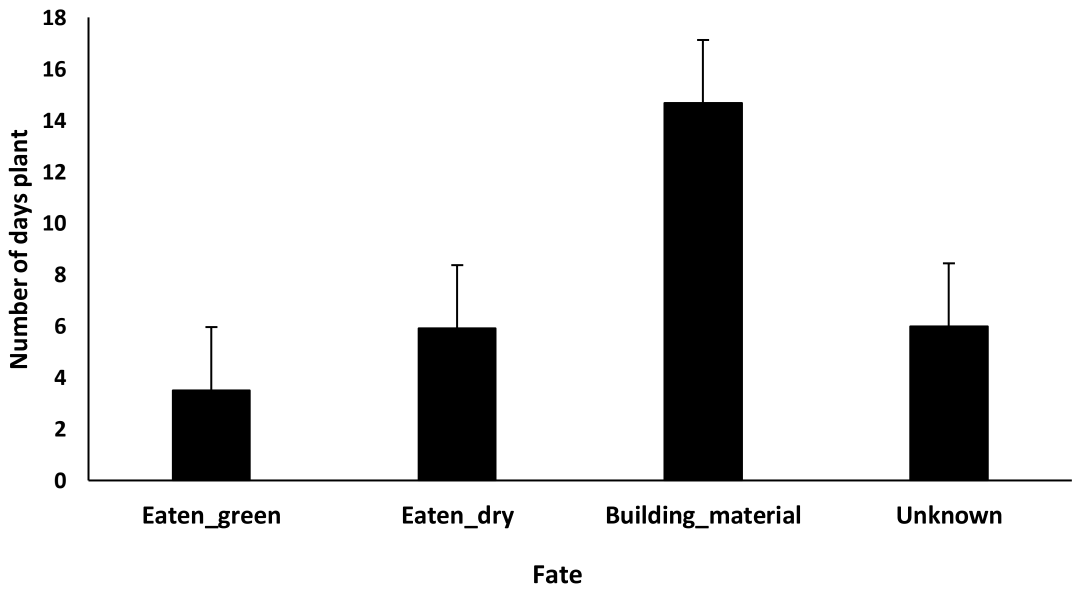


Figure 8: Mean ± StDev days taken for the plant pieces on the lodge to be categorised as eaten green, eaten dry, used a building material and classified as unknown (disappeared, probably decomposed).

Table 8: Outcome of Fisher's exact tests per plant species, which analysed the ratio of plants eaten green versus the combined ratio of eaten dry, building material and unknown. Significant values indicated in bold show plant species that were significantly more eaten green than any of the other outcome. Significant outcomes indicated in bold. For EG (eaten green), ED (eaten dry), BM (building material).

Plant species	**Description**	**Result/direction**	***p***
Atriplex lindleyi	Shrub	EG<(ED+BM)	**<0.001**
Drosanthemum hispidum.	Succulent	EG>(ED+BM)	**<0.001**
Galenia sarcophylla	Shrub	EG>(ED+BM)	**0.010**
Helichrysum	Shrub	Only EG	0.500
Hermannia	Shrub	Only EG	0.500
Juncus acutus	Grass	EG>(ED+BM)	0.125
Lycium cinereum	Shrub	EG<(ED+BM)	**0.009**
Mesembryanthemum guerichianum	Succulent	EG>(ED+BM)	**<0.001**
Loranthus sp.	Shrub	EG>(ED+BM)	**0.025**
Psilocaulon sp	Succulent	EG>(ED+BM)	0.000
Salsola kali	Succulent	EG>(ED+BM)	0.000
Zygophyllum retrofractum	Shrub	EG>(ED+BM)	**<0.001**

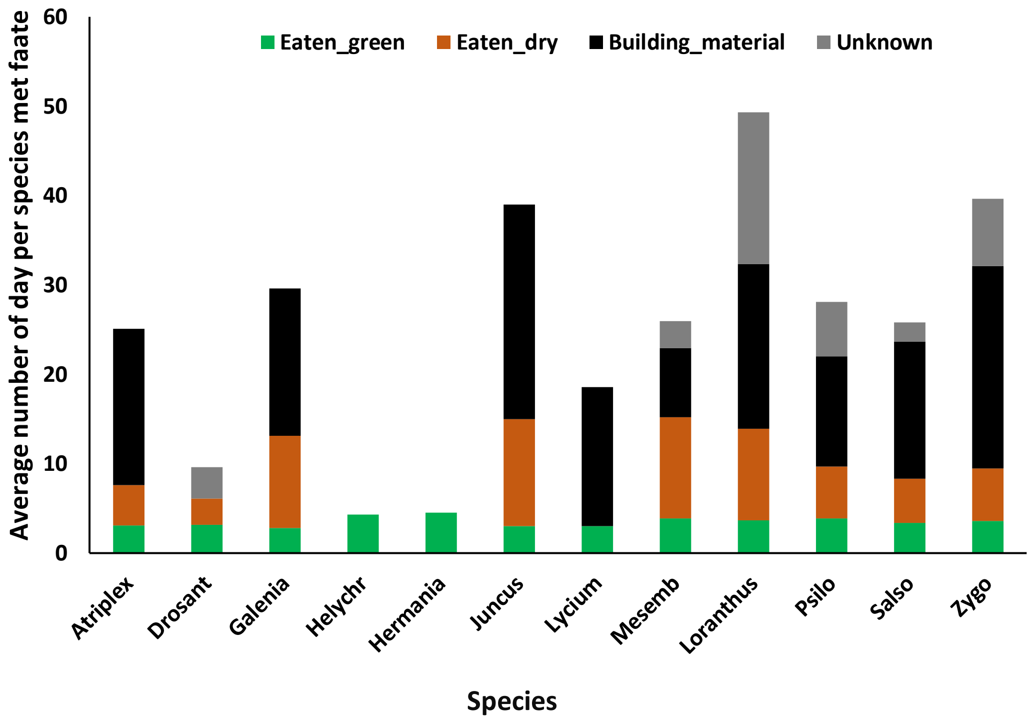


Figure 9: Average number of days until each plant piece of the different plant species collected by bush Karoo rats were categorised into their final fate. For example, *Atriplex* was eaten green within 2 days, within 8 days if it was eaten as plantong, and within 26 days if it was used as building material and never disappeared. Plant species names in full: *Atriplex lindleyi, Drosanthemum hispidum, Galenia sacrophyll, Helichrysum, Hermannia disermifolia , Juncus acutus, Lycium cinereum, Mesembryanthemum guerichianum, Loranthus spec, Psilocaulon sp., Salsola zeyherila, Zygophyllum retrofractum.*

<u>Do captive bush Karoo eat plantong?</u>

Experiment #1: Consumption and choice of dry vs frozen plant pieces in the dry and moist season

From the 48 individuals bush Karoo tested, 39 individuals consumed plantong and frozen plant pieces, 6 did not consume plantong, and only 3 individuals did not eat anything especially in the moist season. In the dry season, for the frozen plant pieces, 77% of *Galenia sarcophylla*, 37% of *Psilocaulon* sp. and 28% of *Mesembryanthemum*, were consumed. For plantong, 16% of *Galenia sarcophylla* was eaten, 37% of *Psilocaulon* sp., and 3% of *Mesembryanthemum*. In the moist season, frozen plant pieces were mostly consumed, with *Psilocaulon* sp. being the highest at 72%, followed by *Mesembryanthemum* at 34% and *Galenia sarcophylla* at 21% (Figure 10 and Table S7 in the supplementary). Regarding choice, in the dry season, bush

