

Comprehensive review of the current status of ethological studies on *Funambulus pennantii* (Wroughton, 1905), the five striped northern palm squirrel

Deepali Agarwal¹ and Reshma Bhatnagar²

Department of Zoology, Faculty of Science

Dayalbagh Educational Institute (Deemed to be University), Agra-282005

¹Email id: deepaliagarwal1710@gmail.com

²Corresponding author: reshma.bhatnagar@gmail.com

ABSTRACT

Squirrels flourish in varied habitats of all continents except Antarctica. They evolved around 36 million years ago. According to their mode of life, squirrels are categorized as tree squirrels, flying squirrels and ground squirrels. *Funambulus pennantii*, commonly known as five striped northern palm squirrel is listed under Least Concern (LC) category according to IUCN. Due to different habitats and ecology, squirrels seem to have evolved their behavioral patterns. Though squirrels perform various ecosystem services such as pollination and dispersal of seeds, according to some researchers *F. pennantii* is a pest of fruits, vegetables and crop granaries. Hence, there is an ambiguity in the ecological status of squirrels and needs further evaluation. Except for some activities, to observe behavioral patterns only manual observations have been documented so far. Analysis through softwares is needed for more accurate results because change in behavior is the first response by animals to any environmental modifications. Cognitive techniques and analysis in behavioral ecology has not been studied in *F.pennantii* and thus needs thorough evaluation. In this article we review the current status of behavioral studies on *Funambulus pennantii* (Wroughton, 1905) which would provide significant information for relevant studies.

Key words: *Funambulus pennantii*, behavior, squirrels, habitat, climate.

Received 14.03.2019

Revised 08.05.2019

Accepted 30.05.2019

CITATION OF THIS ARTICLE

Deepali Agarwal and Reshma Bhatnagar. Comprehensive review of the current status of ethological studies on *Funambulus pennantii* (Wroughton, 1905), the five striped northern palm squirrel. Int. Arch. App. Sci. Technol; Vol 10 [2] June 2019: 151-156

INTRODUCTION

Apart from Antarctica, there is no landscape left which is not inhabited by squirrels. There are approximately 278 species of squirrels in the world which evolved around 36 million years ago in late eocene or early oligocene to form a distinct lineage of rodents[31]. They are categorized according to their mode of life, viz. – Flying squirrels, Tree squirrels and Ground squirrels. Flying squirrels have been categorized separately due to their gliding ability with the help of patagium. Among Tree squirrels, about 9 species have been introduced outside their native places[16]. [31] mentioned the continent wise distribution of all the three categories of squirrels, however they showed absence of population of squirrels in Australia, but [16] mentioned that *Funambulus pennantii* have been introduced in Australia since 1898. Moreover, 5 species of genus *Funambulus* have also been reported as introduced species of squirrels in Australia[5]. Among tree squirrels, nine species have been introduced outside their native places[16]. Population ecology of squirrels has not been widely studied by scientists all over the World (Table 1). However, population density of tree squirrels near

the Neches river in Eastern Texas was determined by using time- area count method of census[1]. [3]reported the population structure of *F. tristriatus* in cultivated land in Kannada district of Karnataka.[4]examined the effect of burning an ungrazed tallgrass prairie on population density of 13 striped ground squirrels.

Table 1: Population studies of different species

Species studied	Area	Method used	Reference
Tree squirrels	Eastern Texas	Time and area method	Baker, [1]
<i>Funambulus tristriatus</i>	Karnataka	Direct enumeration technique	Bhat and Mathew, [3]
<i>Spermophilus tridecemlineatus</i>	Manhattan	Capture-mark-recapture technique	Clark <i>et al.</i> , [4]

Squirrels are the members of Sciuridae family which consists of five subfamilies. A group of South Asian tree squirrels included under Callosciurinae subfamily which has 64 species[31] among them, squirrels of genus *Funambulus*, popularly known as Indian palm squirrel comprise five species viz. *F. pennantii*, *F. palmarum*, *F. tristriatus*, *F. layardi*, *F. sublineartia*[5].*Funambulus pennantii*(Wroughton, 1905) is commonly known as Northern palm squirrel or five striped squirrel having three sub species *F. pennantii pennantii*, *F. pennantii lutescens*and *F. pennantii argentescens*[30].

