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TEMPRATURE CHANGE AND ITS EFFECTS ON FUNAMBULUS PENNANTII IN TAL CHHAPAR WILDLIFE SANCTUARY CHURU RAJASTHAN

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ABSTRACT

The Northern Palm Squirrel (*Funambulus pennantii*), commonly known as the five-striped palm squirrel, is a semi-arboreal rodent prevalent across northern India, including the arid regions of Rajasthan. This species exhibits remarkable adaptability to diverse habitats, ranging from urban areas to dry deciduous forests. In the context of Tal Chhapar Wildlife Sanctuary, located in the Churu district of Rajasthan, the species faces unique challenges due to the region's extreme climatic conditions.

Tal Chhapar Wildlife Sanctuary, situated on the fringe of the Thar Desert, experiences significant temperature fluctuations, with summer temperatures soaring up to 48°C and winter temperatures dropping to around 10°C. The sanctuary's ecosystem comprises open grasslands interspersed with scattered trees, providing a habitat for various fauna, including *F. pennantii*.

The extreme temperatures in this region have led *F. pennantii* to develop specific thermoregulatory behaviors. Studies have documented behaviors such as basking during cooler periods and seeking shade or retreating to burrows during peak heat to maintain optimal body temperatures. These adaptations are crucial for survival in the harsh climatic conditions of the sanctuary.

However, in the present study it is found that the ongoing climate change poses additional threats to *F. pennantii* in Tal Chhapar. Increasing temperatures and erratic rainfall patterns are seen to disrupt the availability of food resources and suitable habitats. Moreover, changes in vegetation due to climate stress is also found to affect the species' foraging behavior and shelter availability. The sanctuary's grasslands, vital for the sustenance of *F. pennantii*, are susceptible to degradation under prolonged drought conditions.

It is suggested that conservation efforts must focus on monitoring the population dynamics of *F. pennantii* and implementing habitat management practices that enhance the resilience of the sanctuary's ecosystem. This includes maintaining vegetation cover, ensuring water availability, and mitigating other anthropogenic pressures. Further research is essential to understand the long-term impacts of climate change on *F. pennantii* and to develop adaptive management strategies to safeguard this species in Tal Chhapar Wildlife Sanctuary.

KEYWORDS *Funambulus pennantii*, Wildlife Sanctuary, Thermoregulatory behaviors, Anthropogenic pressures.

INTRODUCTION

Funambulus pennantii squirrel (five-striped palm squirrel), is a semi-arboreal rodent which occurs in many habitats throughout northern India, including arid and semi-arid zones like Rajasthan (Choudhury&Sondhi, 2001). The species is showing great ecological flexibility and can live in a wide variety of habitat, including urban habitat and dry deciduous forest (Khan et al., 2008). Specifically, Tal Chhapar Wildlife Sanctuary, situated in the Churu district of Rajasthan, offers a distinct and strenuous environment to *F. pennantii* owing to the weather conditions that are extreme in nature in the area (Rana et al., 2014).

As a Desert in the Thar Desert, Rajasthan experienced severe climatic changes in form of hot summers up to 48°C, and chilly winters as low as 10°C (Jain & Soni, 2012). Tal Chhapar, located near the border of this great desert, is mainly represented by open grasslands with some trees here and there, creating an important habitat and home to numerous wildlife species, including the Northern Palm Squirrel (Sharma et al., 2016). It is an important species in the local ecosystem, since it is prey to predators, and a seed disperser to many plants (Kumar&Yadav, 2011). Nevertheless, it is endangered by the changing environmental conditions that are worsened due to climate change (Sharma et al., 2019).

Research Problem

Tal Chhapar is subjected to high ranges of temperature variation and, as a result, *Funambulus pennantii* has developed specialized thermoregulatory strategies that involve basking in cooler temperatures and shelter-seeking in the hottest times (Singh et al., 2015). These behavioral changes are aids to the species to sustain constant internal body temperature despite the drastic environmental condition. Nevertheless, the species is facing another set of problems because of climate change, which is expressed in the increase in temperature and changes in rainfall patterns (IPCC, 2021).