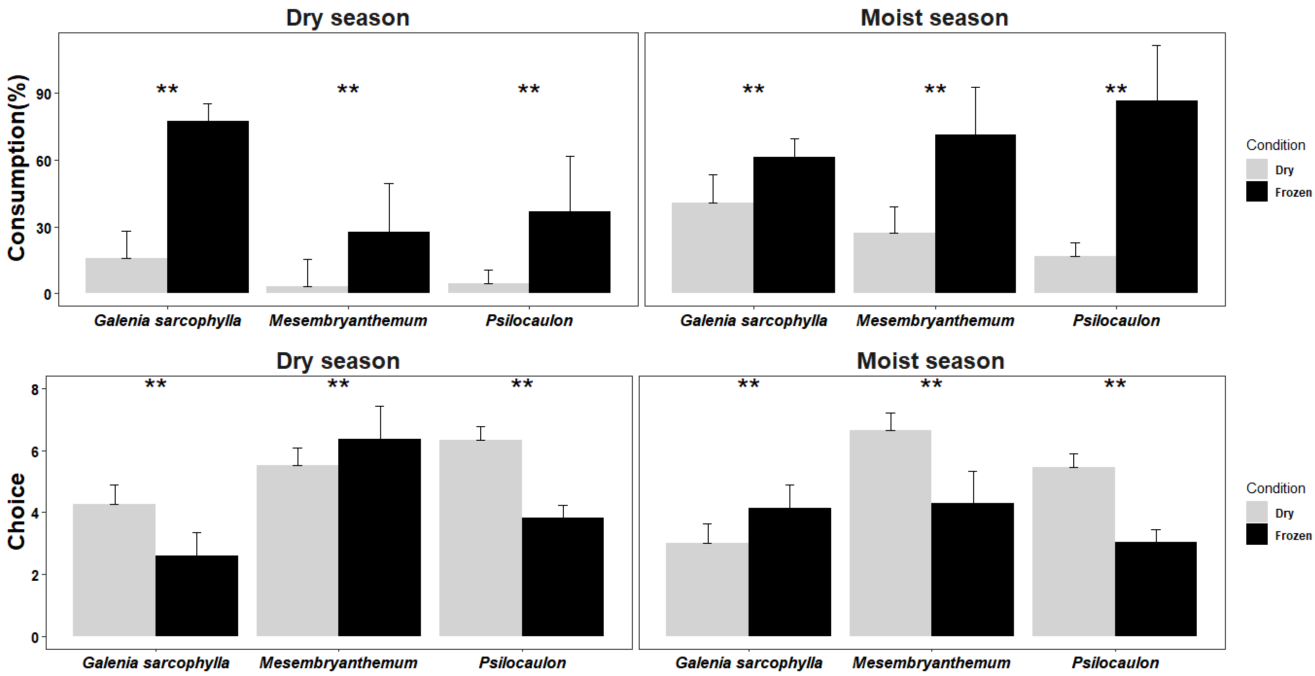
Karoo rats first chose frozen plant pieces, especially *Galenia sarcophylla* and *Psilocaulon* sp, except for a choice for dry rather than frozen *Mesembryanthemum*. In the moist season, frozen *Galenia sarcophylla* and *Mesembryanthemum*, were similarly chosen (5^{th} and 6^{th} preferred) p = <0.0001 (Table S7), with dry *Psilocaulon* sp, having a score of five. Dry *Mesembryanthemum* was typically not chosen by the bush Karoo rat during the experiments (Figure 10).

Experiment #2: Consumption and choice of dry vs fresh plant pieces in the dry and moist season

Bush Karoo rats predominantly consumed freshly harvested plant material. Among the 24 individuals tested, 9 individuals ate the plantong, the rest of the 15 individuals ate mostly fresh plant material. Freshly harvested *Galenia sarcophylla* (72%) and *Mesembryanthemum* (83%) slightly differed in consumption. Although there was some consumption of dry plant materials, it remained relatively low, with *Galenia sarcophylla* at 18%, *Mesembryanthemum* at 5%, and *Psilocaulon* sp. at 9% (Figure11). With choice, the bush karoo rat showed preference for freshly harvested food plants over dry plant materials. *Galenia sarcophylla* scored two, indicating it was predominantly chosen first, followed by *Mesembryanthemum* with a score of three. In the case of dry plant material, *Galenia sarcophylla* scored five as the first choice, while both *Mesembryanthemum* and *Psilocaulon* sp scored seven, indicating they were not preferred choices (Figure 11).

Experiment #3: Consumption and choice of dry vs fresh vs frozen plant pieces (in between the moist and dry season)

For percentage consumption the bush Karoo rats consumed more frozen plant pieces followed by freshly harvested plant pieces and the least consumed was plantong. Of the 24 individuals tested, 11 individuals ate the plantong as well as fresh and frozen pieces, while 12 ate only frozen and fresh plant pieces, and only 1 individual that did not eat anything. For freshly harvested plant pieces, 72% *Galenia sarcophylla*, 34% of *Mesembryanthemum* and 57% of *Psilocaulon* sp. were eaten For frozen plant pieces, 28% of *Galenia sarcophylla*, 29% of *Mesembryanthemum* and 25% of *Psilocaulon* were eaten. The plantong were consumed <5% of the time (Figure 12 and Table S9 in the supplementary). For choice, the bush Karoo rats firstly chose freshly harvested plant pieces with frozen plant pieces second and dry plant pieces were the least or sometimes not chosen (Figure 12 and Table S10 in the supplementary).



<u>Figure 10:</u> Mean ± StDev percentage consumption for plant pieces provided to bush Karoo rats and choice of which plant pieces were eaten first in the dry and moist season. Frozen vs Plantong treatment, N = 48 rats, with 24 individuals per season. For choice, a score of 1 represents the plant eaten first and 6 represents the last plant pieces eaten and 7 representing food plants that were not eaten. Asterisks: 0.05 (*), 0.01 (**), and 0.001 (***).

Table 9: Results of a Generalised Linear Mixed models to test whether species and condition of plant pieces influenced consumption. Experiments were done in the dry and moist season. Significant outcomes are indicated in bold. Results for the food plant species are in relation to *Galenia*.

Predictors	**Estimates**	***95%* CI**	***p***
Intercept	15.86	3.43 – 28.31	**0.05**
Mesembryanthemum	-12.38	-28.89 – 4.14	0.150
Psilocaulon	-11.08	-27.60 – 5.43	0.197
Condition Frozen	61.67	45.15 – 78.18	**0.001**
Moist Season	24.57	7.38 – 41.76	**0.01**
*Mesembryanthemum** Frozen	-37.21	-60.56 – -13.85	**0.01**
*Psilocaulon** Frozen	-29.46	-52.81 – -6.11	**0.05**
*Mesembryanthemum** Moist Season	-1.19	-24.30 – 21.93	0.921

*Psilocaulon** Moist Season	-12.88	-35.99 – 10.23	0.284
Condition Frozen* Moist Season	-40.95	-64.06 – -17.83	**0.001**
*Mesembryanthemum**Frozen* Moist	60.45	27.76 – 93.14	**0.001**
*Psilocaulon** Frozen * Moist	78.46	45.77 – 111.14	**0.001**

Table 10: Results of a Generalised Linear Mixed models to test whether species and condition of plant pieces influenced choice. Experiments were done in the dry and moist season. Significant outcomes are indicated in bold. Results for the food plant species are in relation to *Galenia.*

Predictors	**Estimates**	***95%* CI**	***p***
Intercept	4.24	3.41 – 5.07	**0.001**
Mesembryanthemum	1.25	0.08 – 2.42	**0.045**
Psilocaulon	2.08	0.91 – 3.25	**0.001**
Condition Frozen	-1.67	-2.84 – -0.50	**0.01**
Moist Season	-1.24	-2.41 – -0.08	**0.05**
*Mesembryanthemum** Frozen	2.54	0.89 – 4.20	**0.01**
*Psilocaulon** Frozen	-0.83	-2.49 – 0.82	0.333
*Mesembryanthemum** Moist Season	2.39	0.75 – 4.03	**0.01**
Psilocaulon * Moist Season	0.36	-1.28 – 2.00	0.675
Condition Frozen* Moist Season	2.79	1.15 – -4.42	**0.01**
*Mesembryanthemum** Frozen * Moist	-6.02	-8.34 – -3.70	**0.001**
Psilocaulon * Frozen * Moist	-2.69	-5.01 – -0.37	**0.05**

