Influence of Predation Risk on Foraging Behaviour of Indian Desert Jird (*Meriones hurrianae*) in the Thar Desert

by

Ananya Singh

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in

Wildlife Science

Under the supervision of

Dr. Parag Nigam, Scientist – G

Dr. Sutirtha Dutta, Scientist – E

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DECLARATION

I hereby declare that the work conducted under the thesis entitled **"Influence of Predation Risk on Foraging Behaviour of Indian Desert Jird (*Meriones hurrianae*) in the Thar Desert"**, is a record of original and independent research work done by me and subsequently submitted for the award of the degree of **Master's in Wildlife Science** at the **Academy of Scientific and Innovative Research**. This research work has been carried out under the guidance and supervision of **Dr. Parag Nigam, Scientist - G**, and co-supervision of **Dr. Sutirtha Dutta, Scientist - E** of Wildlife Institute of India, Dehradun. The work has not formed the basis for the award of any other degree, diploma, or any other qualification. I also declare that the thesis embodies my own work, analysis, observation, understanding and the particulars given in it are true to the best of my knowledge.

Ananya Singh
Ananya Singh
Enrolment No. 50BB23A73002
Place: Dehradun
Date: 27/06/2025

Dr. Parag Nigam

Dr. Sutirtha Dutta

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

This is to certify that the thesis by **Ananya Singh** entitled **"Influence of Predation Risk on Foraging Behaviour of Indian Desert Jird (*Meriones hurrianae*) in the Thar Desert"** is an original and independent research work submitted to the **Academy of Scientific and Innovative Research**, for the award of the degree of **Master's in Wildlife Science**.

Ananya Singh has put one semester of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted to any other University or Institute for the award of any degree, diploma or distinction.

(Dr. Parag Nigam)

Supervisor

Ruchi

(Dr. Ruchi Badola)

Dean

Faculty of Wildlife Science

सकायाध्यक्ष / Dean
भारतीय वन्यजीव संस्थान
WILDLIFE INSTITUTE OF INDIA
देहरादून / Dehradun

पत्रपेटी सं. 18, चन्द्रबनी, देहरादून-248001, उत्तराखण्ड, भारत
Post Box No. 18, Chandrabani, Dehradun-248001, Uttarakhand, INDIA
ई.पी.ए.बी.एक्स. :+91-135-2640111 से 2640115, फैक्स :0135-2640117
EPABX : +91-135-2640111 to 2640115, Fax : 0135-2640117
ई–मेल/E-mail : wii@wii.gov.in, वेब/website : www.wii.gov.in

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

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Chandrabani, Dehradun - 248 001

(Dr.Parag Nigam)

Scientist – G

पत्रपेटी सं० 18, चन्द्रबनी, देहरादून – 248 001, उत्तराखण्ड, भारत
Post Box No. 18, Chandrabani, Dehradun - 248 001, Uttarakhand, INDIA
ई.पी.ए.बी.एक्स : +91-135-2640111 से 2640115 फैक्स : 0135-2640117
EPABX : +91-135-2640111 to 2640115 Fax : 0135-2640117
ई–मेल/E-mail : wii@wii.gov.in वेब/Website : www.wii.gov.in

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Introduction

Animal lives are riddled with choices they must make daily between maximising their survival in face of constraints that bind them to become ‘evolutionarily successful’ individuals. Optimality theory stems from this balance between maximising individual fitness whilst compromising on the extent of opportunities available.

Foraging is fundamental to all organisms to obtain energy from their environment for basic survival. Feeding behaviours have been studied to look at how an animal perceives and navigates through their surroundings. Choices on when, where and how to forage reflect the decisions they make to optimise their survival and reproductive abilities. Time allocation decisions made by a species is an essential metric to understand these choices. The foraging behaviour of an animal is governed by a combination of intrinsic and extrinsic factors. Intrinsic factors refer to the physiological condition of the animal. Energetic state, reproductive status and nature of the individual can influence their foraging decisions. For instance, individuals with higher metabolic demands or hungrier individuals will be more willing to take risks while foraging compared to other conspecifics. Extrinsic factors of the environment include predation risk, habitat characteristics, competition with conspecifics or other species and distribution of resource patches. Resource distribution can dictate the life history patterns of a species. Species which inhabit resource scarce or patchy environments will tune themselves to become more conservative in their approach which leads to favour certain life history strategies such as delayed reproduction. Thus, foraging decisions reflect a link between the environment's conditions and the evolutionary responses towards it. Although not a purview of this study, food acquisition can be broadly applied as resource acquisition of any form, such as looking for mates (Stephens & Dunlap 2008).

Foraging theories developed over time have viewed individuals as ‘economic decision makers’ who make predictable decisions. Optimal Foraging Theory (OFT) is an ecological model which provides a framework to predict how an animal behaves in search of food given the different costs associated with foraging. Various foraging models have been built upon the OFT which investigate the decisions made for a task quantified against currencies and constraints revolving around the particular task. For instance, the Prey Choice model or the Contingency model quantifies the profitability of a prey in terms of energy obtained versus the handling time involved to consume the prey item to predict which kind of prey a predator is more likely to acquire (Krebs & Davies 1993). These models allow us to factor in basal nutrient requirements, digestive constraints and search time required which determines the choice of diet. The Ideal Free Distribution model explains how foragers distribute themselves in resource patches to harvest resource and provides another optimality framework to investigate how resource abundance and competitive constraints affect spatial distribution patterns (Fretwell & Lucas 1970; Harper 1982).

The marginal value of the patch is a concept stemming from the Marginal Value Theorem stated by Charnov (1976). The ‘patch’ is a limited area that hosts food resources for the species under study. As the forager consumes more, the rate of energy gain decreases and the rate of return at which the forager leaves the patch, due to insufficient reward in light of efforts made or predator risk, is termed as the marginal value of the patch. Empirical studies have confirmed MVT predictions in diverse species, such as birds (Cowie, 1977), bees (Waddington & Holden, 1979), and primates (Stephens & Krebs, 1986). The marginal value framework also adapts to complex environments where patch quality is uncertain or variable (Nonacs, 2001). The marginal value of the patch has also been extended to state-dependent and stochastic settings that give importance to risk, energy state and predation pressure (McNamara & Houston, 1985). The inclusions make the estimation of marginal value of the patch flexible and more accurate to real-world foraging decisions.

Giving up density (hereafter, GUD) stems from the MVT which predicts that optimal individuals forage in a way to maximise their net energy intake per unit time while exploiting a patch of depleting resource. This energy intake per unit time is referred to as ‘harvest rate’, and the density of resources at which the forager leaves or ‘quits’ the patch as it is no longer profitable to continue harvesting is termed ‘harvest quitting rate’. In other words, harvest quitting rate is the harvest rate at which the benefit of foraging equals the costs incurred. Since the relationship between harvest rate versus food density is monotonic, the harvest quitting time can be quantified as the density of food at which the forager quits the patch. Thus, giving up density provides an ingenious and simple method to quantify foraging choices based on the amount of feed left in the patch.

The concept of giving up density was proposed by J.S. Brown in his seminal paper where he introduced the rationale behind the technique and tested it out empirically by applying it on a community of four Arizonian rodents (Brown, 1988). He advocated the use of foraging behaviour to investigate predation risk, habitat preferences, and interspecific competitive relationships through controlled field experiments.