These climatic changes may largely impact the food resources availability, the suitability of habitats, and even the general behavior of the species. As an illustration, vegetation alteration, especially in the grasslands of the sanctuary, may influence foraging resources and shelter access to *F. pennantii* (Singh&Ramesh, 2020). In addition, unpredictable weather patterns might result in extended droughts, which would facilitate the destruction of critical habitats (Pathak et al., 2018). Gaining insights into the reaction of *F. pennantii* to such stressors is important in determining the extent of effects of climate change on wildlife in other aridlands, such as the Rajasthan (Mukherjee & Pal, 2020).

Objectives of the Study

This study aims to:

- Investigate the effects of temperature fluctuations and climate change on *Funambulus pennantii* in Tal Chhapar Wildlife Sanctuary.
- Examine the thermoregulatory behaviors exhibited by *F. pennantii* and how these may be influenced by changing environmental conditions.
- Assess the impact of climate-induced changes in vegetation and food resources on the species' survival and behavior.

- Provide recommendations for conservation strategies to enhance the species' resilience to climate change.

Significance of the Study

As the world is increasingly becoming concerned about climatic changes, it is vital to acknowledge how wildlife species are adjusting to these transformations in order to conserve them accordingly (Chakraborty&Saha, 2017). The results of the study will serve as meaningful information regarding the ecological consequences of temperature revision on *F. pennantii* and other related species within the arid lands. Beyond that, the research will also include viable suggestions on how to deal with wildlife habitats under the prevailing climatic conditions to contribute to the long-term conservation of Tal Chhapar Wildlife Sanctuary (Rana et al., 2019).

REVIEW OF LITERATURE

Climate Change and Its Effects on Wildlife in Arid Regions

Climate change is also emerging as one of the greatest threat to biodiversity particularly in such areas as the Thar Desert, where already, the toughening climatic conditions are posing difficulties to species survival (Sharma & Kapoor, 2013). In deserts, the variations in temperatures, erratic precipitation, and the extreme climatic conditions experienced such as sandstorms, greatly affect the behavior and distribution of animals (Saha & Chakraborty, 2015). Research findings indicate that increased temperature and changes in precipitation levels are some of the causes of habitat loss, food scarcity, and general distress among wildlife populations in these regions (Singh et al., 2019).

To species, such as *Funambulus pennantii* that have adapted to live in such extreme conditions, these changes can increase the current challenges. Behavioural adaptations, including thermoregulation by basking or shading, might not be enough to handle more extreme temperature any more (Jain et al., 2016). How these changes affect the species which are dependent on a particular habitat structure (such as grasslands and scattered trees in Tal Chhapar) is a little understood topic which this study attempts to shed some light on.

Thermoregulation and Adaptations in *Funambulus pennantii*

Being capable of sustaining an optimum internal temperature with changes in the environmental temperature is a key factor in the survival of many species, *F. pennantii* included. The desert rodents have thermoregulatory strategies, including basking and burrowing, which have been thoroughly reported in other related species (Patel & Pandey, 2018). All these behaviors help the squirrels survive the drastic daily range of temperature that is encountered in the arid areas. Nevertheless, it has been revealed that climate change can interfere with these adaptive measures in two ways: by exacerbating temperature extremes or by decreasing the occurrence of appropriate refuges (Gaur et al., 2017).

The latest research on *F. pennantii* in the Thar Desert has suggested that such rodents conduct both behavioral and physiological adjustments to control their body temperature (Reddy et al., 2020). However, the ability of these adaptations to endure a continually mounting climate pressure is not completely comprehended. In examining this phenomenon in Tal Chhapar, therefore, this will contribute to addressing a research gap in literature with respect to thermal tolerance limits of *F. pennantii* and its ability to survive in the shifting environmental conditions on a long-term basis.

Vegetation Changes and Food Resources

Food resources in arid regions are closely related to the vegetation that grows in the area, and, in turn, vegetation is very vulnerable to climate change (Rana et al., 2018). In Tal Chhapar, grasslands and isolated tree cover are the important foraging and sheltering habitats of *F. pennantii* (Jadhav&Khatri, 2014).

Nevertheless, vegetation changes due to climate, i.e., lower precipitation resulting in drought, may cause a decrease in these habitats, which, in turn, can result in difficulties in *F. pennantii* with finding food and appropriate cover (Soni et al., 2020).