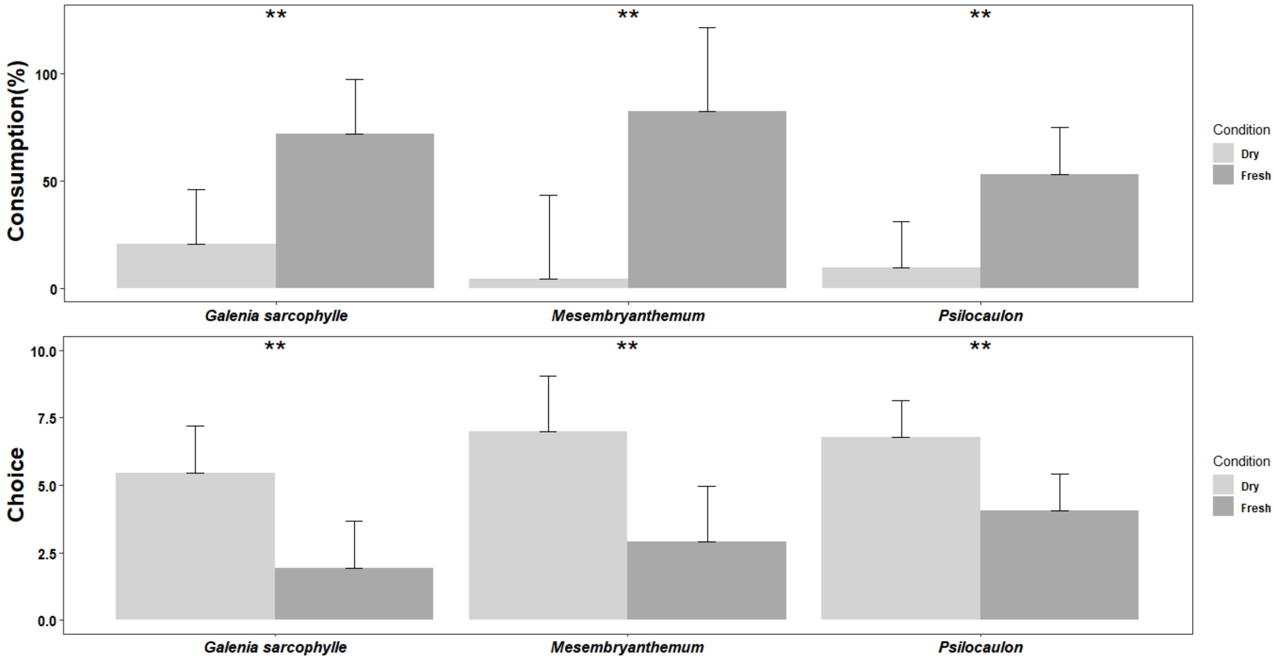


Figure 11: Mean ± StDev percentage consumption for plant pieces provided to bush Karoo rats and choice of which plant pieces were eaten first in November. Fresh vs Plantong treatment, N = 48 rats, with 24 individuals per season. For choice, a score of 1 represents the plant eaten first and 6 represents the last plant pieces eaten and 7 representing food plants that were not eaten. Asterisks: 0.05 (*), 0.01 (**), and 0.001 (***).

Table 11: Results of a Generalised Linear Mixed models to test whether species and condition of plant pieces influenced consumption. Experiment done in November**.** Significant outcomes indicated in bold. Results for the food plant species are in relation to *Galenia*

Predictors	**Estimates**	***95% CI***	***p***
Intercept	20.64	8.72 – 35.57	**0.001**
Mesembryanthemum	-16.39	-32.86 – 0.08	0.057
Psilocaulon	-11.09	-27.56 – 5.38	0.195
Condition Fresh	51.39	34.92 – 67.86	**<0.001**
*Mesembryanthemum** Fresh	27.04	3.75 – 50.34	**0.05**
*Psilocaulon**Fresh	-7.65	-30.95 – 15.64	0.526

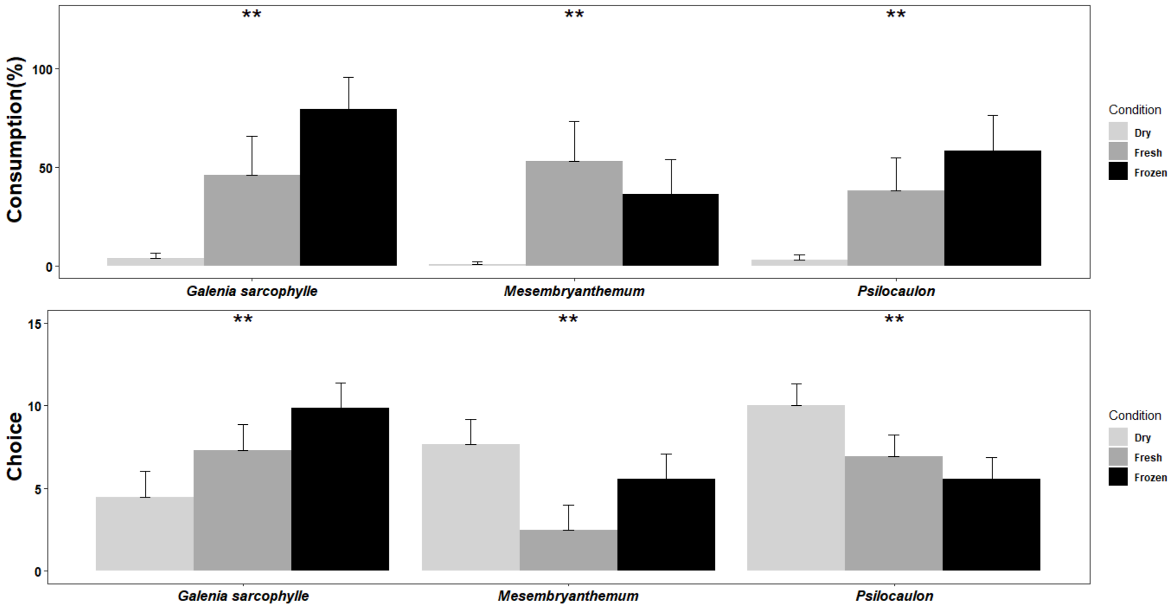


Figure 12: Mean ± StDev of percentage consumption for plant pieces provided to bush Karoo rats and their choice on which plant pieces was eaten first. Fresh vs Frozen vs Plantong, N = 24 rats. For choice, a score of 1 represents the plant eaten first and 9 represents the last plant pieces eaten and 10 representing food plants that was not eaten. Asterisks: 0.05 (*), 0.01 (**), and 0.001 (***).

Table 12: Results of a Generalised Linear Mixed models to test whether species and condition of plant pieces influenced consumption. Experiments were done in January (between the moist and dry season)**.** Significant outcomes are indicated in bold. Results for the food plant species are in relation to *Galenia*.

Predictors	**Estimates**	***95%* CI**	***p***
Intercept	4.04	-8.91 – 17.00	0.548
Mesembryanthemum	-3.00	-19.95 – 13.95	0.733
Psilocaulon	-0.88	-17.82 – 16.07	0.920
Condition Fresh	42.33	25.39 – 59.28	**0.001**
Condition Frozen	75.75	58.80 – 92.70	**0.001**
*Mesembryanthemum** Fresh	9.92	-14.04 – 33.88	0.426
*Psilocaulon**Frozen	-7.33	-31.29 – 16.63	0.555
*Mesembryanthemum**Frozen	-40.21	-64.17 – -16.24	**0.01**
*Psilocaulon**Fresh	-20.46	-44.42 – 3.51	0.101

Table 13: Results of a Generalised Linear Mixed models to test whether species and condition of plant pieces has an effect on choice. Experiments were done in January (between the moist and dry season)**.** Significant outcomes are indicated in bold. Results for the food plant species are in relation to *Galenia.*

Predictors	**Estimates**	***95%* CI**	***p***
Intercept	20.83	17.97 – 23.70	**0.001**
Species *Mesembryanthemum*	4.17	0.15 – 8.18	**0.05**
Species *Psilocaulon*	7.08	3.06 – 11.10	**0.001**
Condition Frozen	-6.25	-10.26 – -2.23	**0.01**
Mesembryanthemum* Condition Frozen	9.58	3.90 – 15.26	**0.01**
Species Psilocaulon* Condition Frozen	-2.50	-8.19 – 3.18	0.3967

DISCUSSION

I studied the function of green plant pieces carried by bush Karoo rats back to their lodges. I specifically tested the hypothesis that such material is mainly collected in the food rich moist season and then functions as food storage for the food restricted dry season. I found that most food plants were collected in moist winter and spring. Dried plant pieces (referred to here as plantong) was consumed more often in autumn, which was the end of the dry season. However, plantong was not stored from the moist season but collected at the current time, and not being older than 2 weeks. Most food plants were eaten green while only 12% of the food plants dried out and then occurred as plantong that was then eaten relatively quickly, i.e., within days rather than months. In captive experiments, the bush Karoo rats consumed all plant pieces including plantong provided to them. Overall, my study found that while plantong is eaten by bush Karoo rats it is not collected in spring to be stored for the food restricted dry season.

What plant species are carried back to the lodge? (Objective 1)

Bush Karoo rats carry plant pieces back to their lodge (Hoepfl, 2013; Brown and Willan, 1991)**.** In my study, the bush Karoo rats collected over 2000 plant pieces of which 14 plant species were collected out of the 21 plant species found within the 10x10 metre area. The 21 plant species present within the 10x10 metre area were all food plants for bush Karoo rats, and the

14 plant species that were carried back to the lodges were mostly eaten green before they became plantong. Moreover, the area around occupied bush Karoo rat lodges were mostly covered by food plants, including plant species that become plantong when collected.

