



Ecological and Behavioural Aspects of Five Striped Palm Squirrel, *Funambulus pennantii* Wroughton in Natural Habitat in Agricultural Landscape

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Abstract: Present study on ecology and behaviour of five striped palm squirrel, *Funambulus pennantii* was conducted in agricultural landscape in district Ludhiana and Sangrur (Punjab, India) from October, 2020 to September, 2021. Seasonal activity, time spent on different kinds of activities, vegetation preferred, interaction with other animals, nest analysis, and home range of five striped palm squirrel were studied. There was bimodal activity in summer season and unimodal activity in winter season. Squirrels spent most of their time in feeding, exploring and resting. They mostly fed on leaves, bark and fruits of trees. Squirrels were found to interact with different species of birds. Mostly human presence had no effect on their activity. The nest height ranged from 3.6 -10.5 m. Home range of male and female squirrels varied from 12.0-15.2 m and 10.1-16.0 m, respectively. The squirrels changed their day time activity with season, thermal conditions and day length. The mid-day resting period was observed to avoid excessive heat in all the seasons except winters. The present study on ecology and behaviour of squirrels may be helpful in suggesting different management methods against them.

Keywords: Activity pattern, Ecology, Feeding, Home range, *Funambulus pennantii*, Nesting

Squirrels (Class Mammalia; Order Rodentia; Family Sciuridae) are considered to be the excellent model organism for examining ecological and behavioural difference in the wildlife. Squirrels are present in all biogeographic zones except Australia, Madagascar, Antarctica, and other oceanic islands and deserts (Yousefi et al 2013). Worldwide, there are about 285 species of squirrels within 58 genera (Wilson and Reeder 2011). Among three pest species of squirrels in India, the northern palm squirrel, *Funambulus pennantii* is the most abundant (Parshad 1999). Their key diagnostic features include a bushy tail and five conspicuous stripes running along their bodies (Yadav et al 2019). Palm squirrels are arboreal and usually found near human habitations. They have sharp, curved, non-retractable claws that help them to climb and feed. Palm squirrels are highly mobile, agile, and quite vocal. Like other species in the order Rodentia, palm squirrels have one pair of chisel shaped incisor teeth in each jaw that grow constantly (Yadav et al 2019). *F. pennantii* have opportunistic diets, consuming a range of foods that vary depending on season. These are mainly herbivores and are known to feed on seeds, leaves and soft fruit, but may consume certain animal matter such as bird eggs/chicks and insects, especially locusts. Food resources along with reproductive efforts and environmental parameters are the key biotic and abiotic factors that have considerable effect on home range of squirrels (Edelman and Koprowski 2006). Home range in male is affected by spatial distribution and

presence of females. The pattern of substantial seasonal changes in home-range was same for both male and female squirrels (Lurz et al 2000, Koprowski et al 2008). The selection of a site for nest construction is often based on the choice of specific features of the environment (Goodenough et al 2009, Skorka et al 2011). The selected site is the best compromise between minimum predation and maximum access to food and thereby increasing the animals' fitness (Barea and Watson 2013). Nest is constructed by the female using pieces of cloth, jute fibers, small twigs of plants, dry grasses, plastic rope etc. preferably on tree branches, holes in tree trunks, or inside the crevices in the walls of the old buildings (Sharma 2004). Litters are protected in the nest by the females. The composition of tree species and structural attributes play an important role in the use of the habitat by squirrels (Kumara and Singh 2006). Crops preferred by palm squirrels include pineapple, mango, pomegranate, apple, guava, blackberries, grapes, sugarcane, groundnut, maize, etc. (Chakravarthy 2004). To reduce the damage caused by squirrels to these crops, it is important to know about the key characteristics of the landscape that support their population along with their seasonal activity pattern and food preference. Such information on basic ecological and behavioural aspects of *F. pennantii* is limited. Present study was therefore conducted to record the seasonal activity pattern, food preference, home range and nesting of *F. pennantii* in their natural habitats in agricultural landscape.