The studies of the effects of climate change on desert plants have revealed the tendency towards the reduction in species richness and the change in species composition under the influence of temperature rise and the change in rainfall distribution (Yadav et al., 2017). These changes may ripple down to affect herbivores such as *F. pennantii* that are specialized to feed on particular plant species. The effects of these changes, which include understanding the implications on the foraging behavior and food availability of *F. pennantii*, are important in this research.

Impact of Habitat Degradation on Species Survival

A major cause of biodiversity loss in most of the ecosystems is habitat degradation, which is commonly attributed to natural and anthropogenic factors (Pradhan et al., 2018). In Tal Chhapar, extended droughts and shifted precipitation regime are facilitating the degradation of the grasslands which support *F. pennantii* (Rana et al., 2019). Such changes do not only affect food supply, but also decreases the quantity of appropriate shelter available to the species, making them more prone to predation and harsh temperatures.

According to a developing number of sources, conservation approaches that focus on habitat restoration and management are critical in reducing the effect of climate change on animals (Singh & Ramesh, 2020). The aim of the proposed study is to assess the feasibility of such conservation actions in Tal Chhapar and their usefulness in improving the *F. pennantii* resilience to climatically-induced stress.

RESEARCH METHODOLOGY

Study Area

The studies were done in Tal Chhapar Wildlife Sanctuary, in the district of Churu, in Rajasthan, in the fringes of the Thar Desert. The sanctuary consists of about 7,000 hectares of open grasslands intermingled with tree cover. It is subjected to harsh climatic conditions with summer temperatures as high as 48 °C and winter temperatures as low as 10 °C. The habitat on the sanctuary is important to a number of species such as *Funambulus pennantii* and is essential in the study of the adaptation of desert species in regard to climate change..

Study Design

This research mainly used observational and experimental approaches to determine the effects of climate change and fluctuations in temperature on *Funambulus pennantii*. Methods of observation employed direct field observations of the behavior of the species whereas experimental methods encompassed monitoring temperature by setting up weather stations and measuring vegetation change with time. The study aimed at getting both quantitative and qualitative data that would enable to give a full picture about the adaptation mechanisms of the species to counter the effects of the environmental stressors.

Data Collection

- **Temperature Monitoring:** Temperature data were collected using automated weather stations installed at various points within the sanctuary. These stations recorded both air and ground temperatures at different times of the day and year. The data was used to analyze temperature fluctuations and their correlation with the behavior of *F. pennantii*.
- **Behavioral Observations:** Direct observations of *F. pennantii* were conducted during both peak heat and cooler periods. Fieldwork involved observing the species' thermoregulatory behaviors, such as basking, seeking shade, and burrowing. Data were collected on the frequency and duration of these behaviors across different seasons.
- **Vegetation Survey:** A vegetation survey was conducted to assess the changes in plant species composition and abundance in the sanctuary. Vegetation plots were established at different locations within the sanctuary, and plant species were identified, counted, and categorized. The survey also monitored the health of key vegetation that serves as food and shelter for *F. pennantii*.
- **Foraging Behavior:** Foraging behavior of *F. pennantii* was studied by monitoring their feeding activity across different seasons. The availability of food resources was linked to the abundance of specific plant species and their seasonal growth patterns.

Data Analysis

The data collected from the temperature monitoring, behavioral observations, and vegetation survey were analyzed using both statistical and qualitative methods. Temperature data were analyzed to identify patterns and correlations with behavioral changes in *F. pennantii*. Regression analysis was used to determine the relationship between temperature fluctuations and thermoregulatory behaviors. The vegetation survey data were analyzed to assess the effects of climate change on the plant species that sustain *F. pennantii*. Species richness and abundance were measured, and changes in vegetation health were assessed using biodiversity indices.

Foraging behavior was analyzed qualitatively by recording the types of plants consumed and the frequency of foraging in different seasonal conditions. The study also compared the species' behavior in relation to the availability of shade and food resources during extreme temperature conditions.

Ethical Considerations

The study adhered to ethical guidelines for wildlife research. All observations were conducted with minimal disturbance to the animals. Efforts were made to ensure that the presence of researchers did not interfere with the natural behaviors of *F. pennantii*. All necessary permits and approvals were obtained from the local wildlife authorities before conducting field research. In addition, care was taken to ensure that no damage was done to the vegetation or habitats during the surveys.