Do plantong species have a high nutritional value? (Objective 2)

Plantong, when stored for future consumption, was expected to have high nutritional value. Other small mammal species in semi-arid habitats, such as the Mongolian gerbil (*Meriones unguiculatus*), spinifex hopping mouse (*Notomys* sp), fat-tailed gerbil (*Pachyuromys duprasi*), and desert pocket mouse (*Chaetodipus* sp), adjust their foraging behavior in response to fluctuations in nutritional content and water availability (Cheibler and Waiblinger, 2018; Pei et al., 2001). However, the dry plantong found on bush Karoo rat lodges had a lower concentration of sugar than non plantong species, indicating lower energy content. The presence of Dragendorff, Mayer, and Wagner (these are reagents that react to alkaloids which are secondary nonprotein nitrogen compounds that are present in plant as amino groups (-NH2), imine groups (-C=N-), or aromatic rings) further supports the idea that these plants are not ideal for consumption. Food plants had slightly lower crude protein, nitrogen, and biorad (soluble energy) but higher ash content and water concentration than non-food plants. Despite the initial expectation of high nutritional value in stored Plantong, my results indicate lower sugar concentration in the dry plantong on bush Karoo rat lodges.

Are there seasonal differences in how much plantong bush Karoo rats collect? (Objective 3)

If plantong serves as stored food, I predicted that most plantong to be collected during the food rich spring and consumed during the food-restricted dry season. In support, most of the plant pieces was collected by bush Karoo rats in winter and spring, i.e., during the rainy season when more food plants were available. This was also reflected in the number of plants marked at the lodges: More were marked in winter and spring. Plantong was mostly consumed in Autumn which is in the dry season. Overall, my results showed an influence of season on food collection in bush Karoo rats. However, my results mainly indicate that when more food is available, bush Karoo rats brought more food to the lodge and ate it there but did not store them specifically for the dry season. This behaviour is consistent with studies on small mammals e.i, *kangaroo rats (Dipodomys merriami*) that adjust their foraging efforts in response to seasonal changes in resource availability (Brown and Heske, 1990).

The bush Karoo rat can be considered a central place forager since it carried food plants back to its lodge and predominantly fed and foraged in the proximity of its lodge (Vermeulen and Nel, 1988). Central place foragers collect food within close proximities to their shelters and they can easily retreat into the shelter in case of any disturbance by a predator or to avoid thermoregulatory challenges (Orians and Pearson, 1979). This further supports the idea of bush Karoo rats collecting food plants in all seasons. Furthermore, during the dry season, food availability decreases with less cover, as such collecting food plants during this time might pose danger from aerial predators. Feeding comfortably and safely in a central place of the lodges more advantageous to bush Karoo rat.

What happens to the plantong over time: Is it consumed, does it become part of the lodge, or does it decompose? (Objective 4).

Bush Karoo rats construct lodges from sticks, wood, stones, and also food plants (Vermeulen and Nel, 1988; Brown and Willan, 1991). There was clear evidence that plant species can have multiple functions. Several annual plants functioned both for lodge building and consumption, while perennial plants were mostly used for consumption. Most plant pieces (68%) carried to the lodges were consumed green. Some (12%) plant pieces were consumed after it had dried and had become plantong, which typically occurred within 6 days of collection. 11% of the collected plant pieces became building material or part of the lodges after about 2 weeks, with the remaining 9% disappearing, probably due to decomposition. Scatter-hoarding rodents such as red squirrels (*Tamiasciurus hudsonicus*), Kangaroo rats (*Dipodomys merriami*), and ground squirrels (*Callospermophilus lateralis*) consume food soon after collection, and they preferentially harvest and consume lower-tannin seeds, cache higher-tannin alternatives, and retrieve cached high-tannin seeds in lower proportions (Lichti et al., 2017). Such a behaviour or strategy is also seen in bush Karoo rats since they consumed almost all the green material with only some being left over. My results thus show that the function of the collected plant pieces is multifunctional, primarily as food, stored for later consumption, or used building material for the lodges.

If bush Karoo rats are presented with plantong in captivity, will they eat it (Objective 5)?

Food selection may be driven by a variety of factors, including predation, and nutritional content (such as energy, protein, fat, vitamins, minerals, all possibly influencing taste) (Kenagy and Trombulak, 1986; Green et al., 1997). In my study, the bush Karoo rats showed selective feeding behaviours when presented with food plant pieces in different states. When they had a choice between plantong and frozen or fresh plants, they mostly consumed frozen and fresh plant pieces. Such a choice may be due to higher moisture content and nutritional value of these with the food plants, which are essential for maintaining hydration and meeting their dietary requirements in arid conditions (Van Deventer and Nel, 2006; Randall, 1993; Kenagy and Trombulak, 1986).

In some cases, plantong of *Galenia sarcophylla* was preferred and consumed over green and fresh plant pieces, the bush Karoo rat also chose plantong of *Galenia sarcophylla* as first choice. *Galenia sarcophylla* is a rich source of essential minerals and nutrients, including calcium, magnesium, potassium, iron, and dietary fibre (data from my study). These nutrients are important for the growth and development of rodents (De Silva et al., 2013; Kenagy and Trombulak, 1986). As observed from my study bush Karoo rats do readily consume plantong and in some cases even prefer it over the frozen food plant.

Comparison with other folivorous species

Omnivorous species tend to have fewer challenges in their diet selection compared to a folivorous diet, since their wide diet buffers the effects of nutritional changes in food and also food availability (Verde and D'Elía, 2021). Folivorous species face the challenge that leaves have often very low nutritional and energy content, especially when compared seeds and fruits (Chapman et al., 2003). Leaves are instead high in fibre such that digestion is physiologically demanding, needing gut adaptations and a long retention time for fibre fermentation (Chivers and Hladik, 1980; Corkand Kenagy, G.J., 1989). Moreover, the nutritional content of leaves tends to vary seasonally and between plant species especially during winter where most deciduous trees shed their leaves (Chapin III and Kedrowski, 1983). Therefore, such challenges highly contribute to the diverse strategies employ for nutritional gain by folivorous species. The nutritional content of food affects the minimal body size possible, and it has been argued that folivorous species cannot be very small (Droescher et al. 2016; Demment and Van Soest, 1985). For primates, it has been stated that the white-footed sportive lemur *(Lepilemur leucopus*) with a body mass of only around 500g is the smallest primate folivore, as leaves won't provide sufficient energy and nutrition for even smaller primates (which are omnivore or insectivore in most cases; Droescher et al. 2016). It is therefore surprising, that the smallest African folivores rodent, the bush Karoo rat (approximately 100g), is so much smaller than the smallest folivores primate. As one would predict, this seems to be explained by the differences in nutritional and energetic content of the leaves bush Karoo rats feed on. The bush Karoo rat diet is by far nutritious compared to *Lepilemur leucopus*, the food plants of bush Karoo rat's diets are comprised of 8% more sugar, 11% more fat and 12% less non digestible fibre (NDF) (compared Table S4 with Table 1 in Droescher et al. 2016).

Most small mammals (Brush-tailed mulgara (*Dasycercus blythi*); ground squirrels (Spermophilus citellus); Namaqua rock mouse (*Aethomys namaquensis*); South African gerbil (*Gerbilliscus leucogaster*), and Namaqua dune mole rat (*Bathyergus janetta*)) inhabiting semi-arid habitats with similar body size to the bush Karoo rats consume a variety of food items, including leaves, seeds, insects, and small vertebrates, or supplement their diet with leaves and other plant as part of their diet, and not a lot depend strictly on a folivorous diet (Huntley, 2023; Fuller et al., 2021; Van Deventer and Nel, 2006). Unlike the bush karoo rat which is strictly folivorous (exclusive consumption of leaves), these other species have the advantage of diet breadth (Kelt, 2011). Being strictly folivorous may be less common among rodents in arid habitats but has been observed in my study, and as such further highlights the strategy employed by the bush Karoo rats contributing to its nutritious diet.