GUD is based on the framework that the harvest rate of a patch (H) is balanced by metabolic cost of foraging (C), predation cost (P) and the missed opportunity costs (MOC) which constitute not partaking in other activities.

$$H = C + P + MOC$$

An optimal forager quits a patch when the benefit (energy / nutrient) derived from the patch equals the cumulative cost of staying in the patch. To examine the effect of any of the components of the framework such as predation cost (P), artificial patches of resource can be placed wherein the other components (C and MOC) are controlled for by keeping them constant. This allows us to explore the forager's decision and strategies applied under different scenarios of predation risk.

Extensive work has been done on granivorous kangaroo rats (*Dipodomys*) in North American Sonoran Desert and gerbilline rodents in Negev desert, investigating the response of rodent communities to environmental heterogeneity in the resource scarce desert ecosystem. Resources vary both spatially and temporally for desert rodents and research has largely investigated how this heterogeneity in resource influenced foraging patterns and species coexistence in different desert ecosystems (Kotler and Brown 1988). Multiple mechanisms of coexistence have been hypothesised to predict how several rodent species partition their resource, using optimal foraging theory. In resource scarce environments, most rodents tend to have a generalist diet and forage on the same resource. Patch use experiments have been used to investigate how different components such as patch quality, microhabitat cover, predation risk, effect of illumination and energetic costs affect foraging behaviour of the animal (Kotler 1984, Lemen 1978, Hutto 1978).

Predation cost is one the major evolutionary forces which has shaped behavioural and morphological traits of species (Lima & Dill 1990). Predators not only have direct lethal effects on prey populations i.e. suppress prey populations, which in turn affects trophic interactions, but also impose ‘risk effects’ by forcing their prey to make behavioural adaptations or modify their life history patterns (Schmitz et al 1997). Predation risk effects refer to changes in prey behaviour caused by predators, and this has especially been studied in case of foraging strategies of animals. It has been well documented that the foraging patterns of animals reflect trade-offs they make between the benefit of foraging on the patch (energy intake) and the costs associated with it (predation cost, thermoregulatory cost, handling time, etc). Predation cost of a patch is dictated by the forager’s energy state, marginal value of the patch and lethality of the predator. Animals trade-off predation risk and food through time allocation and investment in vigilance behaviour.

Time allocation refers to where, when and how long the forager decides to spend time acquiring resources (Brown and Kotler 2004). Seemingly minor changes in the microhabitat can lead to drastic variation in the cost of predation for small mammals. Elements like vegetation cover, ground clutter, illumination etc. can significantly alter the predation risk perceived by small mammals. Desert gerbils (*Gerbillus allenbyi*) have been reported to respond to vegetation cover and moonlight intensity in their foraging pattern (Kotler et al. 1991). The gerbils avoided foraging on bright moonlit nights, as it increased the risk of being spotted by predatory birds. Orrock, Danielson, and Brinkerhoff (2004) reported that cotton rat (*Sigmodon hispidus*) changed their foraging pattern in light of minor fluctuations in fallen leaf litter. The leaf litter provided greater visual obstruction and escape opportunities in case of an attack. Even when patches exhibit similar food availability, a study on *Acomys cahirinus* revealed a preference for patches that had habitat microstructures (Embar, Kotler, and Saltz 2011). These observations have given rise to the concept of “landscape of fear” that is affected by minimal fluctuations (Brown & Kotler, 2004). The animal constantly adapts to the microhabitat features that decrease risk exposure and may lead to large behavioural shifts due to the beneficial predator-prey dynamics.

According to the perception abilities of a prey, they can detect the presence of a predator through olfactory, auditory or visual cues which in turn instil anti-predatory responses. Anti-predatory responses can be diverse, ranging from seeking refuge or retreating to safer habitats to altering group size and increasing vigilance (Bednekoff, 2006; Werner et al. 1983; Brown et al. 1998). These responses can result in decreased foraging rates, modification of diets (Christianson and

Creel 2010) or chronic stress responses which can also be transmitted intergenerationally (Sheriff et al., 2010). They can manifest as reduced mobility linked with reduced foraging opportunities. Consequently, the low energy availability (Lima & Dill 1990), and reduced mating opportunities due to low encounter with suitable mates (Magnhagen 1991) can suppress prey growth and decrease reproduction (Relyea and Werner 1999). At certain population levels these ‘indirect’ risk effects may even overshadow lethal ‘direct effects’ of predation (Preisser et al. 2005).

Rodent communities have been well studied in other desert ecosystems around the world as a model system to investigate coexistence mechanisms using optimal foraging theory. Studies on rodent communities are lacking in the Thar desert region where recent increased land use changes have unknown effects on the trophic structures of the native ecosystems. There is a need to investigate functional roles of rodents and other small mammals in these arid grassland ecosystems where they form a major prey base for mammals such as foxes and many raptor species. It is believed that the large-scale conversion of grasslands to agriculture, partly facilitated by the advent of irrigation and modern farming tools, and renewable energy generation and distribution through transmission lines are impacting and reducing raptor and terrestrial predator populations in the Thar desert. This can release the predation risk effect from prey populations such as rodents, in turn altering the latter's habitat use and seed predation patterns that might even have cascading effect on vegetation assemblages. By using GUD, a well-developed methodology which has extensively been used on other rodent communities, the study aims to gain more understanding about the system as we look at the behavioural response of a prey towards predation pressure.

Study species

Indian Desert Jird or Indian Desert Gerbil (*Meriones hurrianae*) is a semi-fossorial desert rodent found in arid and semi-arid areas of Rajasthan, Gujarat and Haryana and parts of National Capital Region. It is an abundant rodent species found in sandy habitats and inhabits agricultural fields. Being the only diurnal desert rodent in the region it forms an important prey base for many native predators.

This species belongs to the family Muridae, the largest family in Mammalia. It is a Turano-Rajasthani species found in arid and semi-arid regions of Iran, Afghanistan, Pakistan and northwestern India (Prakash 1974). They live in colonies with varying group sizes of 5-40 individuals (Prakash 1981) and form a network of interconnected burrows which go up to a metre deep. Jirds are largely found in sandy habitats with shrub hummocks of species like *Capparis decidua* or *Ziziphus nummularia* and inhabit agricultural lands. They are diurnal in nature and show more crepuscular activity during the peak summer seasons. Their diet shifts seasonally according to the availability in the environment. They predominantly consume seeds in winters (Oct - Mar), vegetative parts like stems and rhizomes in summers (Apr- Jun) and leaves and insects during monsoons (Jul-Sep). Previous studies on this species were conducted by Central Arid Zone Research Institute as monographic works mostly from a pest management perspective, a few studies on its xeric adapted physiology (Goyal *et al* 1982; Goyal 1988), burrow structure and reproductive behaviour in laboratories (Sinhasane & Joshi 1998).

The role of small mammals in the Thar desert has not been investigated in detail. Population dynamics studies on a few rodent species including *Meriones hurrianae* and *Tatera indica* have been carried out in the past mostly from a pest management perspective (Prakash 1981). There are a few studies in India which investigate the response of small mammals to woody encroachment (Misher 2022; Jayadevan 2018).

Aim:

The aim of the study is to understand how predation risk influences the foraging behaviour of Indian Desert Jirds in terms of time allocation of certain behaviours (vigilance and foraging), daily activity pattern and giving up densities (GUD) framework.

Objective 1: To examine activity pattern and time allocation between sites with different predator densities.

Objective 2: To examine perceived predation risks through the Giving-up Density (GUD) framework.

Research Question:

1. How does predation risk and resource availability influence foraging decisions of jirds?
1.1 How does predation risk vary between sites?
1.2 Is the activity pattern or time allocation to behaviours (vigilance and foraging) affected by predator risk?
2. Are they differentially predating on certain seed types under predation risk and thereby affecting the plant community around them?