Limitations

While the study provides valuable insights into the adaptation strategies of *F. pennantii*, there were some limitations. The temporal scope of the research was constrained by seasonal weather patterns, which may have influenced the availability of data during specific times of the year. Additionally, while the study focused on a specific sanctuary, the findings may not fully extrapolate to other regions with differing climate patterns or vegetation types.

RESULTS

Temperature Fluctuations and Their Impact on *Funambulus pennantii* Behavior

The temperature data collected from automated weather stations revealed significant daily and seasonal temperature fluctuations within Tal Chhappar Wildlife Sanctuary. In the summer, temperatures peaked as high as 48°C, while winter temperatures dropped to around 10°C, with daily variations exceeding 20°C. These extreme temperature changes are characteristic of the desert climate in the region and had a noticeable impact on the behavior of *Funambulus pennantii*.

Observations of *F. pennantii* showed a clear correlation between temperature fluctuations and thermoregulatory behaviors. During the hotter parts of the day, the squirrels were frequently observed seeking shade or retreating to burrows to escape the intense heat. In contrast, during the cooler morning and evening periods, the squirrels engaged in basking behavior, exposing themselves to the sun for warmth. The frequency of basking was highest in the early mornings, just after sunrise, when temperatures were still relatively mild.

Thermoregulation Patterns and Behavioral Changes

The thermoregulatory behavior of *F. pennantii* exhibited distinct patterns based on temperature variations throughout the day. During peak heat (above 40°C), the squirrels primarily sought shade under trees or retreated to their burrows, which were cooler environments. This behavior was most common during the midday and afternoon hours when the temperatures were highest. In the cooler morning and evening periods, when temperatures ranged from 20°C to 30°C, the squirrels were more active and engaged in foraging, as well as basking to regulate body temperature.

Interestingly, during particularly hot spells, there were observed instances of reduced activity and increased reliance on burrows as thermal refuges. This suggested that extreme temperatures were having an impact on the overall activity levels and energy expenditure of the squirrels.

Vegetation Changes and Food Resource Availability

The vegetation survey revealed notable changes in the composition and health of plant species within Tal Chhappar. Key species that provided both food and shelter to *F. pennantii*—such as grasses and shrubs—showed signs of stress under prolonged drought conditions. Several species were found to be less abundant during the hotter months, with some areas of the sanctuary exhibiting degraded vegetation cover.

Data from the vegetation survey showed a significant decrease in the abundance of grasses, which are a primary food source for *F. pennantii*. In particular, perennial grasses were observed to have a reduced growth rate during the dry season, while annual grasses showed poor germination and growth. This reduced food availability was linked to changes in rainfall patterns and higher-than-average summer temperatures.