Few studies have been done on small mammals such as rodents weighing less than 100g inhabiting semi-arid environments, especially studies on how they use adaptive strategies to cope with seasonal variation directly affecting food availability, energy requirements, and hash environments. As a result in future, we should ask at least two questions related to my findings. The first question being do bush Karoo rats meet their energy requirements? To answer this question, we would need data on the metabolic rate of bush Karoo rats in the dry season and in the wet season (Agnani et al., 2020). Also, there is a need to combine these data with the available data on chemical components of plant species and counts of where bush Karoo rats were seen consuming these plant species. We could also add home range size and use (Makuya and Schradin, 2023). A combination of such data would help us to quantify the energy requirements of bush Karoo rats seasonally and in relation to home range size. Conducting comparative studies with other rodent species (e.g. the syntonically sister species, the whistling rats) in similar arid environments would provide insights into common adaptations and differences in dietary preferences and foraging strategies (Jackson et al., 2002). A second question would be to investigate other potential food sources especially when food is scarce. Data for this could be collected from stomach contents and using metabarcoding for diet analyses (Kohl et al., 2022; Stapleton et al., 2022). Analyses of faecal samples can also add more information on the different plant species or the possibility of other food types that the bush Karoo rats eat that I was not able to record during behavioural observation.

Comparison with other species: food storage

Many rodents (e.g. Mongolian gerbil (*Meriones unguiculatus*), spinifex hopping mouse (*Notomys alexis*), fat-tailed gerbil (*Pachyuromys duprasi*), and desert pocket mouse(*Chaetodipus penicillatus*)) that inhabit harsh environments, such as deserts and semi-arid deserts, store food for periods of food scarcity (Scheibler and Waiblinger, 2018; Pei et al., 2001; Price, 1978; Vander, 1990). Small rodents such as ground squirrels (*Spermophilus citellus*), and kangaroo rats (*Dipodomys merriami*) are well known for their seed and nut caching behaviour, but seeds, for example, provide an advantage for longer storage with no change in texture (Huntley, 2023). Unlike storing only leafy succulent plants and leaves only which dry out in hot climates. The bush Karoo rats showed some interesting differences when compared to these other species inhabiting similar habitats, in terms of the type of food stored, the condition or texture of the stored food, and how the food is stored. In the bush Karoo rats, plantong does not represent food specifically dried to be stored, but rather leftover of green plant pieces carried to lodges for consumption which then dried up over time. Most of the plant pieces were left outside the lodges and were thus exposed to the sun. This contrasts with seed storing strategies in other rodents, which are mostly deposited underground and thus preserved over time (Mortori and MacMillen, 1982). The protective seed coat also allows for longer periods of storage compared to plants which usually dehydrate (Mortori and MacMillen, 1982).

Shortcomings of dissertation

Some of the short comings of my study were that all plant species occurring around occupied lodges were food plants. This made it difficult to assess whether food plants are of better nutritional value than non-food plants. The plant pieces that were marked at the lodge to establish their final fate were sometimes difficult to track especially when more plant pieces were added cumulatively to the top by the rats, which were then most often categorised as building material, but might also have decomposed..

Conclusions

My study revealed that bush Karoo rats feed on multiple food plants throughout the year, irrespective of seasonal fluctuations in plant availability. Season influenced collection and consumption of food plants. Certain plant species, such as the long-living shrubs like

Zygophyllum retrofractum, Lycium cinereum, Galenia sarcophylla, and Salsola zeyheri, were highly nutritious and mostly formed part of the bush Karoo rat diet throughout the year. Additionally, there is multifunctional use of plantong in lodge construction and gradual consumption which highlights the means of bush Karoo rats adapting to seasonal resource variations. However, plantong does not represent food stored specifically for consumption during harsh conditions several weeks and months later. Rather, plantong represents the leftovers of green plant pieces collected several days earlier, which dried up within a short period. Thus, the drying of these plants does not represent a strategy to make the plant storable for long periods such as the harsh dry season several months later. Nonetheless, plantong offers an alternative food source in times of need.

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SUPPLEMENTARY INFORMATION

Table S1: Description of how common plant species were around lodge and what plant species were stored as plantong, carried for building, and eaten on site during nest observation. Data from January 2022 to June 2023, in total there were 998 observations with 164 individuals observed by 7 researchers.

Plant species	How common around lodge (surveys around 12 lodges)	Frequency observed at lodges during observations (Fresh, green, and dry)	Frequency observed as fresh material at lodges during observations	Frequency observed as green material at lodges during observations)	Frequency observed as plantong at lodges during observations
Aptossimum	0	0	0	0	0
Atriplex lindleyi	2	61	9	16	36
Berkeya	0	1	0	1	0
Chlorophytum crassinerve	3	0	0	0	0
Cotula leptalea	10	2	2	0	0
Drosanthemum hispidum.	8	91	38	40	13
Galenia sarcophylla	15	305	85	111	109
Grass	9	29	1	10	18
Greilum humilus	4	0	0	0	0
Helichrysum	3	7	0	0	7
Hermannia disermifolia	1	15	6	5	4
Hypertelis salsoloides	0	26	2	9	15
Juncus acutus	5	11	0	1	10
Leysere tenella	0	1	1	0	0
Lycium cinereum	29	58	15	25	18
Loranthus spec	0	36	8	26	2

Mesembryanthemum guerichianum	26	708	116	197	395
Ornithogaum	3	0	0	0	0
Osteospermum pinnatum	1	0	0	0	0
Oxalis sp	4	0	0	0	0
Reeds	7	6	0	2	4
Salsola zeyherila	13	252	74	87	91
Schismus inermis	25	15	0	5	10
Senecio arenarius	0	3	0	3	0
Stipiagrostis	0	4	0	0	4
Trachyendra totalis	1	0	0	0	0
Zygophyllum retrofractum	21	510	99	164	247

Table S2: Plant species of both the food, non-food, and dry plant(plantong) material around occupied bush Karoo lodges in all the seasons.

Season	Lodge	Species	Food plant (yes/no)	Plantong (yes/no)
Autumn	557	*Lycium cinereum*	yes	yes
Autumn	557	*Zygophyllum retrofractum*	yes	yes
Autumn	557	*Psilocaulon* sp.	yes	yes
Autumn	532	*Lycium cinereum*	yes	yes
Autumn	532	*Psilocaulon* sp.	yes	yes
Autumn	502	*Psilocaulon* sp.	yes	yes
Autumn	502	*Lycium cinereum*	yes	yes
Autumn	501	*Psilocaulon* sp.	yes	yes
Autumn	501	*Lycium cinereum*	yes	yes
Autumn	731	*Psilocaulon* sp.	yes	yes
Autumn	555	*Psilocaulon* sp.	yes	yes
Autumn	555	*Lycium cinereum*	yes	yes

Autumn	542	*Zygophyllum retrofractum*	yes	yes
Autumn	542	*Lycium cinereum*	yes	yes
Autumn	719	*Zygophyllum retrofractum*	yes	yes
Autumn	719	*Lycium cinereum*	yes	yes
Autumn	720	*Zygophyllum retrofractum*	yes	yes
Autumn	720	*Lycium cinereum*	yes	yes
Autumn	20	*Reeds*	no	no
Autumn	20	*Salsola zeyherila*	yes	yes
Autumn	550	*Reeds*	no	no
Autumn	550	*Salsola zeyheri*	yes	yes
Autumn	167	*Salsola zeyheri*	yes	yes
Autumn	706	*Salsola zeyheri*	yes	yes
Autumn	531	*Zygophyllum retrofractum*	yes	yes
Autumn	531	*Lycium cinereum*	yes	yes
Autumn	504	*Zygophyllum retrofractum*	yes	yes
Winter	502	*Psilocaulon* sp.	yes	yes
Winter	502	*Juncus*	no	yes
Winter	502	*Lycium cinereum*	yes	yes
Winter	502	*Mesembryanthemum*	yes	yes
Winter	502	*Chlorophytum crassinerve*	yes	yes
Winter	502	*Grass*	yes	yes
Winter	501	*Grass*	yes	yes
Winter	501	*Juncus*	no	yes
Winter	501	*Mesembryanthemum*	yes	yes
Winter	501	*Greilum humilus*	no	no
Winter	501	*Chlorophytum crassinerve*	no	no