Hypothesis 1:

Time allocation to vigilance vs foraging and activity pattern will vary between sites depending on the predation risk perception.

Prediction:

Different habitats or cover types represent varying predation risk and forage availability, therefore jirds should allocate time between foraging and vigilance accordingly.

Hypothesis 2:

Foraging decisions will depend on microhabitat cover, seed preference and seed size

Predictions:

i) GUD will vary between open and bush microhabitats
ii) Higher predator encounter rates will yield a sharper change in GUD (due to increased cost)

Study Area:

The study was conducted in two satellite enclosures of Desert National Park Wildlife Sanctuary (DNP) located in Ramdevra, Jaisalmer district, Rajasthan. The two enclosures Ramdevra ABC and Ramdevra Conservation Breeding Centre (RCBC) were chosen due to presence of ample jird colonies, differing predator activity as well as logistic feasibility. These enclosures are maintained to protect grassland habitats for the Critically Endangered Great Indian Bustard and other related fauna. The study site lies under biogeographic province 3A in the Thar desert region (Rodgers and Pawar 1988). Existing information of the Bustard Recovery Program shows high predator density (foxes and raptors) in ABC enclosure. Whereas, being a conservation breeding centre for the Critically Endangered Great Indian Bustard (*Ardeotis nigriceps*), RCBC has low mammalian predator presence due to regular predator management efforts to reduce the risk to captive-reared birds.

The region experiences harsh winters with temperatures dropping to 5°C from December through February and hot, dry summers with temperatures rising up to 50°C from April through June.

The grassland in the enclosures is dominated by *Aristida adscensionis*, *Dactyloctenium aegyptium*, *Dactyloctenium scindicum, Cenchrus ciliaris* and *Panicum turgidum*. Shrubs include *Aerva pseudotomentosa, Indigoferra* spp, *Crotolaria burhia*. Grasslands are interspersed with native woody plants, the dominant ones being *Salvadora oleoides*, *Ziziphus nummularia*, *Capparis decidua, Leptadenia pyrotechnica* and the exotic *Vachellia tortilis.*

The native mammal fauna of the study area includes chinkara (*Gazella benneti*), nilgai (*Bosephalus tragocamelus*), wild pig (*Sus scrofa*), Bengal or Indian fox (*Vulpes bengalensis*), desert fox (*Vulpes vulpes pusila*), Indian hedgehog (*Paraechinus micropus*) and Indian grey mongoose (*Herpestes edwardsii).*

Bird life includes the Great Indian Bustard (*Ardeotis nigriceps*), Common Babbler (*Turdoides caudata*), White-eared Bulbul *(Pycnonotus leucotis*), Indian Silverbill (*Euodice malabarica*), House Sparrow (*Passer domesticus)* and Yellow Throated Sparrow (*Petronia xanthocollis*). Birds of prey include Great Gray Shrike (*Lanius excubitor*), Shikra (*Accipiter badius*), Black-winged Kite (*Elanus caeruleus*), Montagu's Harrier (*Circus pygargus*), Pallid Harrier (*Circus* *macrourus*), Tawny Eagle (*Aquila rapax*), Steppe Eagle (*Aquila nipalensis*), Short-toed Snake Eagle (*Circaetus gallicus*), Indian Spotted Eagle (*Clanga hastata*) and Short-eared Owl (*Asio flammeus*). Reptiles include spiny-tailed lizard (Saara hardwickii), calotes sp., agamid lizards and red sand boa (*Eryx johnii)*.

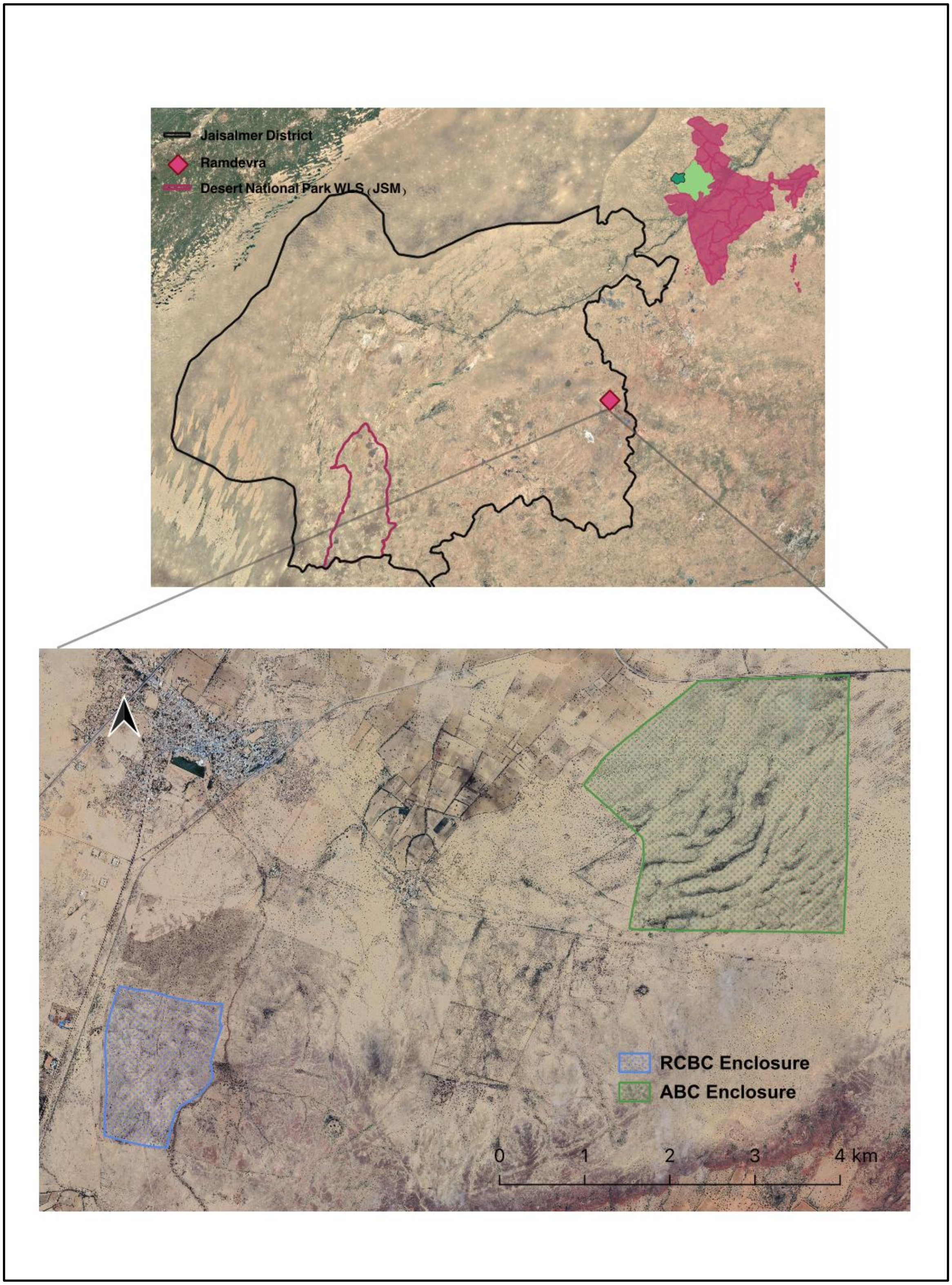


Fig. 1: Map of study area (A) Location of study site within Jaisalmer district (B) Study enclosures Ramdevra ABC and RCBC

Objective 1: To examine time allocation and activity pattern between sites with different predator densities.