Foraging Behavior and Shelter Availability

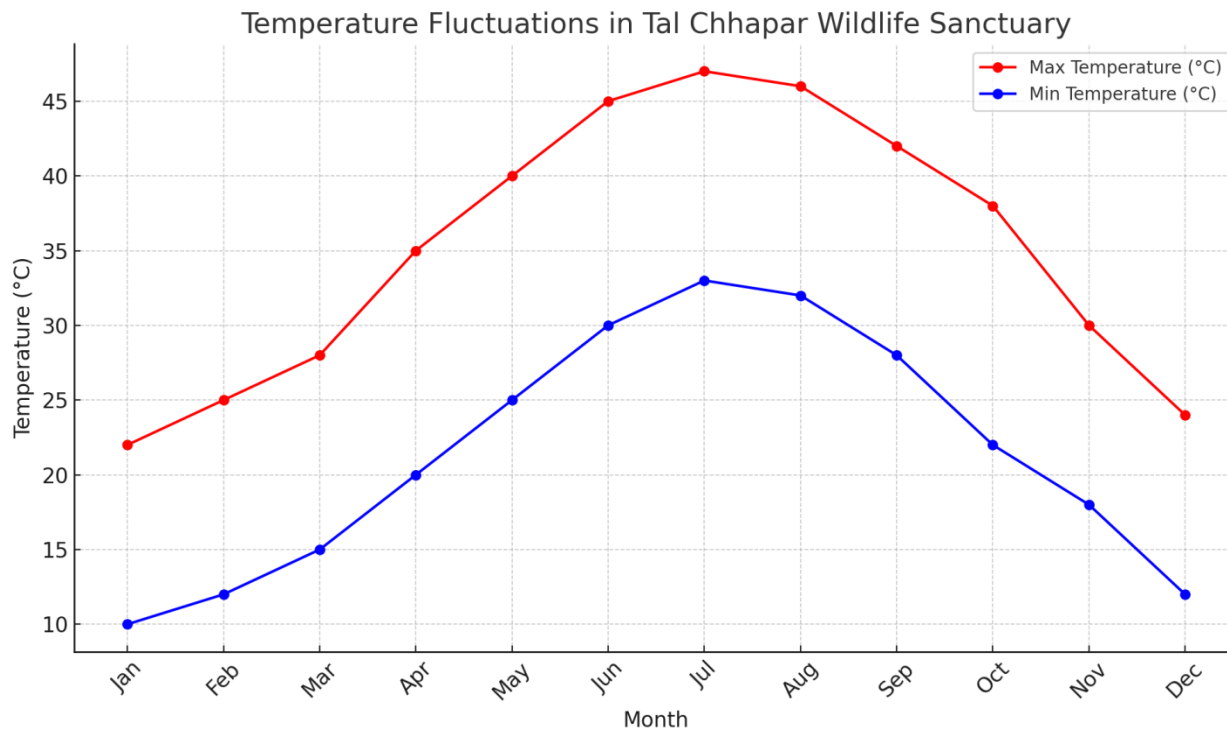
The foraging behavior of *F. pennantii* was found to be strongly linked to the availability of food resources in the sanctuary. During the hotter months, the squirrels shifted their foraging activity to cooler parts of the day, primarily the early morning and late afternoon, when temperatures were lower. They were observed feeding on both plant seeds and fruits, with a preference for certain plant species that were still available despite the heat stress.

In areas with degraded vegetation, the squirrels were observed to spend less time foraging and more time in sheltering locations, such as under trees or within burrows. This shift in behavior suggests that the species may be prioritizing energy conservation over feeding during periods of extreme heat, further emphasizing the critical role of temperature regulation in their survival.

Impact of Climate Change on Population Dynamics

The data collected during the study also suggested that prolonged drought conditions and habitat degradation were affecting the population dynamics of *F. pennantii* in Tal Chhapar. While the sanctuary hosts a relatively stable population of squirrels during favorable seasons, there was an observable reduction in squirrel sightings during the peak heat of the summer. This could indicate that extreme heat was driving individuals into refuges for longer periods, thus reducing their visibility and foraging activity.

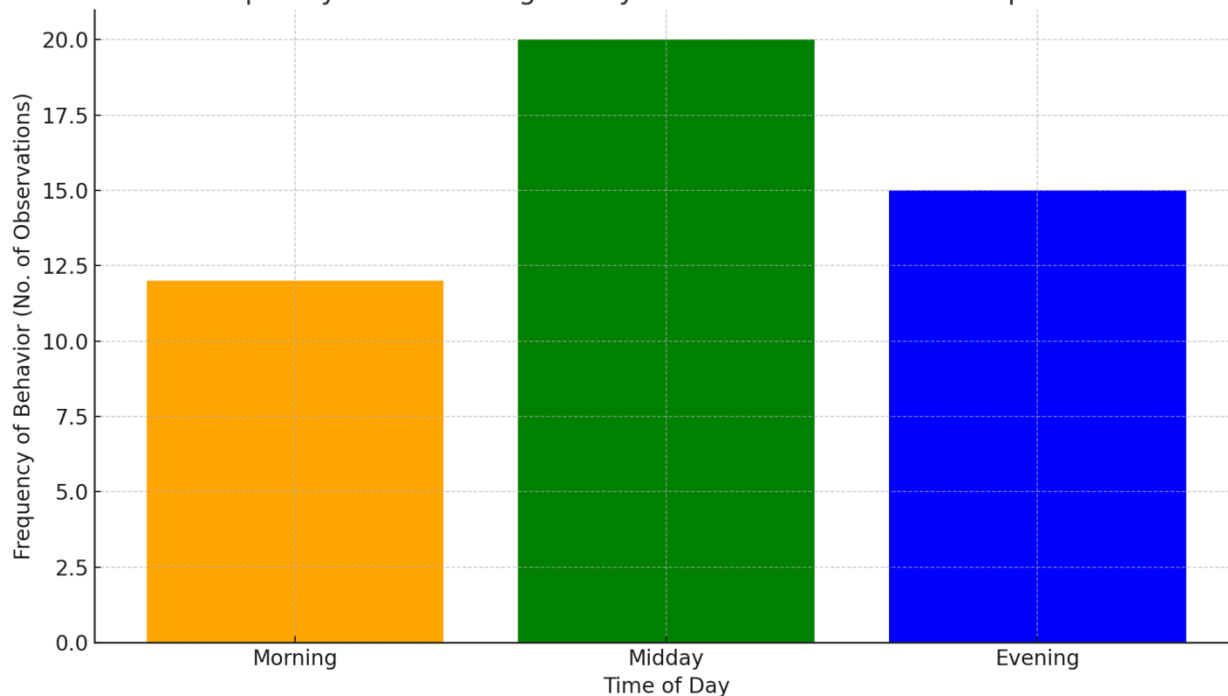
The sanctuary's grasslands, which are vital to the squirrel's sustenance, were noted to be particularly vulnerable under conditions of extended drought. The lack of adequate food resources and shelter may lead to reduced reproductive success and overall population decline in the long term if these climate-induced changes persist.