MATERIAL AND METHODS

Seasonal activity: The seasonal activity pattern of *F. pennantii* was studied by keenly observing their activities in a natural habitat in a plant nursery located at Punjab Agricultural University (PAU), Ludhiana, Punjab (India). Animals were observed since their exit from nesting sites in the morning till their return back in the evening. Observations were recorded from 5:00 am to 7:00 pm at weekly intervals from October, 2020 to September, 2021. Mean time of sunrise and sunset and day length in each month were used to correlate the activity periods.

Time allocation to different activities: Activities of squirrels like exploring (running and climbing), feeding (foraging, actively ingesting food or processing food items), resting (remaining motionless on the substrate for more than 5 min), moving (walking and hopping), calling, grooming and chasing were recorded in the selected plant nursery at PAU campus on alternate days during the months of March-April, 2021. The observations were made for one hour each during morning (06:00 am-09:00 am) and evening (03:00 pm-06:00 pm) and time spent on each kind of activity along with their frequency were determined by following the activities of one animal at a time (total 4-5 animals). Mean time and frequency allocated to different activities were determined from fortnightly data and the comparison in different activities was made between morning and evening hours. Squirrels were surveyed using the focal animal observation method (Altmann 1974) through naked eye from a distance of about 5-10 m.

Preference for vegetation: To record the preference of squirrels for different types of vegetation in PAU campus, six quadrants each of size 13×13 feet covering the whole plant nursery were selected. In each quadrant, different type of vegetation like trees, herbs and nursery plants were present.

Data on proportion of time spent by squirrels on each type of plant were recorded by observing each quadrant for 30 min on alternate days during March-April, 2021.

Home range: Home range of squirrels in the plant nursery was recorded by measuring the distance moved from the tree used for nesting or resting purpose to the place of activity. Average distance travelled by male and female squirrels (10 each) in the morning and evening hours was measured.

Nesting: Nests of five striped palm squirrel were located initially by perceiving their vocalizations in the evening hours in the selected plant nursery and agricultural landscape at PAU campus and villages of district Ludhiana and Sangrur (Fig. 1), Punjab (India). The timing of nest entries and exit were observed at regular basis. Nest analysis was done only for those nests which were found actively used by the squirrels. Nests were then photographed and monitored without disturbing the squirrels. Various parameters such as height of the tree, height of the nest and material used for nesting were recorded.

Association with other animals: Observations were also made on the association of squirrels with other animals such as different bird species present in the plant nursery.

Statistical analysis: The data was analysed by using SPSS version 27 software. Values were considered significant at 5% level of significance.

RESULTS AND DISCUSSION

Seasonal pattern of time and activity allocation: During autumn (October, 2020), the average time of sunrise and sunset was 6:29 am and 5:54 pm, respectively with day length of 11:22 hours. Squirrels were found active from 7:00 am-12:00 pm in the forenoon and 2:00 pm-6:00 pm in the afternoon (Tables 1 and 2). In winter (November, 2020-

Table 1. Seasonal pattern of activity of squirrels in the forenoon hours at selected plant nursery in PAU campus

Months	Sun rise (h:min)	5:00-6:00AM	6:00-7:00AM	7:00-8:00AM	8:00-9:00AM	9:00-10:00AM	10:00-11:00AM	11:00-AM 12:00PM
October 20	6:29	x	x	√	√	√	√	√
November 20	6:53	x	x	√	√	√	√	√
December 20	7:16	x	x	√	√	√	√	√
January 21	7:23	x	x	√	√	√	√	√
February 21	7:06	x	x	√	√	√	√	√
March 21	6:34	x	x	√	√	√	√	x
April 21	5:57	x	x	√	√	√	√	x
May 21	5:31	√	√	√	√	√	x	x
June 21	5:08	√	√	√	√	√	x	x
July 21	5:34	√	√	√	√	√	x	x
August 21	5:32	√	√	√	√	√	x	x
September 21	6:10	√	√	√	√	√	x	x