Methods:

Field Methods

1. **Behaviour Sampling**

Behavioural observations were conducted following focal animal sampling method (Altmann 1974) on six colonies in Ramdevra ABC in winter and 4 colonies in Ramdevra ABC and RCBC each in summers. Since the individuals could not be marked as planned, traditional focal sampling was replaced by recording duration of all behaviours of all individuals within sight during the sampling session. For winter sampling sessions, behavioural observations were made from a portable hide placed at least 15-20 m away from the colony since jirds were not habituated to human presence and this helped avoid observer bias. This also ensured that the jirds not being habituated to human presence. The duration of each sampling session was 30 minutes. Time duration of all behaviours presented were recorded using a voice recorder. Starting time of each behaviour code was recorded during the sampling. Behaviour sampling of multiple individuals could be done simultaneously, therefore all individuals observed were recorded during the sampling sessions. Behaviour was recorded as *states* - foraging, digging, vigilance and moving and others. Events were jumping and foot drumming.

Table 1: Behaviour categories of Indian Desert Jird in Thar Desert (2025)

S. No	State	Description
1.	Foraging	Feeding, chewing or handling food items.
2.	Digging	Mostly hind limb digging for burrowing, occasionally front limbs are used during foraging.
3.	Vigilance	Erect bi-pedal position with front paws held up while scanning around the burrows by rotating
4.	Moving	Walking or movements whilst stationary
5.	Sitting	Semi-erect position can either be performed with vigilant behaviour at the burrows or just resting in general. Since they can be confused as one, sitting stances have not been included with vigilance
5.	Others	Grooming, interacting and running/sprinting have been grouped as other behaviours.

During the sampling session, presence of predators within a 50 m radius were recorded to quantify raptor encounter rates. Black-winged Kite, Harriers (Pallid and Montagu's), Shikra, Kestrel and Great Gray Shrike were observed either scanning jird colonies by soaring a few metres above ground or attempting to hunt by ambush.

2. Activity Pattern

Temporal activity patterns were recorded using camera traps placed on/over the colonies. Browning cameras were used on a timelapse interval of one minute throughout the day. The cameras activated automatically from sunrise to sunset. 1-2 camera traps were positioned over each colony to cover the active burrows. Custom-made stands built from metal pipes were used to hoist the cameras at an angle from 3 m height facing the ground to cover a larger portion of the colony.

Analytical Methods

1. Behaviour Sampling

Behaviour durations were calculated using Microsoft Excel. Proportion of time spent on each behaviour was computed by dividing the duration of each behaviour during a session (30 minutes) by the total duration of all recorded behaviours within a session. The transformed proportions (arcsine transformation) were used in Generalized Linear Models (GLMs) to examine the effects of site and season on behavioural activities. Three models were used for each category - (1) a null model including only the intercept, (2) an additive model including the combined effects of site and season (site + season), and (3) an interactive model including both main effects as well as their interaction (site x season). Since the aim of the study is focused on looking at effects on foraging behaviour, predictors site and raptor encounter were run separately with a null model on foraging and vigilance. The models were run separately for summer and winter.

2. Activity Pattern

Activity pattern data was recorded as Browning timelapse videos (.TLS files) which were accessed through Browning's "Time lapse Viewer Plus" software. The timelapse files were converted to .AVI and snapshot images of every minute were extracted using package 'av' on R software (R Core Team 2025 <https://www.R-project.org/>). The date and time stamp on each image were read using an OCR engine package 'tesseract'. ExifPro 2.1 was used to annotate the images for labelling the number of jirds present. The photocapture rate or activity rate was calculated as the frequency of snapshots containing jird captures (out of the total number of images). Time activity pattern was plotted against time of the day for summer and winter separately across sites.

Results:

1. Behavioural sampling

The sampling was restricted to ABC Fence and Mound Site during winters, and Mound Site and RCBC during summers. Table 2 shows the results obtained for effect of site and season on different behaviour categories. Results on general linear model explaining time allocation to behaviour showed that in ABC Mound Site jirds tended to spend more time in vigilance and less time in movements, whereas, digging activity was less in winter than summer.

The raptor encounter rate data (Fig 2) showed that there was no significant difference between raptor encounter between the two sites in winters. However, the encounter rates in summers between Mound Site and RCBC is significantly different as raptor encounters in RCBC was zero.

Site was the best predictor for model run on foraging and vigilance according to AICc values. Using predict function, the best model was used to predict behaviour proportions (Foraging vs Vigilance) in each site as shown in Fig 3.

2. Activity Pattern

Winter Activity Pattern of ABC Mound Colonies

Camera trap data show that there is a steady increase in activity from beginning of photo-captures at 0800 hrs until around 1100 hrs with a peak at 1000 hrs (see Fig. 4). All three colonies show similar activity curves with general activity dipping in the afternoon after 1300 hrs.

Winter Activity Pattern for ABC Fence Colonies

Photocaptures from FX colony show a much greater amount of activity compared to other colonies in the site, as well as the mound colonies. This could be possibly due to greater number of individuals present in FX colony as observed during behavioural sampling. The activity pattern is bimodal, with peaks in activity at 1000 hrs and a lower maximum between 1400 – 1500 hrs. Activity between the peaks reaches its minimum at around 1300 hrs. The activity patterns for FC6 and FC2 appear to be offset by approximately 2 hours. In both cases, we see a rise in activity which peaks at 1100 hrs and 1300 hrs respectively followed by a steady decrease.

However, in FC6, we observe that the activity begins to increase again after 1600 hrs. (see Fig. 5)

Summer Activity Pattern

Summer activity pattern data in both Mound Site and RCBC show a lot of variation in the data. Photocaptures in summer show a strong similarity in activity between colonies in RCBC. They show a strong bimodal peak which was consistent with field observations. At all three colonies, there is an increase in activity between 0600 hrs and 0900 hrs, followed a general decline until 1100 hrs. There is an upward trend in activity after 1600 hrs. However, activity in RCBC_OG increases more dramatically (see Fig. 6 & 7).