According to IUCN status, Northern palm squirrel, *Funambulus pennantii* is listed under Least Concern (LC) category. It is native to India, Nepal, Pakistan, Iran[16,17,30]although a wild colony has existed in Perth, Western Australia since the late nineteenth century[24]. They flourish in varied habitats such as orchards, forests, gardens, granaries, rangelands[13,14,20]and also remain close to human habitation[18,28].They are diurnal[9,14,21,22,29], arboreal[18,28].Five striped squirrel as five light coloured stripes run along the dorsal side of its body. Head is grey in colour. Tail is comparatively longer than the whole body. Tail alone makes about half of the total body length[29]. It is bushy and middle stripe runs along through its whole length.[32]stated that species can be distinguished by its considerably flat head and neck, big eyes and triangular ears. [27]first witnessed leucism in five striped palm squirrels in Maharashtra. Albinism has also been reported in them[26].Palm squirrels, generally *F. pennantii* have life span of approximately five to six years and gestation period of about 42 days with breeding season generally from August to May peaking in October and April with litter size of average 5 young ones[5]. Squirrels have different habitat and ecology and thus seem to evolve different behavior patterns.

ROLE IN ECOLOGY

Squirrels perform considerable ecosystem services such as pollination and dispersal of seeds and influencing plant form and function[9,10]. They may also serve as indicator species in some forest types. By-products of some squirrels are also collected for potential medicinal value[10]. According to some researchers, *F. Pennantii* is a significant pest of fruits, vegetable crops, granaries and considered as an agricultural pest[11,13,14]. Hence there is an ambiguity in the ecological status of squirrels and needs further evaluation. Their significant role in ecosystem can outweigh the harm caused by them in agricultural fields.

Feeding habits of *F. pennantii* include a variety of foods. This species is mainly omnivore. They can eat nuts, fruits, vegetables, barks of trees, insects, termites and also consume birds' eggs[5]. However, millets are highly preferred by them[9] especially the whole moist millets[13]. According to[32], this species never caches food and inhabits areas close to human settlements, thus also consume kitchen remains like bread.They use vision for foraging of food[8]. According to[29], they use sight, touch, smell and acoustics for perceiving the food but no activity budgets regarding these behaviors have been reported till now (**Table 2**). Home ranges are found to be overlapping *i.e.*, they do not defend the whole range but they exhibit territorial behavior during reproductive season[23]with respect to

their nest and other shelter spots, they squeak in shrill voice keeping tail upright when any other animal or conspecifics of other territory enters in their territory[18]. According to[19], during mating season individual females are surrounded by a number of willing males and sometimes they bite the tail of female in an attempt to grasp it. Males have a fight among them and the winning male chases the female and it appears as if chasing is a part of their courtship. Female squirrel can mate 3-4 times in a day with the same or different partner and more than one male gets chance to mate with one female[18]. According to[29], after mating male leaves the female within 2-3 days and female alone builds the untidy nest and nurses the young ones.[19]also mention some trees where nests have been found.Squirrels have been used extensively to study the effects of light on circadian rhythms[24] and clock resetting effects of light in terms of sensitivity of circadian clock[12]. [2]demonstrated how targeted behavior can alter the brain in context with various animals including red and gray squirrels but no such studies have been reported in palm squirrels which shows that there is still a paucity regarding behavior of five striped palm squirrels (**Table 2**).

Table 2: Brief description of research on different behavioral parameters.