Winter	501	*Ornithogalum secundum*	no	no
Winter	501	*Oxalis* sp	no	no
Winter	555	*Chlorophytum crassinerve*	yes	yes
Winter	555	*Helichrysum*	yes	yes
Winter	555	*Oxalis* sp	yes	yes
Winter	555	*Galenia sarcophylla*	yes	yes
Winter	555	*Psilocaulon* sp.	yes	yes
Winter	555	*Mesembryanthemum*	yes	yes
Winter	555	*Lycium cinereum*	yes	yes
Winter	542	*Ornithogalum secundum*	no	no
Winter	542	*Zygophyllum retrofractum*	yes	yes
Winter	542	*Lycium cinereum*	yes	yes
Winter	542	*Mesembryanthemum*	yes	yes
Winter	542	*Galenia sarcophylla*	yes	yes
Winter	542	*Greilum humilus*	no	no
Winter	542	*Hermannia*	yes	yes
Winter	719	*Zygophyllum retrofractum*	yes	yes
Winter	719	*Lycium cinereum*	yes	yes
Winter	719	*Grass*	yes	yes
Winter	719	*Psilocaulon* sp.	yes	yes
Winter	720	*Zygophyllum retrofractum*	yes	yes
Winter	720	*Lycium cinereum*	yes	yes
Winter	720	*Psilocaulon* sp.	yes	yes
Winter	720	*Juncus*	no	no
Winter	524	*Psilocaulon* sp.	yes	yes
Winter	524	*Zygophyllum retrofractum*	yes	yes

Winter	524	*Juncus*	no	no
Winter	524	*Oxalis* sp	yes	yes
Winter	524	*Ornithogalum secundum*	no	no
Winter	524	*Mesembryanthemum*	yes	yes
Winter	524	*Greilum humilus*	no	no
Winter	525	*Zygophyllum retrofractum*	yes	yes
Winter	525	*Psilocaulon* sp.	yes	yes
Winter	525	*Galenia sarcophylla*	yes	yes
Winter	525	*Trachyandra tortilis*	no	no
Winter	525	*Oxalis* sp	yes	yes
Winter	525	*Juncus*	no	no
Winter	557	*Mesembryanthemum*	yes	yes
Winter	557	*Grass*	yes	yes
Winter	557	*Helichrysum*	yes	yes
Winter	557	*Lycium cinereum*	yes	yes
Winter	557	*Zygophyllum retrofractum*	yes	yes
Winter	706	*Salsola zeyheri*	yes	yes
Winter	706	*Drosanth*	yes	yes
Winter	706	*Grass*	yes	yes
Winter	706	*Mesembryanthemum*	yes	yes
Winter	20	*Reeds*	no	no
Winter	20	*Salsola zeyheri*	yes	yes
Winter	20	*Grass*	yes	yes
Winter	20	*Drosanth*	yes	yes
Winter	20	*Mesembryanthemum*	yes	yes
Winter	167	*Grass*	yes	yes
Winter	167	*Salsola zeyheri*	yes	yes
Winter	167	*Drosanth*	yes	yes
Winter	167	*Mesembryanthemum*	yes	yes

Winter	550	*Salsola zeyheri*	yes	yes
Winter	550	*Grass*	yes	yes
Winter	550	*Reeds*	no	no
Winter	550	*Drosanthium*	yes	yes
Winter	550	*Greilum humilus*	no	no
Winter	550	*Mesembryanthemum*	yes	yes
Winter	172	*Grass*	yes	yes
Winter	172	*Mesembryanthemum*	yes	yes
Winter	172	*Zygophyllum retrofractum*	yes	yes
Winter	172	*Drosanth*	yes	yes
Winter	172	*Helichrysum*	yes	yes

Table S3: Description and Interpretation of the chemical components measured on the plant pieces that were sent to the University of Hamburg (Ortmann et al., 2006; Rothman et al. 2012). Nitrogen and crude protein are the same, especially since crude protein is calculated as % Nitrogen * 6.25.

Measurement	**Description**	**Interpretation (level is) why?**
N%	Nitrogen	Good, considers at the raw or total proteins and used to estimate crude proteins in plants. (While we have no data on C%, higher N% also indicates lower C% and as such a better C:N ratio).
Biorad	This is soluble energy	Good, animals feed on food that is high in biorad which is an easily soluble protein.
NDF	Neutral Detergent Fibre: this is a solution (pH 7.0).	Bad, only animals with specialised digestive systems. Higher NDF lower digestibility.
ADF	Acid Detergent Fibre: this residue that remains after boiling in acid filtered.	Bad, part of the cell wall which even species with specialized digestive system cannot digest.
Hemicellulose	This is the weight difference between	Bad, because they are partially or not digestible depending on whether a mammal has symbiotic

	before and after the treatment of dried samples.	microorganisms (i.e., protozoa and bacteria) which assist with digestion.
Sugar	A form of starch which is a primary energy storage.	Good, soluble sugars that allow easy access of energy source.
Condensed tannins	This are secondary compounds that act as a binder of plant proteins.	Bad, these are toxin that which not beneficial to mammals.
Fat	Fat content is mostly waxes that are part of the cuticula of plants and reduce water evaporation.	Good, can act as energy source for mammals especially during the winter when food availability is low.
Ashes	This is an overall inorganic matter or a by-product that remains After burning dry forage at 550 ^{O}C.	Good, all minerals that remain after burning, from inside the plant. But can also include dust on the plants.
Alkaloids	This includes Wagner and Mayer which are secondary nonprotein nitrogen compounds	Bad, they are not necessarily digestible. They act as defence compounds against herbivores.
Water	water content.	Good, act a source of moisture especially for mammals leaving in extremely dry habitats

Table S4: Chemical components in % of dry mass of food and non-food items of bush Karoo rats (Otomys unisulcatus). Alkaloids were analysed qualitatively as present (1) or absent (0). Energy content of 100 g dry plant material is given in kcal. NB higher nitrogen percentage indicates higher nutritional value (higher N% also indicates lower C% and as such a better C:N ratio). Crude protein, which is an estimate of protein content, presented below (note: higher CP% also means a lower C:N ratio). Crude Protein CP (%DM) = 6.25 * N (%DM), 6.25 = Protein conversion factor, N = Nitrogen content in the plant.

Species	Crude protein	N%	BioRad %	NDF %	ADF %	Sugar %	Tannine %	Polyphenole %	Fat%	Ashes %	Water %	Dragendorff	Mayer	Wagner
Amsinckia calycina	16.6875	2.67	7.33	27.41	9.73	7.82	0	0.9	5.8	27.42	84.4865	0	0	0
Arctoitis fastuosa	16.375	2.62	4.99	27.79	20.28	15.5	0	0.95	3.77	24	85.2527	1	1	1
Atriplex lindleyi	18.4375	2.95	3.72	18.63	10.09	5.89	0	0.59	3.5	35.54	79.2321	1	1	1
Cotula leptalea	15	2.4	5.2	15.52	11.05	26.97	0	1.18	3.26	17.02	66.9173	0	0	0
Deverra aphylla	14.9375	2.39	4.68	17.2	11.75	27.36	0	1.39	6.65	7.15	60.8752	1	1	1
Dimorphotheca polyptera	16.1875	2.59	5.15	18.59	13.37	18.55	0	0.89	7.26	11.52	71.9122	0	0	0
Drosanthemum spec.	14.5	2.32	4.65	12.77	6.34	14.91	0	0.65	1.76	22.27	83.3197	1	1	1
Eriocephalus erigoides	8.625	1.38	2.89	31.45	20.16	7.31	0	2.78	4.67	6.09	57.3439	0	0	0
Galenia africana	11.9375	1.91	5.84	27.1	8.13	11.71	0	1.39	4.3	12.57	69.0731	1	1	1
Galenia sacrophylla	12.5625	2.01	4.06	13.93	4.46	15.96	0	0.46	2.4	27.85	85.7657	1	1	1
Gazania lichtensteinii	12.8125	2.05	3.16	15.13	10.44	10.08	0	0.94	4.31	22.76	85.7641	1	1	1
Heliophilla variabilis	17.4375	2.79	5.5	27.03	18.86	18.3	0.27	0.96	2.8	13.91	77.7968	1	1	1
Hermannia disermifolia	12.9375	2.07	4.35	44.44	25.37	5.99	0.28	0.86	2.84	7.67	53.797	1	1	1
Hypertelis salsoloides	13	2.08	6.39	17.06	6.93	16.41	0	0.37	2.35	18.74	86.9077	1	1	1
Juncus acutus	7.5	1.2	2.08	74.39	33.77	9	0	0.32	0.86	3.07	55.2144	0	0	0
Lessertia diffusa	18.8125	3.01	7.78	20.07	10.32	20.74	0	0.63	2.85	12.22	70.705	1	1	1
Leysera tenella	10.125	1.62	4.83	37.45	24.99	17.46	0	1.75	2.19	9.48	60.85	0	0	0
Lycium cinereum	17.25	2.76	4.6	18.34	11.65	6.85	0	1.3	3.44	18.29	79.7991	1	1	1
Mesembryanthemum guerichianum	10.9375	1.75	3.83	5.83	2.72	4.31	0	0.22	1.12	36.96	91.9284	1	1	1
Oncosiphon grandiflorum	16.4375	2.63	5.8	13.74	9.04	32.85	0	1.45	3.93	11.59	69.0997	0	0	0
Peliostomum virgatum	10.0625	1.61	5.16	22.67	15.2	28.62	0	3.1	3.11	11.01	61.8557	0	0	0
Pentzia incana	14.5625	2.33	5.08	21.53	11.77	13.72	0	2.67	5.72	8.29	66.6667	0	0	0
Pentzia pilulifera	20.6875	3.31	7.23	12.31	7.55	29.64	0	1.2	3.13	14.62	71.0907	0	0	0
Psilocaulon spec.	17.5	2.8	5.11	11.54	4.8	4	0	0.36	1.56	30.71	84.8974	1	1	1
Salsola zeyheri	19.5	3.12	2.68	29.21	13.61	3.31	0	0.58	0.94	21.36	73.9496	1	1	1
Schismus inermis	12.25	1.96	4.51	52.42	23.61	16.26	0.28	0.69	2.48	6.3	58.3982	0	0	0
Senecio arenarius	20.1875	3.23	6.38	17.04	10.24	10.48	0	0.82	4.24	21.89	88.3556	0	0	0
Senecio cardaminifolius	20.25	3.24	5.56	13.74	9.39	13.27	0	0.86	2.78	18.29	84.2618	0	0	0
Septulina glauca	11.6875	1.87	8.35	16.3	8.48	16.68	1.35	6.63	2.19	12.64	67.8748	0	0	0
Stipagrostis namaquensis	9.0625	1.45	1.86	72.05	37.13	7.5	0	0.27	0.39	5.9	51.4451	0	0	0
Zygophyllum retrofractum	8.125	1.3	5.93	28.24	8.86	17.02	0	1.51	3.93	7.22	45.1613	1	1	1