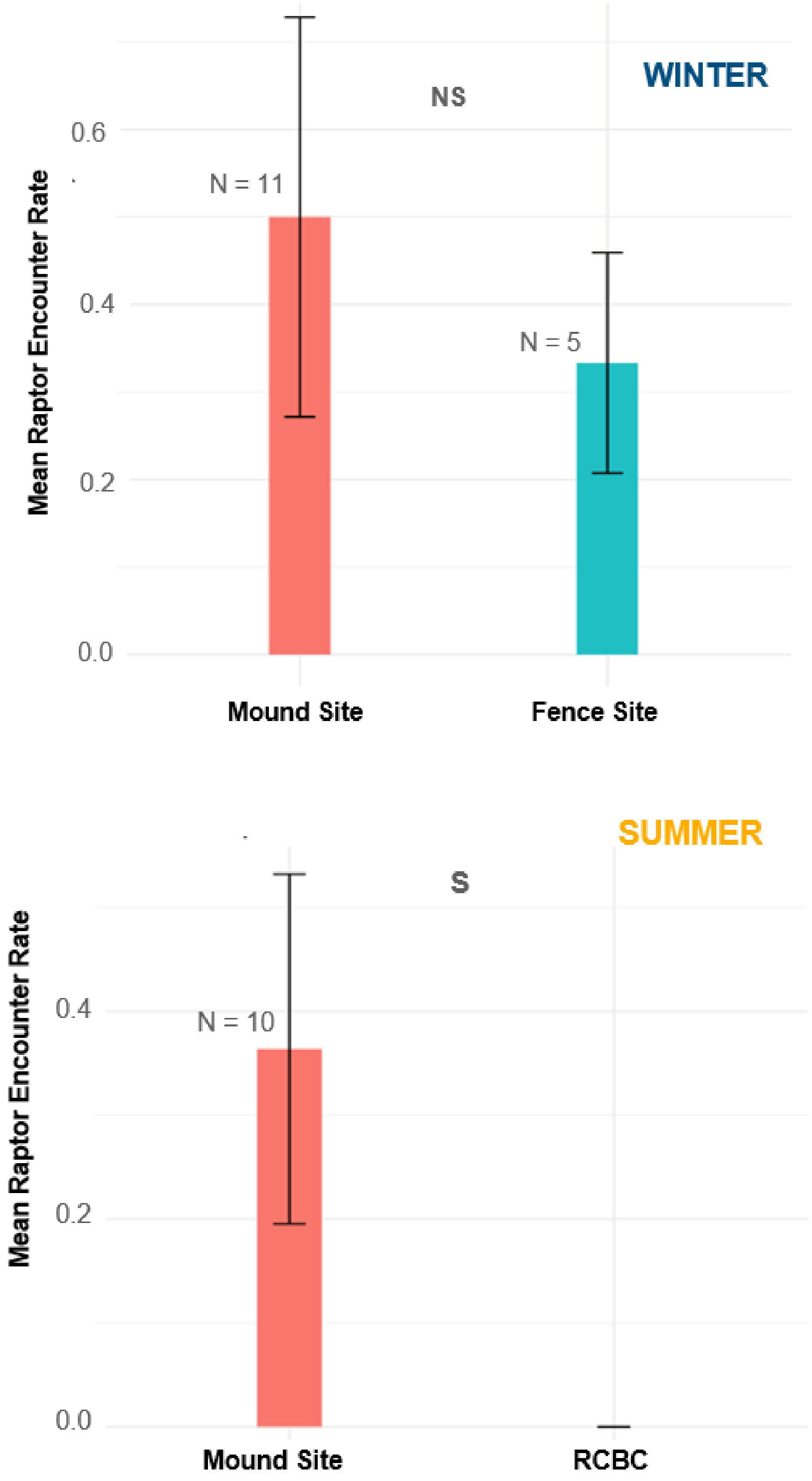
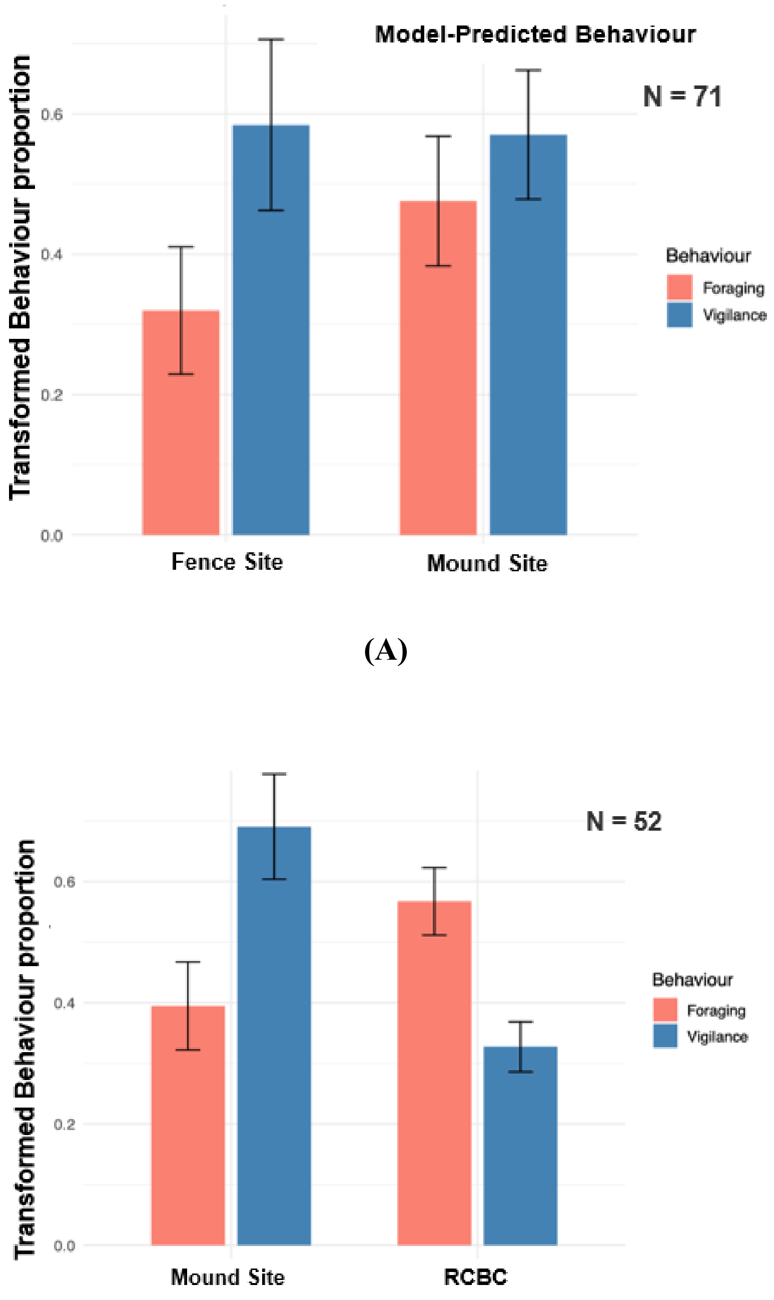


Fig 2: **Mean raptor encounter rate per site between winter and summer (as recorded during behavioural sampling sessions).**



(A)

(B)

Fig 3: Foraging vs Vigilance between the two sites in winter (A) and summer (B). Raptor encounter rates significantly different in summer (B) with Mound Site having significantly greater encounter rate than RCBC.

Table 2. Mean (SE) of effect sizes of sites indicating predation risk (contrast: ABC fence colony) and season (contrast: summer) on arcsine transformed proportion of time spent in various behaviours (columns) by the Indian Desert Jird in Thar Desert (2025) based on the least AICc general linear model

		State				
Variable	**Level**	**Foraging***	**Vigilance**	**Digging**	**Moving**	**Others***
Site	High predation risk (ABC Mound)	-	0.691 (0.378)	-0.480 (0.260)	-0.213 (0.079)*	-
	Low predation risk (RCBC)	-	0.327 (0.377)	-0.333 (0.260)	-0.177 (0.102)	-
Season	Winter	-	0.584 (0.383)	-0.613 (0.264)*	-0.153 (0.071)*	-
Site X Season	High Predation (ABC Mound) x winter	-	-0.705 (0.399)	-0.573 (0.040)*	-0.153 (0.071)	-