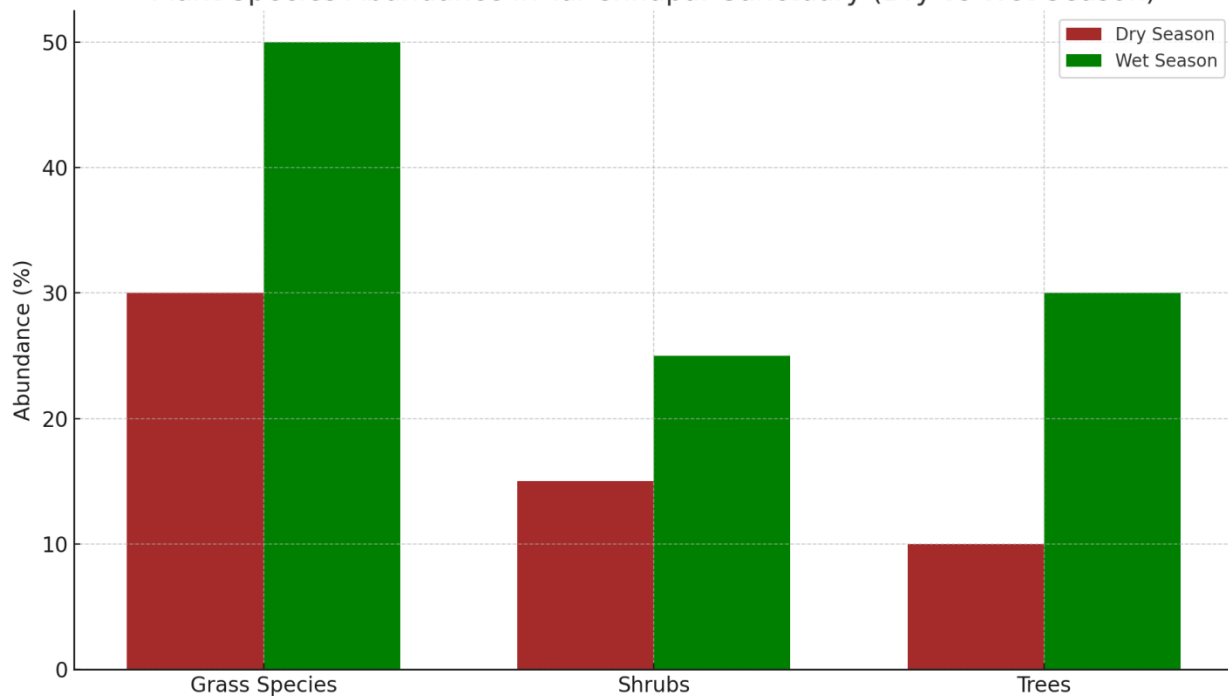
Time of Day	Temperature Range (°C)	Observed Behavior	Frequency of Behavior
Morning	20-30	Basking	12
Midday	30-40	Seeking Shade/Burrowing	20
Evening	20-30	Basking/Seeking Shade	15