February, 2021), average time of sunrise varied from 6:53 am to 7:23 am and of sunset from 5:26 pm- 6:13 pm with day length of 10:11-11:06 hours. Activity started at about 7:00 am and which increased from 9:00 am to 1:00 pm hours. A drop in the activity was noticed from 1:00 pm onwards until 5:00 pm after which no squirrel was seen. In summer season (March-June, 2021), sunrise in March-April, 2021 was observed between 5:57 am-6:34 am and sunset between 6:34 pm-6:54 pm with day length of 12:11-12:26 hours. Activity began at 7:00 am and increased rapidly thereafter. The morning peak in the activity during 7:00-8:00 am was higher than that observed during 11:00 am-2:00 pm. A second peak in activity occurred between 4:00-5:00 pm, after which activity declined. During monsoon season (July-September, 2021), sunrise was observed between 5:32 am-6:10 am and sunset between 6:31 pm-7:19 pm with day length of 12:21-13:55 hours. Squirrels were active from 5.00 am-10:00 am in the morning and from 3:00 pm-6:00 pm in the evening. Squirrels showed a bimodal activity in all the seasons except for the winters. In winters, the peaks were increasingly displaced toward mid-day, eventually resulting in the unimodal patterns of activity. The short, uninterrupted active phase in winter may probably be an adaptation for conserving energy by minimizing the period of heat loss. Long et al (2003) also observed that squirrels reduce their activity during the mid of the day in summer season to avoid intense heat and start their day activity late in winter season. Thermal environment can have a strong influence on activity of tree squirrels. In summers, the active phase was more than twice as long as in winter, and was usually broken by a period of rest. In summer, because of the longer day lengths, the squirrels have the opportunity to separate their feeding activity into two distinct

periods (Skibieli et al 2002).

Time and frequency allocation of different activities:

Time spent and frequency during exploring, feeding, moving and chasing were significantly more during the evening hours than in the morning hours. On the contrary, time spent and frequency of calling and grooming by squirrels were significantly more during morning as compared to that in evening hours (Fig. 1 and 2). The monthly encounter rate of squirrels throughout the study period showed that exploring and feeding were the primary activities of squirrels. Calls of squirrels were mostly harsh when they were frightened. Females used short-duration intermittent sounds to entice the male while playing and before mating. Squirrels have been seen chasing and driving away other squirrels feeding in their territory. The activities got delayed during summer and monsoon as compared to autumn and winter due to very hot temperature in summer and heavy rainfalls in monsoon. The length of day sets the period available for feeding and therefore affects the activity pattern. The decreased day length in winter may lead to less time available for feeding and thus forcing the squirrels to concentrate their activity into a single period. Data also suggests that squirrels forage most in low to moderate temperatures and avoid higher temperatures. This is consistent with the finding that squirrel foraging activity is decreased in the afternoon when temperatures are highest (Palei et al 2015) and also suggested that activity pattern of squirrels may vary depending on geographical location, climate, food resources, and interaction with predator species.

Time allocation for feeding on different kinds of

vegetation: Squirrels were observed to feed primarily on 16 species of plants, mostly trees (Table 3). Parts of 14 species

Table 2. Seasonal pattern of activity of squirrels in the afternoon at selected plant nursery in PAU campus

Months	12:00-1:00PM	1:00-2:00PM	2:00-3:00PM	3:00-4:00PM	4:00-5:00PM	5:00- 6:00PM	6:00-7:00PM	Sun set (h:min)	Day length (h:min)
October 20	×		√	√	√	√	×	05:54	11:22
November 20	√	√	√	√	√	×	×	05:26	10:35
December 20	√	√	√	√	√	×	×	05:27	10:11
January 21	√	√	√	√	√	×	×	05:57	10:24
February 21	√	√	√	√	√	×	×	06:13	11:06
March 21	×	√	√	√	√	×	×	06:34	12:11
April 21	×	√	√	√	√	×	×	06:54	12:26
May 21	×	×	×	√	√	√	√	07:14	13:39
June 21	×	×	×	√	√	√	√	07:34	14:07
July 21	×	×	×	√	√	√	×	07:29	13:55
August 21	×	×	×	√	√	√	×	07:07	13:14
September 21	×	×	×	√	√	√	×	06:31	12:21