Behavior	References	Qualitative analysis	Quantitative analysis	Inferences, if any
Morphology	Yousefi <i>et al.</i> , [32]	----	+	Preying and trapping method to compare morphology of both the sexes.
Feeding	Khan and Khan [9]	+	----	Preference towards millets
	Malhi and Kaur [13] Malhi and Kaur [14]	----	+	Responses towards different food additives observed
	Yousefi <i>et al.</i> , [32]	+	----	-----
	Kour <i>et al.</i> , [11]	+	----	Observed that they never cache food and thus present near human habitation
	Csurhes [5] Sharma [29]	+	----	Sex related seasonal time activity budget but no quantification comparing data of both sexes General assessment of palm squirrels in Queensland Use sight, touch smell for finding food but no activity pattern or reference have been mentioned
Locomotory	Rajaratnam and Redman [23]	----	+	Demonstrated that social contact synchronizes free running activity rhythms in <i>F. pennantii</i>
	Rajaratnam and Redman [24]	----	+	Locomotory rhythms in constant light

	Kour <i>et al.</i> , [11]	+	----	Sex related seasonal locomotion activity without any quantification of data
Social Cognition	Sharma [29]	+	----	Intra specific communication through sound and visual display
Reproductive	Purohit <i>et al.</i> , [19]	+	----	Some of the observations conducted in captivity
	Seth and Prasad [28]	+	+	Invasive work for characterization of squirrel of unknown reproductive history
	Csurhes [5]	+	----	
	Sharma [29]	+	—	General observations without any use of software
Post natal development	Purohit <i>et al.</i> , [19]	+	—	Enlisted nesting sites
	Yousefi <i>et al.</i> , [32]	+	—	General observation on post natal development
	Sharma (2016)	+	—	Males do not show parental care
Territoriality	Prakash <i>et al.</i> , [18]	+	----	Territoriality assessment by toe clipping and ear clipping methods
Vocalization	----	----	----	
Conflict	----	----	----	
Play	----	----	----	
Cognition	----	----	----	

(-):data not available

(+):data available

Methods and technologies followed in behaviors studied

Among the behaviors studied till now (**Table 1**), to observe behavioral patterns and other activities, various methods and technologies have been applied by researchers. However, except for some activities (**Table 3**), only manual observations have been documented. For more accurate results, analysis through a software is needed which not only gives results with more precision but also reduces the analysis time invested by the observer.

Table 3- Methods/Technologies applied for behavioral studies of *F. pennantii*

	Aspect studied	Methods/Technologies used	Reference
1.	Reproduction and post- natal development	Observed manually after trapping the squirrels	Purohit <i>et al.</i> , [19]
2.	Home range and territoriality	Toe-clipping and ear-clipping method for numbering the squirrels	Prakash <i>et al.</i> , [18]
3.	Circadian activity rhythms after melatonin administration	Infrared motion detection to monitor locomotor activity. Actograms generated using tau software	Rajaratnam and Redman [21]
4.	Activity rhythms entrainment to temperature cycles	Infrared motion detection to monitor gross locomotor activity.	Rajaratnam and Redman [22]
5.	Free running activity rhythm	Infrared motion detection system to monitor locomotor activity. Actograms generated using the wheel running program	Rajaratnam and Redman [23]
6.	Circadian locomotor activity rhythms in constant light	Infrared motion detection system to monitor gross locomotor activity. Actograms generated using tau software	Rajaratnam and Redman [24]
7.	Sex related seasonal behavioral patterns	Manual observation	Kour <i>et al.</i> , [11]
8.	Circadian rhythms entrainment to light	Activity wheel monitoring unit software to monitor spontaneous locomotor activity	Kumar and Singaravel [12]
9.	Reproductive behavior	Manual observation	Sharma [29]

APPROACH TOWARDS COGNITION

According to [6], cognition can be defined as neuronal phenomenon which are related with the acquisition and manipulation of information by animals, cognitive ecology reflects on the effects of processing of information and decision making on animal fitness which is the outcome of behaviors such as feeding, mating choice, orientation etc. According to [7], such behaviors can easily exemplify the integrative approach to cognitive ecology. [2] concluded that red squirrels can modulate their hippocampus through their behavior. However, cognitive techniques and analysis in behavioral ecology has not been studied broadly [25] (Real, 1993) and thus needs thorough evaluation.

2011-2015 have been the hottest years of the last hundred years (www.downtoearth.org.in) and this has resulted in climate change across the globe. Changes in behavior is the first response by animals to any environmental modification [15]. So species of squirrels may have also undergone changes in terms of behavior and trends in population, especially in view of changes in habitat. Therefore, there is a need of evaluation of behavioral patterns of palm squirrels which could give us insights into its welfare and conservation.

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