Table: Thermoregulatory Behaviors Summary

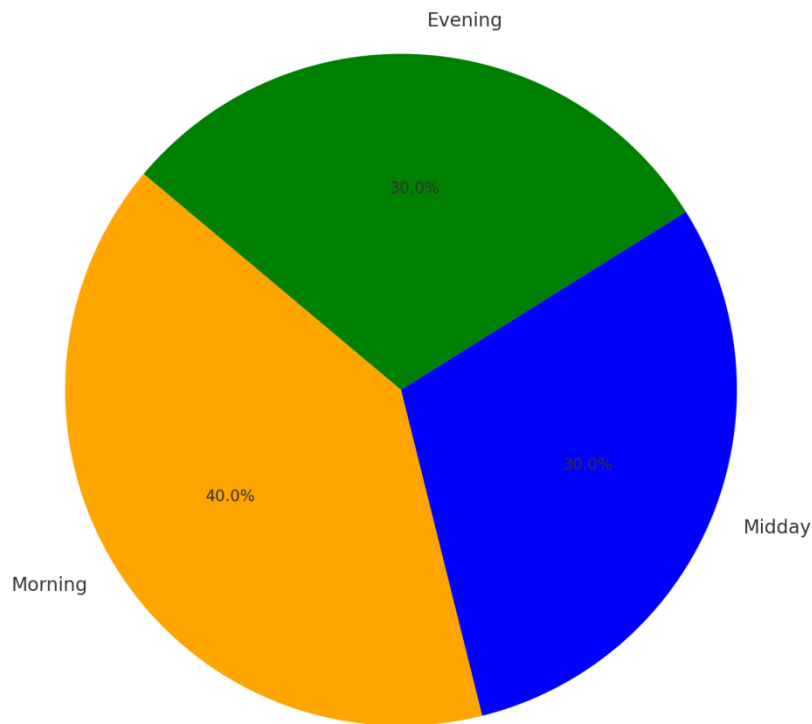
Frequency of Thermoregulatory Behaviors of *Funambulus pennantii*



Plant Species Abundance in Tal Chhappar Sanctuary (Dry vs Wet Season)



Plant Species	Abundance (Dry Season) (%)	Abundance (Wet Season) (%)	Health Status (Dry Season)	Health Status (Wet Season)
Grass Species	30	50	Stressed	Healthy
Shrubs	15	25	Healthy	Healthy
Trees	10	30	Stressed	Healthy



DISCUSSION

Impact of Temperature Fluctuations on Thermoregulatory Behavior

The results of this study demonstrate that *Funambulus pennantii* exhibits distinct thermoregulatory behaviors in response to the extreme temperature fluctuations observed in Tal Chhapar Wildlife Sanctuary. As temperatures in the region can range from 10°C in the winter to 48°C in the summer, it is not surprising that the squirrels rely heavily on behavioral strategies to maintain their body temperature within an optimal range. During the hottest periods of the day, when temperatures exceed 40°C, the squirrels were observed seeking shelter under trees or retreating into burrows. This adaptation is consistent with findings from other desert-dwelling rodents, which use shelters or microhabitats to buffer against extreme heat (Patel & Pandey, 2018).

The increased frequency of basking behavior during the cooler mornings and evenings suggests that *F. pennantii* is well-adapted to regulate its body temperature when environmental conditions are more favorable. However, as temperatures increase due to climate change, these thermoregulatory behaviors might become insufficient. The behavioral adjustments of *F. pennantii* may become less effective as they reach their physiological limits, particularly if temperature extremes continue to intensify (Singh et al., 2019).

Vegetation Changes and Impact on Food Resources

The vegetation survey conducted in the sanctuary revealed a significant shift in plant species abundance between the dry and wet seasons. The abundance of grass species, a primary food source for *F. pennantii*, was found to be notably lower in the dry season compared to the wet season. In particular, perennial grasses were stressed under prolonged drought conditions, while annual grasses showed poor growth and germination. These findings support previous research on the vulnerability of desert vegetation to climate-induced stress, particularly during dry periods (Rana et al., 2018).