* Information Theoretic approach did not support full model over null model

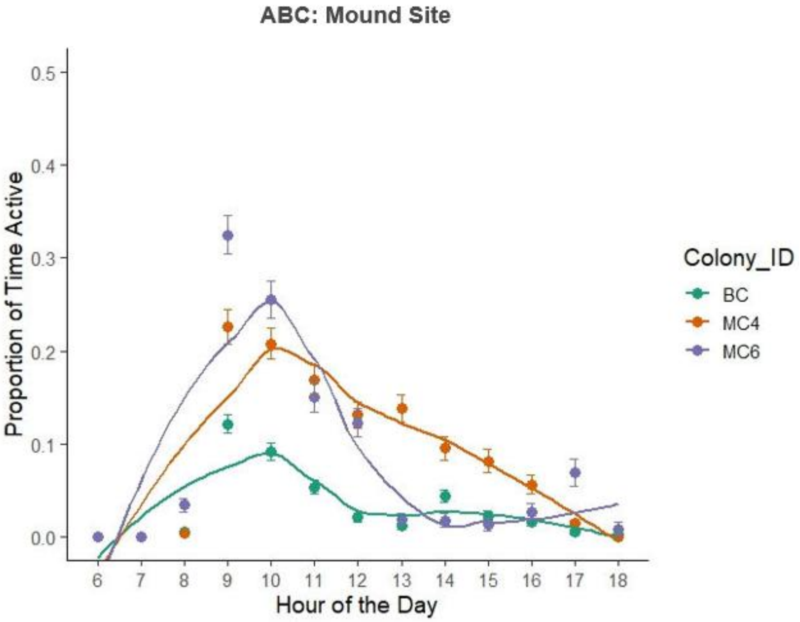


Fig. 4: **Activity Pattern for ABC Mound Colonies in winter (2025): BigCol (green), MC4 (orange), MC6 (purple)**

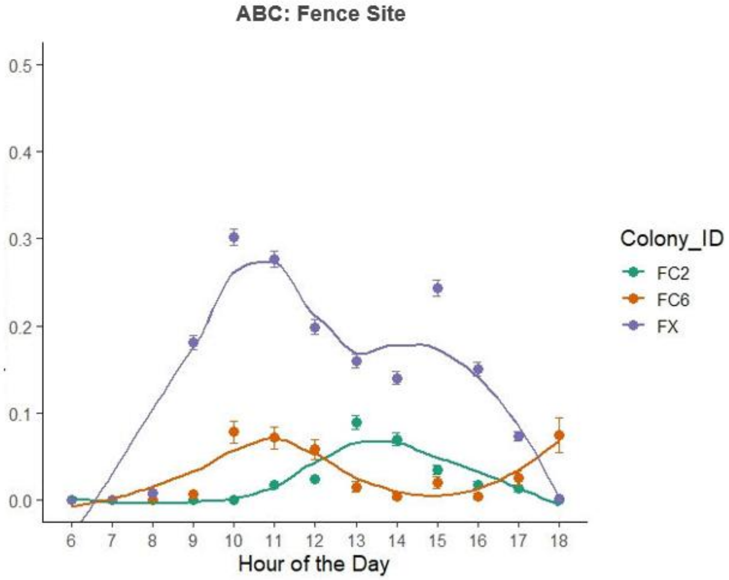


Fig. 5: **Activity pattern for ABC Fence Colonies (moderate predation risk) in winter (2025): FC2 (green), FC6 (orange), FX (purple)**

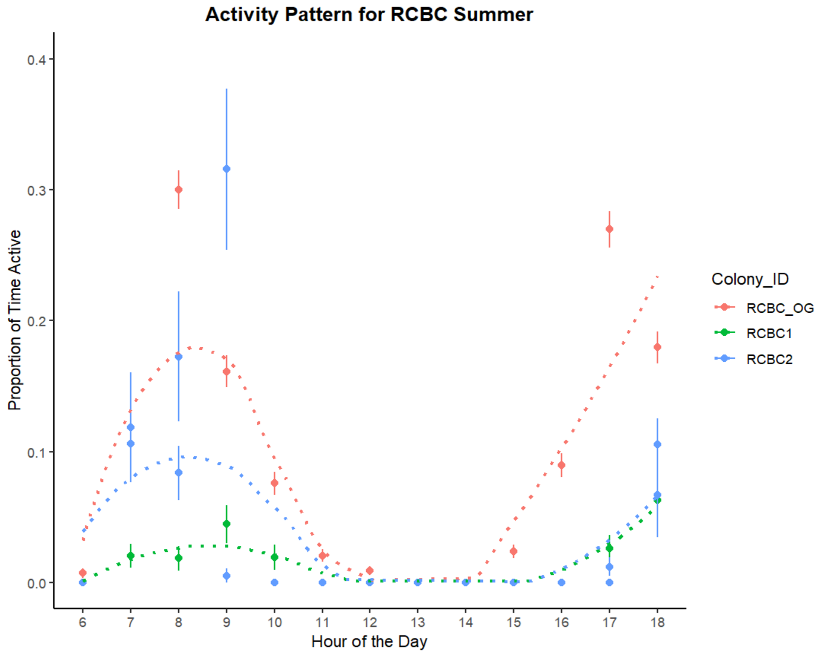


Fig. 6: **Activity pattern for RCBC colonies (low predation risk) in summer (2025): RCBC_OG (orange), RCBC1 (green), RCBC2 (blue)**

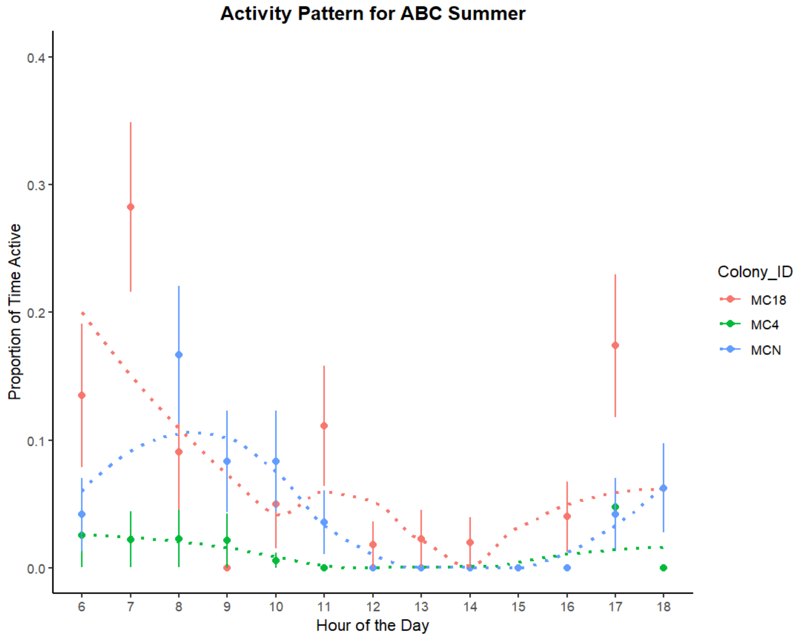


Fig. 7: **Activity pattern for ABC Mound Colony (high predation risk) in summers (2025): MC18 (orange), MC4 (green), MCN (blue)**

Objective 2: To examine perceived predation risk through the "Giving-up Density" (GUD) framework.

Field Methods:

Giving-up density trials were conducted by placing plastic trays of 400 (length) x 300 (width) x 100 mm (depth) placed according to three experiments: microhabitat cover, seed preference and seed size. Initially 'distance from the colony' was considered to examine the effect of predation risk which increases as the animal moves away from the nearest burrow hole. However, due to the animal's natural propensity to create new burrows adjoining the tray within a few hours rendered the distance of the food patch from the colony irrelevant. Hence this experiment was abandoned after a few trials.

Eight colonies in ABC and 4 colonies in RCBC were selected for the GUD trials. Each treatment (see Table 3) was carried out for 4-5 days per colony. Trays were laid for 8 hours each day from morning till evening. The placement of the trays was randomised daily to avoid predictability. Each tray consisted of 7 g of seeds mixed thoroughly with 8 L of sand. Four trays were deployed per colony wherein two trays represented one treatment *i.e.* 14 g of seeds per treatment split into two trays. The pre-weighed seeds were mixed in the sand during tray deployment. After every trial, sand from the tray was sieved and the remaining seeds were collected carefully from the sieve and placed in labelled containers to be weighed. These were used to calculate the giving-up density of each tray. Sand was weighed using a portable scale and stored in bags concealed near the colony to be used for the next trial.