Table S5: Fate of the different marked plant species collected by bush Karoo rat.

species	Eaten_green	Eaten_dry	Building_material	Unknown
Atriplex lindleyi	3.1	4.5	17.5	0.0
Drosanthemum hispidum.	3.1	3.0	0.0	3.5
Galenia sarcophylla	2.8	10.3	16.5	0.0
Helichrysum	4.3	0.0	0.0	0.0
Hermannia disermifolia	4.5	0.0	0.0	0.0
Juncus	3.0	12.0	24.0	0.0
Lycium cinereum	3.0	0.0	15.6	0.0
Mesembryanthemum	3.9	11.3	7.8	3.0

Lycium parasite	3.7	10.3	18.4	17.0
Psilocaulon sp.	3.9	5.8	12.3	6.1
Salsola zeyherila	3.4	4.9	15.4	2.1
Zygophyllum retrofractum	3.6	5.9	22.7	7.5
Total (%)	**68%**	**12%**	**11%**	**9%**

Table S6: Comparison of other species inhabiting similar habitats like the bush Karoo rat (Rymer et al., 2016; Scheibler and Waiblinger, 2018; Pei et al., 2001; Price, 1978; Vander, 1990).

Species	Habitat	Strategy	Type of food stored	Condition of the stored food
Otomys unisulcatus	arid and semi-arid environments	Collect food plant, immediate, consumption, temporary storage	Herbivorous, primarily feeding on grasses and succulent plant parts	Stored fresh,
Parotomys brantsii	arid and semi-arid environments	collecting and storing food outside burrows entrance	consume succulent plant parts, bulbs, and roots	They do not typically store food for extended periods. Instead, they feed on vegetation as it becomes available
Spermophilus citellus	grasslands, meadows, and deserts.	Collect food plant, immediate consumption		
Dipodomys merriami	arid and desert environments			

hoarding mice	Deserts, grasslands, and forests	collecting and storing food in burrows or caches	Omnivorous, feeding on a variety of seeds, insects, and plant pieces	It may remain relatively fresh due to the storage environment.

Table S7: Pairwise differences of the significant factors for the influence of condition of different plant species on consumption by bush Karoo rats. Significant outcomes indicated in bold. Experiment done in the dry and moist season.

Season	***Species and its condition***	Season	P
Dry	*Galenia sarcophylla Dry - Mesembryanthemum Dry*	Dry	0.9534
Dry	*Galenia sarcophylla Dry - Psiloucolon Dry*	Dry	0.9793
Dry	*Galenia sarcophylla Dry - Galenia sarcophylla Frozen*	Dry	**0.0001**
Dry	*Galenia sarcophylla Dry - Mesembryanthemum Frozen*	Dry	0.9607
Dry	*Galenia sarcophylla Dry - Psiloucolon Frozen Dry*	Dry	0.3672
Dry	*Galenia sarcophylla Dry - Galenia sarcophylla Dry*	Moist	0.2098
Dry	*Galenia sarcophylla Dry - Mesembryanthemum Dry*	Moist	0.9861
Dry	*Galenia sarcophylla Dry - Psiloucolon Dry*	Moist	1.0000
Dry	*Galenia sarcophylla Dry - Galenia sarcophylla Frozen*	Moist	**<0.0001**
Dry	*Galenia sarcophylla Dry - Mesembryanthemum Frozen*	Moist	**<0.0001**
Dry	*Galenia sarcophylla Dry - Psiloucolon Frozen*	Moist	**<0.0001**
Dry	*Mesembryanthemum Dry - Psiloucolon Dry*	Dry	1.0000
Dry	*Mesembryanthemum Dry - Galenia sarcophylla Frozen*	Dry	**<0.0001**
Dry	*Mesembryanthemum Dry - Mesembryanthemum Frozen*	Dry	0.1647
Dry	*Mesembryanthemum Dry - Psiloucolon Frozen Dry*	Dry	0.0066
Dry	*Mesembryanthemum Dry - Galenia sarcophylla Dry*	Moist	**0.0028**
Dry	*Mesembryanthemum Dry - Mesembryanthemum Dry*	Moist	0.2773
Dry	*Mesembryanthemum Dry - Psiloucolon Dry*	Moist	0.9520
Dry	*Mesembryanthemum Dry - Galenia sarcophylla Frozen*	Moist	**<0.0001**
Dry	*Mesembryanthemum Dry - Mesembryanthemum Frozen*	Moist	**<0.0001**
Dry	*Mesembryanthemum Dry - Psiloucolon Frozen*	Moist	**<0.0001**
Dry	*Psiloucolon Dry - Galenia sarcophylla Frozen*	Dry	**<0.0001**
Dry	*Psiloucolon Dry - Mesembryanthemum Frozen*	Dry	0.2311
Dry	*Psiloucolon Dry - Psiloucolon Frozen*	Dry	**0.0113**
Dry	*Psiloucolon Dry - Galenia sarcophylla Dry*	Moist	0.0048
Dry	*Psiloucolon Dry - Mesembryanthemum Dry*	Moist	0.3640
Dry	*Psiloucolon Dry - Psiloucolon Dry*	Moist	0.9777
Dry	*Psiloucolon Dry - Galenia sarcophylla Frozen*	Moist	**<0.0001**
Dry	*Psiloucolon Dry - Mesembryanthemum Frozen*	Moist	**<0.0001**
Dry	*Psiloucolon Dry - Psiloucolon Frozen*	Moist	**<0.0001**
Dry	*Galenia sarcophylla Frozen - Mesembryanthemum Frozen*	Dry	**<0.0001**
Dry	*Galenia sarcophylla Frozen - Psiloucolon Frozen*	Dry	**0.0002**
Dry	*Galenia sarcophylla Frozen - Galenia sarcophylla Dry*	Moist	**0.0026**