of trees were used for feeding, while the remaining two species *Bauhinia variegata* (Kachnar) and *Livistona chinensis* (China Palm) contributed marginally towards the overall diet of squirrels. Leaves and bark were generally available almost round the year and therefore they formed the bulk of the squirrel's diet while flowers, fruits and seeds were the supplementary food items. Eventually squirrels adapted to the diet according to the abundance of different food items in relation to seasonal changes. Flowers and leaves of tun, grasses, harshingar, rubber palm and champaca were eaten in considerable quantities over bark and seed. In quadrant I, four types of trees, one herb (common rose) and grasses were present. The proportion of time spent on feeding two trees i.e., toon and Ashoka and the grasses were comparatively high. Squirrels in quadrant II mostly feed on banyan, palm nursery and grasses. The squirrel activity on rubber palm and harshingar were approximately 40 and 50%, respectively. The relatively high number of squirrels recorded on tun plant was probably related to the highest number of trees in nursery. Squirrels were observed to feed on bark and leaves of all plants present in III quadrant. Tun was the most preferred tree used for resting. Only four types of trees (jamun, mango, banyan and neem) were present in quadrant IV. Squirrels were rarely encountered on neem as it was used only for resting purpose. Activity was observed on all plants in quadrant V except China palm. In quadrant VI, only palm nursery plants were observed. Squirrels were found feeding on leaves of these plants (Fig. 3). Feeding time of squirrels included handling, masticating, or swallowing of food items.

Majority of the time to feeding activity was allocated in the evening hours. The most preferred vegetation for feeding and exploring were trees of tun, Ashoka, banyan, jamun, champaca and grasses, while the trees of neem and kachnar were used for resting. Squirrels generally fed on leaves, bark

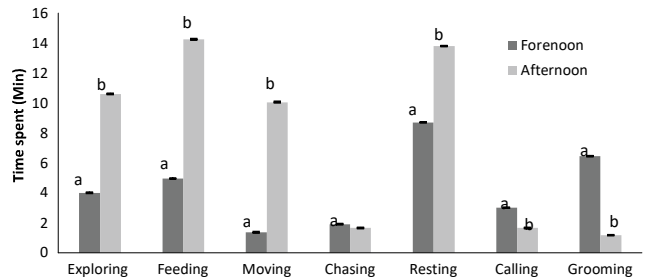


Fig. 1. Comparison of time spent on different activities by squirrels during forenoon and afternoon hours

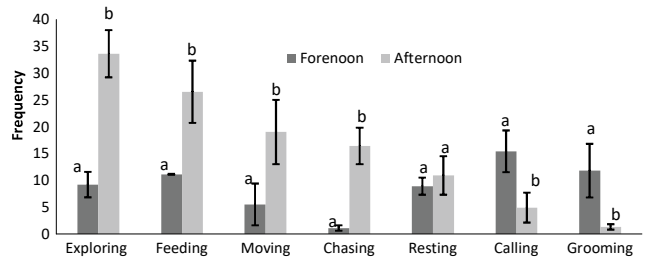


Fig. 2. Comparison of frequency of different activities of squirrels during forenoon and afternoon hours

Table 3. Different kinds of vegetation present in six quadrants at plant nursery in PAU campus

Common name	Scientific name	Family
Ashoka	<i>Saraca asoca</i>	Fabaceae
Banyan	<i>Ficus benghalensis</i>	Moraceae
Champaca	<i>Mangonlia champaca</i>	Mangnoliaceae
China palm	<i>Livistona chinensis</i>	Arecaceae
Common rose	<i>Rosa sp.</i>	Rosaceae
Harshingar	<i>Nyctanthes arbortristis</i>	Oleaceae
Jamun	<i>Syzygium cumini</i>	Myrtaceae
Kachnar	<i>Bauhinia variegata</i>	Fabaceae
Mango	<i>Mangifera indica</i>	Anacardiaceae
Mulberry	<i>Morus alba</i>	Moraceae
Neem	<i>Azadirachta indica</i>	Meliaceae
Palm (Nursery plants)	<i>Livistonia chinensis</i>	Arecaceae
Rubber palm	<i>Hevea brasiliensis</i>	Euphorbiaceae
Sohanjana	<i>Moringa oleifera</i>	Moringaceae
Tun	<i>Toona ciliata</i>	Meliaceae