The three experiments had the following treatments:

1. Microhabitat cover: Open and Cover microhabitats.
   Open treatment involved placing the trays in an area with no or minimal grass or canopy cover while the "cover" trays were placed in abundant grass cover. Grass was supplanted around these trays when required.

2. Seed Size: Whole and ground seeds

Whole and ground (ground as in pounded) peanuts were used for the treatments to test the effect of seed size. All four trays were placed in the open microhabitat to remove the confounding effect of cover.

3. Seed preference

   Wheat and peanuts were used to look at the seed preference in jirds. The size of the seeds was kept similar by sieving ground peanuts through a mesh with similar size as wheat grains, to remove confounding effect of size (Table 3).

Table 3: Details of the treatments carried out for GUD experiments

Experiment	**Treatments**	**GUD Tray Content**
1. Microhabitat	I. Open	7 g Peanut x 2
	II. Cover/Bush	7 g Peanut x 2
2. Seed Size	I. Whole	7 g Ground Peanut x 2
	II. Ground	7 g Whole Peanut x 2
3. Seed Preference	I. Peanut	7 g Peanut x 2
	II. Wheat	7 g Wheat x 2

GUD experiments involved seeds as the resource and sand as the substrate to create a foraging patch. The ratio of seeds and sand had to be standardised for the study. Most GUD studies on rodents are carried out on solitary animals. However, Indian Desert Jirds are colonial species. Since multiple foragers would visit the patch, the weight of seeds and the volume of sand had to be adjusted accordingly. This was done by ensuring that non-zero values of giving-up densities were obtained consistently. One of the principles behind conducting giving up density experiments is to ensure that enough food is left behind for the experimenter to measure the difference to quantify patch use.

Multiple foragers using the same patch can confound results of individual giving up densities. Therefore, the GUD obtained here is not considered as individual forager's giving up density but the cumulative GUD of the colony summed up. The colonies selected were similar in size according to the number of burrow holes and the activity observed during behavioural sampling. Further, I did not compare the GUD across colonies for an experiment but constrained this comparison between treatments within the same colony in a matched/paired design, to negate any confounding bias of colony size on inferences.

Analytical Methods

The scaled GUD difference of each experiment- microhabitat, seed size and seed preference - was calculated by pooling the GUDs of treatments carried out in every trial, and dividing the weight of seeds remaining (in g) by the weight of seeds added initially. This was done to standardise the GUDs across all trials to obtain comparable values as non-visitations and disturbed trays had to be discarded i.e. in case only one tray was visited in a trial, only 7g was considered as the initial weight of seeds rather than the total of 14g. The scaled difference was then calculated by these standardised values to compare the effect of treatment.

$$GUD \; = \; Initial\, weight\, of\, seeds \; - \; weight\, of\, seeds\, foraged$$

$$= \; Weight\, of\, seeds\, remaining\, (after\, each\, trial)$$

$$Scaled\; GUD = \frac{GUD}{Initial\, Wt.of\; Seeds(g)}$$

The difference between the scaled GUD between the two treatments in each trial was calculated and the mean (95% CI) estimates were obtained, to compare the effect of treatment on GUD within colonies.

Results:

Giving up density inferences were similar between enclosures representing different predation risk perception. The GUD was statistically different only for seed preference experiment in both ABC and RCBC sites, and did not differ between the treatments for the other two experiments. The mean (SE) estimate of scaled difference between wheat and peanut seeds is –0.18 (0.069) for ABC and -0.12 (0.03) for RCBC sites (Table 4).

Table 4: Mean, SE & 95% CI of difference between scaled Giving Up Density between the treatment pairs for each experiment type in ABC and RCBC sites of Thar desert (2025)

Site	Experiment	Treatment pair	Mean	S.E.	LCI	UCI
ABC	Microhabitat	Cover - Open	0.07	0.032	-0.074	0.132
ABC	Seed Size	Ground - Whole	0.01	0.041	-0.07	0.09
ABC	Seed Preference	Peanut - Wheat	-0.18 *	0.069	-0.31	-0.04
RCBC	Microhabitat	Cover - Open	0.04	0.042	-0.104	0.12
RCBC	Seed Size	Ground - Whole	-0.02	0.13	-0.16	0.23
RCBC	Seed Preference	Peanut - Wheat	-0.12 *	0.03	-0.264	-0.06

* Statistically significant difference in GUD between treatment pairs

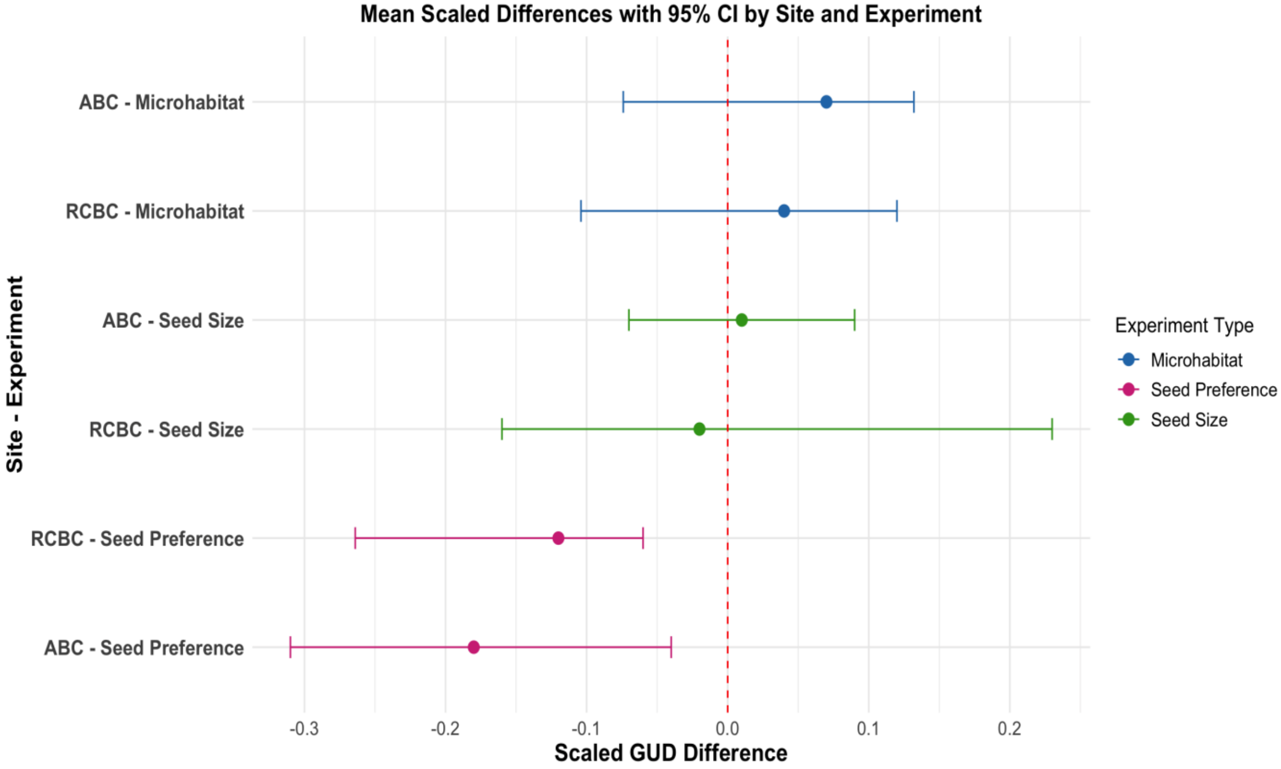


Figure 8. Mean (95% CI as error bars) scaled difference in Giving Up Density between treatment pairs for the three experiments (microhabitat, seed size and seed preference) of Indian Desert Jird in Thar Desert during 2025.