Dry	*Galenia sarcophylla Frozen - Mesembryanthemum Dry*	Moist	**<0.0001**
Dry	*Galenia sarcophylla Frozen - Psiloucolon Dry*	Moist	**<0.0001**
Dry	*Galenia sarcophylla Frozen - Galenia sarcophylla Frozen*	Moist	0.8002
Dry	*Galenia sarcophylla Frozen - Mesembryanthemum Frozen*	Moist	0.9998
Dry	*Galenia sarcophylla Frozen - Psiloucolon Frozen*	Moist	0.9982
Dry	*Mesembryanthemum Frozen - Psiloucolon Frozen*	Dry	0.9961
Dry	*Mesembryanthemum Frozen - Galenia sarcophylla Dry*	Moist	0.9637
Dry	*Psiloucolon Dry - Mesembryanthemum Frozen Moist*	Moist	1.0000
Dry	*Psiloucolon Dry - Psiloucolon Frozen Moist*	Moist	0.9808
Dry	*Galenia sarcophylla Frozen - Mesembryanthemum Frozen*	Dry	**0.0130**
Dry	*Galenia sarcophylla Frozen - Psiloucolon Frozen*	Dry	**0.0002**
Dry	*Galenia sarcophylla Frozen - Galenia sarcophylla Dry*	Moist	**<0.0001**
Dry	*Galenia sarcophylla Frozen Dry season - Mesembryanthemum Dry*	Moist	1.0000
Dry	*Psiloucolon Dry - Mesembryanthemum Frozen*	Moist	0.9931
Dry	*Psiloucolon Dry - Psiloucolon Frozen*	Moist	0.4846
Dry	*Galenia sarcophylla Frozen - Mesembryanthemum Frozen*	Dry	0.2315
Dry	*Galenia sarcophylla Frozen - Psiloucolon Frozen*	Dry	**0.0101**
Dry	*Galenia sarcophylla Frozen - Galenia sarcophylla Dry*	Moist	**<0.0001**
Dry	*Galenia sarcophylla Frozen - Mesembryanthemum Dry*	Moist	0.9022
Dry	*Galenia sarcophylla Frozen - Psiloucolon Dry*	Moist	0.1649
Moist	*Galenia sarcophylla Dry - Galenia sarcophylla Frozen*	Moist	0.3656
Moist	*Galenia sarcophylla Dry - Mesembryanthemum Frozen*	Moist	0.0182
Moist	*Galenia sarcophylla Dry - Psiloucolon Frozen*	Moist	**<0.0001**
Moist	*Mesembryanthemum Dry - Psiloucolon Dry*	Moist	0.9853
Moist	*Mesembryanthemum Dry - Galenia sarcophylla Frozen*	Moist	**0.0034**
Moist	*Mesembryanthemum Dry - Mesembryanthemum Frozen*	Moist	**<0.0001**
Moist	*Mesembryanthemum Dry - Psiloucolon Frozen*	Moist	**<0.0001**
Moist	*Psiloucolon Dry - Galenia sarcophylla Frozen*	Moist	**<0.0001**
Moist	*Psiloucolon Dry - Mesembryanthemum Frozen*	Moist	**<0.0001**
Moist	*Psiloucolon Dry - Psiloucolon Frozen*	Moist	**<0.0001**
Moist	*Galenia sarcophylla Frozen - Mesembryanthemum Frozen*	Moist	0.9918
Moist	*Galenia sarcophylla Frozen - Psiloucolon Frozen*	Moist	0.1203

Table S9: Pairwise differences of the significant factors for the influence of condition of different plant species on consumption by bush Karoo rats. Experiment done in January (between the moist and dry season). Significant outcomes indicated in bold.

Species and its condition	***p***
Galenia sarcophylla Dry - Galenia sarcophylla Fresh	**0.0001**
Galenia sarcophylla Dry - Galenia sarcophylla Frozen	**<0.0001**
Galenia sarcophylla Dry - Mesembryanthemum Fresh	**<0.0001**
Galenia sarcophylla Dry - Mesembryanthemum Frozen	**0.0084**
Galenia sarcophylla Dry - Psiloucolon Fresh	**0.0044**

Galenia sarcophylla Dry - Psiloucolon Frozen	**<0.0001**
Galenia sarcophylla Fresh - Galenia sarcophylla Frozen	**0.0059**
Galenia sarcophylla Frozen - Mesembryanthemum Frozen	**0.0001**
Mesembryanthemum Dry - Galenia sarcophylla Fresh	**<0.0001**
Mesembryanthemum Dry - Galenia sarcophylla Frozen	**<0.0001**
Mesembryanthemum Dry - Mesembryanthemum Fresh	**<0.0001**
Mesembryanthemum Dry - Mesembryanthemum Frozen	**0.0024**
Mesembryanthemum Dry - Psiloucolon Dry	**1.0000**
Mesembryanthemum Dry - Psiloucolon Frozen	**<0.0001**
Psiloucolon Dry - Galenia sarcophylla Fresh	**0.0001**
Psiloucolon Dry - Galenia sarcophylla Frozen	**<0.0001**
Psiloucolon Dry - Mesembryanthemum Fresh	**<0.0001**
Psiloucolon Dry - Mesembryanthemum Frozen	**0.0059**
Psiloucolon Dry - Psiloucolon Fresh	**0.0031**
Psiloucolon Dry - Psiloucolon Frozen	**<0.0001**
Psiloucolon Fresh - Galenia sarcophylla Frozen	**0.0001**

Table S10: Pairwise differences of the significant factors for the influence of condition of different plant species on choice/selection by bush Karoo rats. Experiment done in January (between the moist and dry season). Significant outcomes indicated in bold.

Species and condition	**P**
Galenia sarcophylla Dry - Mesembryanthemum Dry	0.0083
Galenia sarcophylla Dry - Psiloucolon Dry	**<0.0001**
Galenia sarcophylla Dry - Galenia sarcophylla Fresh	**0.0337**
Galenia sarcophylla Dry - Mesembryanthemum Fresh	0.3705
Galenia sarcophylla Dry - Psiloucolon Fresh	0.1109
Galenia sarcophylla Dry - Galenia sarcophylla Frozen	**<0.0001**
Galenia sarcophylla Dry - Mesembryanthemum Frozen	0.9304
Galenia sarcophylla Dry - Psiloucolon Frozen	0.9436
Mesembryanthemum Dry - Psiloucolon Dry	0.1566
Mesembryanthemum Dry - Galenia sarcophylla Fresh	1.0000
Mesembryanthemum Dry - Mesembryanthemum Fresh	**<0.0001**

Mesembryanthemum Dry - Psiloucolon Fresh	0.9944
Mesembryanthemum Dry - Galenia sarcophylla Frozen	0.2373
Mesembryanthemum Dry - Mesembryanthemum Frozen	0.2865
Mesembryanthemum Dry - Psiloucolon Frozen	0.2612
Psiloucolon Dry - Galenia sarcophylla Fresh	**0.0514**
Psiloucolon Dry - Mesembryanthemum Fresh	**<0.0001**
Psiloucolon Dry - Psiloucolon Fresh	**0.0135**
Psiloucolon Dry - Galenia sarcophylla Frozen	1.0000
Psiloucolon Dry - Mesembryanthemum Frozen	**<0.0001**
Psiloucolon Dry - Psiloucolon Frozen	**<0.0001**
Galenia sarcophylla Fresh - Mesembryanthemum Fresh	**<0.0001**
Galenia sarcophylla Fresh - Psiloucolon Fresh	1.0000
Galenia sarcophylla Fresh - Galenia sarcophylla Frozen	0.0869
Galenia sarcophylla Fresh - Mesembryanthemum Frozen	0.5637
Galenia sarcophylla Fresh - Psiloucolon Frozen	0.5303
Mesembryanthemum Dry - Psiloucolon Dry	**<0.0001**
Mesembryanthemum Dry - Galenia sarcophylla Fresh	**<0.0001**
Mesembryanthemum Fresh - Psiloucolon Fresh	**0.0135**
Mesembryanthemum Fresh - Galenia sarcophylla Frozen	**0.0159**
Mesembryanthemum Fresh - Mesembryanthemum Frozen	**0.0251**
Mesembryanthemum Fresh - Psiloucolon Frozen	0.8349
Psiloucolon Fresh - Galenia sarcophylla Frozen	0.8100
Psiloucolon Fresh - Mesembryanthemum Frozen	**0.0001**
Psiloucolon Fresh - Psiloucolon Frozen	**0.0001**
Galenia sarcophylla Frozen - Mesembryanthemum Frozen	1.0000
Galenia sarcophylla Frozen - Psiloucolon Frozen	**0.0083**
Mesembryanthemum Frozen - Psiloucolon Frozen	**<0.0001**

Table S11: Results of the generalised linear mixed model(Car::ANOVA) to test how the number of dry plant pieces collected by the bush Karoo rat differed between seasons. Significant highlighted in bold.

Predictors	**Estimates**	***95%* CI**	***p***
Intercept	15.86	3.43 – 28.31	0.764
Spring	-0.05	-1.42 – 0.05	0.985
Summer	-0.1	-2.46 – -0.88	0.931
Winter	0.09	-2.04 – -0.16	0.952
Plantong yes	24.57	7.38 – 41.76	**0.018**
Spring *Plantong yes	-37.21	-60.56 – -13.85	**0.005**
Summer*Plantong yes	-29.46	-52.81 – -6.11	**0.535**
Winter*Plantong yes	-1.19	-24.30 – 21.93	**0.004**