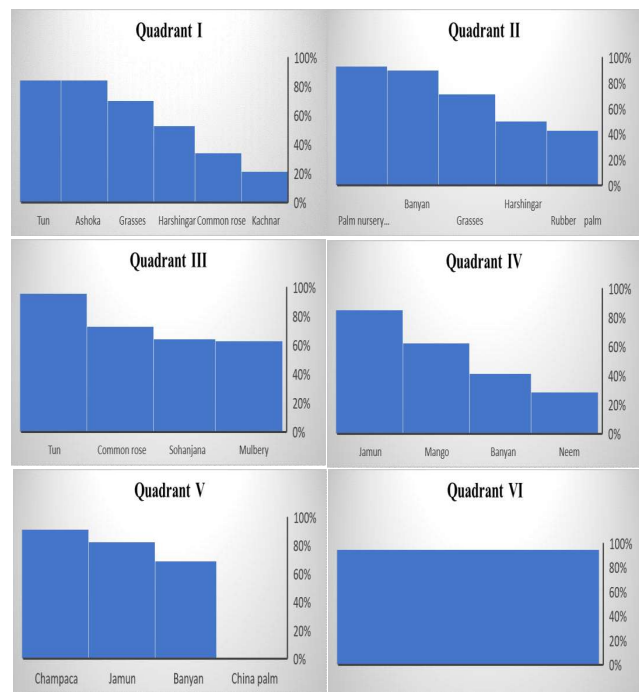


Fig. 3. Proportion of time spent by squirrels on different types of vegetations

and fruits of the trees. The rough bark of jamun trees helps to escape from terrestrial predators such as dogs. Its dense and intermingled canopy also helps the squirrels to extend the area of home range and escape from predators like cats which can climb the trees (Thorington et al 2012). The plant nursery at PAU campus provides a high-quality habitat or ecosystem structure with abundance of food material. Ecologically these are the most important factors that contribute towards higher animal diversity in the nursery.

Home range: The home range for male and female squirrels was worked out in plant nursery at PAU campus in the morning and evening hours (Table 4). On average, males covered maximum 12.0 m distance in the morning and 15.2 m distance in the evening hours whereas, the females covered maximum 16.00 m distance in the morning and 10.10 m distance in the evening hours. The significant difference was found in home ranges of male and female squirrels as well as in the home range of one sex between morning and evening hours. These home ranges of male and female squirrels were overlapping with each other. In the present study, females traveled a longer distance in the morning and shorter in the evening as compared to males. Similar home-range size for both male and female squirrels was observed by Koprowski et al (2008). Jacques et al (2017) observed the mean size of home range of adult *F. pennantii* ranging from 0.07 to 0.22 m.

Table 4. Home range of male and female squirrels

Sex (n = 10 each)	Distance travelled from nests and resting places (m)	
	Morning	Evening
Male	12.00± 1.10 ^a	15.20±1.00 ^b
Female	16.00±3.60 ^c	10.10±2.40 ^d

Values are expressed as Mean±SD

Values with different superscripts (a-d) in a row as well as in a column differ significantly at P<0.05