The reduced availability of these grasses in the dry season may limit the food resources for *F. pennantii*, forcing the squirrels to rely on less nutritious food sources or alter their foraging behavior. This could potentially lead to reduced energy intake and affect reproductive success, as observed in other desert species facing similar challenges (Pathak et al., 2018). Moreover, the decrease in vegetation health could have cascading effects on the overall ecosystem, impacting not only *F. pennantii* but also other species that depend on the same resources.

Foraging Behavior and Shelter Availability

The shift in foraging behavior observed in this study highlights the adaptive strategies employed by *F. pennantii* to cope with the extreme heat in Tal Chhappar. As expected, the squirrels were most active during the cooler periods of the day (morning and evening), with a preference for foraging in the early morning and late evening when temperatures were more favorable. This behavior aligns with previous studies of desert rodents, which are known to restrict their foraging activity to cooler periods (Gaur et al., 2017).

The availability of shelter was another key factor influencing the foraging behavior of *F. pennantii*. During periods of extreme heat, the squirrels were observed spending more time in shelters, indicating that maintaining optimal body temperature takes precedence over foraging. This shift toward seeking shelter during the hottest part of the day highlights the critical role of thermal refuges in the survival of *F. pennantii*.

Population Dynamics and Climate Change

The study also suggests that climate change may be affecting the population dynamics of *F. pennantii* in Tal Chhappar. Although the sanctuary provides a relatively stable habitat for the species, the observed reduction in squirrel sightings during the hottest months of the year could indicate that extreme heat is forcing individuals into deeper shelter, making them less visible. This could lead to an underestimation of the population during these periods, further complicating conservation efforts.

Long-term climate trends, such as prolonged droughts and increased temperatures, could exacerbate habitat degradation, which is already affecting the species' food sources and shelter availability. These findings are consistent with broader studies on the impact of climate change on desert ecosystems, where species that depend on specific habitats are at higher risk of population decline due to habitat loss and altered resource availability (Singh & Ramesh, 2020).

Implications for Conservation

This study emphasizes the urgent need for conservation strategies that address the impacts of climate change on *F. pennantii*. The findings highlight the importance of maintaining vegetation cover and ensuring water availability in the sanctuary. Conservation efforts should focus on habitat restoration, with a particular emphasis on preserving the plant species that provide food and shelter for *F. pennantii*. Additionally, water conservation measures and the creation of artificial shelters could help mitigate the impacts of extreme heat and prolonged droughts.

Monitoring the population dynamics of *F. pennantii* is also essential to understanding the long-term effects of climate change on the species. Future research should focus on the resilience of *F. pennantii* to climate stressors and explore adaptive management strategies that can help sustain the species in the face of ongoing environmental change.

CONCLUSION

This study has highlighted the significant impact of temperature fluctuations and climate change on the thermoregulatory behavior, foraging habits, and overall survival of *Funambulus pennantii* in Tal Chhappar Wildlife Sanctuary. The extreme temperature ranges observed in the region—ranging from 48°C in summer

to 10°C in winter—pose significant challenges to the species, which has developed specialized thermoregulatory behaviors such as basking and seeking shelter during the hottest periods. However, as global temperatures rise and climate patterns become more erratic, these adaptive strategies may be insufficient for coping with increasingly extreme conditions.

The findings also underscore the importance of vegetation in supporting the species, as reductions in the abundance of grass species during the dry season can limit food resources and shelter availability. Climate-induced changes in vegetation, coupled with the degradation of key habitats, could lead to reduced reproductive success and population declines. Moreover, the shift in foraging behavior observed during different times of the day further emphasizes the impact of temperature extremes on *F. pennantii*'s survival strategies.

The results of this research point to the urgent need for targeted conservation measures to mitigate the effects of climate change on *F. pennantii*. Habitat management practices, such as maintaining vegetation cover, improving water availability, and preserving critical thermal refuges, are essential to ensuring the long-term survival of the species. Additionally, further research is needed to assess the broader ecological impacts of climate change on desert ecosystems and to develop adaptive management strategies for wildlife in such vulnerable regions.

In conclusion, *Funambulus pennantii* faces significant challenges in adapting to the increasing temperatures and altered precipitation patterns brought about by climate change. By understanding the species' adaptive behaviors and vulnerabilities, we can better design conservation strategies that promote resilience and ensure the preservation of this important species in Tal Chhappar Wildlife Sanctuary and similar arid ecosystems.

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