Discussion

My study provides an understanding of the foraging behaviour vis-a-vis time allocation to other behaviour of the Indian Desert Jird, a common diurnal rodent of India's desert ecosystem, using a combination of traditional behavioural sampling - based on observations and camera trapping - and the methodologically well-developed Giving Up Density framework.

In the study site, although the colony size estimation was not carried out, a maximum of 4-5 individuals in each colony were seen at a time based on observation and camera trap images. Initially (during the winter sampling), they were not habituated to human presence and would immediately foot drum at my presence and disappear. Foot drumming is an anti-predatory response which involves a few seconds of repeated thumping on the ground with the hind limb. This can be either done by an individual outside the burrow or from inside the burrows as well. Drumming is generally followed by a period of inactivity for a spell thus affecting the behaviour sampling. The use of a mobile hide, although a bit tedious to transport and assemble, was quite effective for observation and could be placed close to the colonies. Foot drumming was also observed when raptors would visit the colony, especially when harriers would glide or skim over a couple of metres above ground in their characteristic hunting style. Mammal and reptile predation was not observed during the study period.

The most conspicuous behaviours performed by jirds in general are foraging, digging and vigilance. Grass (particularly grass stem or shoots) was the most abundant forage around jird colonies and they were observed feeding on *Aristida spp.*, *Dactyloctenium spp*., *Cenchrus ciliaris* (even the spiky inflorescence) and *Indigoferra* spp. Rhizomes appeared to be particularly relished as they would put great effort digging the soil with their front limbs to pull them out. The remnants of a particular species were found in a lot of jird burrows but I could not identify them.

Digging generally done out by hind limbs as mentioned was performed inside and around burrows, they would start pushing out the loose soil from inside and then dig at the entrances to scoop the sand into little heaps. This was most prominent outside active burrows and thus you could make out the active parts of the colony even if no track marks could be seen. Although in other semi-fossorial species digging is a metabolically expensive activity, it seemed almost effortless in this species and they would continuously maintain their burrows or make new ones throughout the day. It would be interesting to compare the morphology of their hind limbs with that of other rodent species.

Vigilant behaviour was observed before exiting the burrows. They would pop their heads out and stand in bipedal posture facing each direction for a few seconds. They are extremely alert and sensitive to movement during this phase. Once they have spent a few minutes scanning, they would then exit the burrow to start foraging or move to another part of the colony. During the behaviour sampling, it is best for the observer to not make any movements when they are scanning as they retreat immediately on disturbance. Another interesting observation made was their response to bird alarm calls (particularly Common Babbler and White-eared Bulbul). They may be looking out for nearby bird alarm calls because they immediately become vigilant or retreat into their burrows. Playback experiments can be explored to test their response to bird calls as auditory cues for predation risk.

Generally, the behaviour state changes very quickly in jirds, lasting for just a few seconds each. Therefore, voice recording during the behaviour sampling is required to not miss out on the states. Other activities recorded such as grooming and social interactions were observed very rarely. Interestingly, individuals of a one colony in summer (MC4) showed a lot of grooming activity (mainly scratching), with coats showing darker brown splotches in one individual. Territoriality is not observed in jirds and they are more or less individual foragers and do not feed together at once. However, when the GUD trays were placed and they started associating the trays with food, individuals were seen chasing each other away from the tray often. Curiously this behaviour was also observed with empty trays when the seed and sand had not been added yet. Even though the study area seems to have ample supply of food (grass cover), this territorial behaviour has interesting implications in the event when food resources are depleted in a larger area (in an already scarce landscape) where even shifting colonies cannot guarantee access to forage.

Behavioural observations indicated that time allocation in foraging varies between summer and winter within the same site. In winters, the time spent foraging is greater than in the summer. This may be due to the increased metabolic requirement (heat production) of the rodents during winters. Behavioural time allocation also differed between ABC and RCBC sites in summer, the season where the raptor encounter rates were significantly different between the two sites. Jirds in RCBC, the site with low predation risk, exhibits lower proportion of time spent in vigilance, compared to ABC.

The winter activity pattern peaks vary throughout the day among different colonies whereas summer RCBC activity peaks are consistently from 0800 - 09:00 hrs. The activity ranges between 0600-11:00 followed by inactivity in the afternoon till about 1500 hrs when the activity starts picking up again. Considerable variation in activity patterns was noticed among the colonies.

The GUD experiments did not show significant difference between microhabitat types and seed sizes. Microhabitat is established to be an important factor in rodent predation studies, but it was not reflected in this case. Perhaps the jirds' propensity to dig burrows within a very short duration of a few hours gives them an advantage to create new escape refuges around resource patches and possibly nullifies the effect of microhabitat as safer refuges. During the placement of trays in the GUD trials it was observed that new burrows were formed around the tray by the end of the trial when they had to be removed. Although being an important structural feature in small mammal risk perception, Indian desert jirds did not respond to it in this study.

Seed size is related to the handling time during foraging has been seen to differ within gerbils of different sizes (Garb et al. 2000). In a patch of GUD tray, larger seed size represents more energy benefits with greater handling constraints and an increased search per unit time within the sand matrix while smaller seeds offer lesser energy value but easier to search and consume. During behavioural observations jirds were observed carrying larger seeds to the burrows and consuming them and at times even hoarding a few in a single burrow. Smaller ones were observed to be consumed on the spot. However, during the trials, the seed size did not seem to play much of a role in jird foraging preference.

Seed preference experiment allows us to examine the species' selectivity towards a certain seed type, when offered with seeds representing different nutritional values. Peanuts represent a high protein-high fat food source with nearly double the amount of protein content than in wheat. Wheat is a better source of carbohydrates between the two seeds. These preferences could reflect which plant part or seed type, Indian desert jirds prefer to predate upon. Being a colonial species which are not only modifying their environment through soil disturbance and providing refuges to other species, their effect on vegetation in their system is not much understood. Jirds showed greater preference to peanut than wheat in both sites - ABC and RCBC. This may indicate to the fact that their dietary habits are not of voracious eaters consuming everything available to them, but that there is a degree of selectivity in their diet. The study site hosts a diverse assemblage of grass species with potentially different nutritional content and secondary metabolites. Although this result cannot be used to draw inferences on their natural diet preference, it is worth investigating their link with the plant communities around them. As seen in pest management studies conducted on this species in this region (Prakash 1975), they are known to cause large scale damage to crop plants and thus, their extent of foraging pressure on native vegetation as well cannot be sidelined.

Notably, the GUD results are similar between sites with varying predation risk. This finding, along with the negligible role of microhabitat type and seed size on foraging decisions of the Indian Desert Jird imply that the species can exploit a large array of (micro)habitats and food resources (seeds). Their propensity to create escape refuge by prolifically digging new burrows to offset predation risk, that confers them a major advantage in the evolutionary arms race and a formidable adaption to deal with resource scarce desert environments.

Going forward, marking individuals for focal sampling and colony size estimation using mark-recapture and placing cameras at GUD trials to see how different individuals or age-sex classes are interacting with each other will provide greater insights into their foraging behaviour.

Predator simulations by using visual cues in form of raptor models and auditory cues by using bird alarm calls can be conducted on field to further solidify the findings of this study.

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ANNEXURE

Typical jird colony in the study area

Camera trap setup for activity pattern

Adult jird with two sub-adults vigilant at burrow

Giving-up Density Tray Setup