Table 5. Nest analysis of squirrels at different locations

District	Village/Location	Common name of tree	Scientific name of tree	Number of nests	Tree height (m)	Nest height (m)
Ludhiana	PAU campus	Neem	<i>Azadirachta indica</i>	2	9.14±0.00	7.60±0.00
	PAU campus	Ber	<i>Ziziphus mauritiana</i>	4	8.65±0.38	7.30±0.67
	PAU campus	Tahli	<i>Dalbergia sissoo</i>	2	9.10±0.00	7.60±0.85
	PAU campus	Ashoka	<i>Saraca asoca</i>	1	11.50	9.10
	PAU campus	Kikar	<i>Acacia karroo</i>	1	8.80	5.70
	PAU campus	Mango	<i>Mangifera indica</i>	1	12.10	10.30
	Phullanwal	Pomegranate	<i>Punica granatum</i>	1	4.50	3.60
	Phullanwal	Cheeku	<i>Manilkara zapota</i>	3	10.70	5.67±2.51
Sangrur	Balian	Kikar	<i>Acacia karroo</i>	2	8.20±0.84	4.40±0.64
	Balian	Ber	<i>Ziziphus mauritiana</i>	2	7.15±0.63	3.81±1.07
	Balian	Dharek	<i>Melia azedarach</i>	1	9.10	7.00
	Balian	Piikan	<i>Ficus virens</i>	1	9.10	10.00

Values are expressed as Mean±SD

Nesting: A total of 24 nests of *F. pennantii* were sighted at different places i.e., at PAU campus (13), village Phullanwal (four), district Ludhiana and Balian (seven), district Sangrur. Squirrels preferred significantly more the trees with wider canopy to build their nests (Table 5). The material used for constructing nests was cloth, cotton, rope, grasses, twigs and synthetic fibrous material. Maximum number of nests (6) was found on Indian jujube trees. Squirrels preferred trees with maximum number of branches for nest building. Nests were found supported by 'V' shaped interlocking branches of the trees and located at a height ranging from 3.6-10.5 m. There was considerable variation in height at which the nests were made. The height of nesting trees was between 4-8 m, while maximum nesting was observed even at height of >9 m. This may be due to easy movement to and from the nest in all directions, and escape from predators. Further, tree branches provided substantial support for the nest to withstand harsh weather conditions. Similar to present study, Mohan and Singh (2018) also observed that the squirrels make nests using leaves, twigs, threads, mosses and other soft materials. Many of the Holarctic squirrel species such as *Sciurus arizonensis* (Cudworth and Koprowski 2011) and *Sciurus aberti* (Edelman and Koprowski 2006) select trees with more interlocking branches and more access routes. Nests in upper canopy are known to provide proper protection from terrestrial predators and provide moderate weather conditions (Cudworth and Koprowski 2011). In present study also nest heights did not show any correlation with tree heights and nests at a lower region of smaller trees. These small squirrels may be able avoid heat stress by direct sunlight, rain and wind and get protection from avian predators. These factors might possibly contribute to the selection of a lower nesting height. Our study additionally revealed that *F. pennantii* selected nesting substrates irrespective of its proximities to roads and buildings.

Table 6. Interaction of squirrels with different bird species in plant nursery at PAU campus

Bird species	Number of birds	Number of squirrels around birds	Kind of interaction
Common Myna (<i>Acridotheres tristis</i>)	3.90±0.56	2.80±0.30	Feeding and chasing
House Crow (<i>Corvus splendens</i>)	3.60±0.96	2.50±0.10	Sitting together
Rose-ringed Parakeet (<i>Psittaciformes manillensis</i>)	1.20±1.00	3.00±0.50	Sitting together
Jungle Babbler (<i>Turdoides striata</i>)	5.20±3.30	4.20±1.20	Feeding together
Red vented Bulbul (<i>Pycnonotus jocosus</i>)	1.00±0.80	4.60±1.10	Sitting together and chasing

Values are expressed as Mean±SD

Interaction of squirrels with other animals: Squirrels were spotted in plant nursery with five distinct bird species, namely Common Myna, House Crow, Rose ringed Parakeet, Jungle Babbler and Red vented Bulbul (Table 6). Birds and squirrels shared the same environment when it comes to feeding habits. The presence of humans did not seem to impact squirrel activity much, which can be due to habituation.

CONCLUSIONS

The present study provides an insight of the activity patterns, foraging preferences, home range and nesting characteristics of squirrels in an agricultural landscape. Further research on various ecological and behavioural aspects will help to understand their ecological adaptations to agricultural areas and their role in ecosystem health. Knowledge about ecology and behaviour of squirrels may be helpful in suggesting different management methods against them.

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