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New Distribution Records of Small Kashmir Flying Squirrel *Eoglaucomys fimbriatus* (Gray, 1837) (Mammalia: Sciuridae), with Notes on its Diel Activity in the Musk Deer National Park, Azad Jammu and Kashmir, Pakistan

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Abstract: Small Kashmir Flying Squirrel (SKFS) *Eoglaucomys fimbriatus* (Gray, 1837) is a resident of thick forests in northern parts of Pakistan. The species faces many threats in Pakistan and is listed as vulnerable in Pakistan. A camera trapping study was carried out in the Musk Deer National Park (MDNP) from 11 May to 26 June 2014, with the main purpose to study the distribution of SKFS. A total of 40 trail cameras were deployed for 1,025 trap nights in different watersheds of the park territory. The species was photo-captured at seven stations during 11 capture events. The camera-trapping results showed that SKFS was present in the central and western parts of the park. The photo-captured history of the species shows nocturnal activity between 20:00 to 3:00 hrs. Based on photo-captured data, we assume that moon phases do not affect the activity of SKFS in MDNP. Rainfall had a negative impact, while the temperature was directly correlated with the species' activity. Current research has helped to redefine this species' range, as its presence was confirmed about 38 km from the IUCN nearest declared range.

Key words: Distribution, camera trapping, activity, IUCN, ecology, conservation

Introduction

The small Kashmir flying squirrel (SKFS) *Eoglaucomys fimbriatus* (Gray, 1837) is a small-sized squirrel with a short tail as compared to other flying squirrel species found in Pakistan (Roberts 1997, Sheikh & Molur 2005). Its other distinct features include prominent up-standing ears and a pointed snout. The ears are hairless and the outer line is pointed towards the tips. Body hair is short and belly hair is creamy. The hair on the back is a dull pink colour combined with black hair. Across the shoulders, there is a V-shaped pattern of black hairs. The incisor teeth are bound by their bright red crust (Pasha & Suhail 1997, Roberts 1997, Sheikh & Molur 2005).

The SKFS is found in north-eastern Afghanistan, northern parts of India and Pakistan (Dar 1996, Nowak 1999, Sheikh & Molur 2005). In Pakistan, it is found in the lower parts of Chitral, many parts of Swat Kohistan and Upper Dir, throughout

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the Murree Hills, Hazara District, Azad Jammu and Kashmir (AJK) and Gilgit (Roberts 1997). SKFS is found at an elevation of 1800–3500 m a.s.l. (Sheikh & Molur 2005) but it may descend to 900 m a.s.l. in winter. The species predominantly inhibits the moist temperate forest (combination of coniferous and deciduous tree species) of the Himalayas (Roberts 1997). SKFS feeds on deciduous tree leaves and a variety of nuts. They give birth in summer; the youngs are naked and helpless and are cared for by their mother for eight to ten weeks. With the help of flexible flaps, it can leap over 50 m (Niethammer 1967).

The loss of habitat because of selective and subsistence cutting at a small scale and deforestation are the main threats to its survival (Sheikh & Molur 2005). Globally, the SKFS is enlisted as least concern (IUCN 2021), while its population is declining in Pakistan due to several threats and the species has been added to the national threatened species list (Sheikh & Molur 2005). Worldwide, flying squirrels have attracted researchers and research has been conducted thoroughly on their ecology, biology and population (Oshida et al. 2005, Abbasi et al. 2010, Dinets, 2011, Qamar et al. 2012, Din et al. 2015, Wassmer & Refinetti 2016). However, information on species distribution range and behavior remains limited since a large part of its reported distribution has not been surveyed (Abbasi et al. 2010).

The pattern and level of animal activities in the 24-hours cycle and during the seasons are critical to reproductive success and species existence (Reeder & Kramer 2005, Larivée et al. 2010, Zhao et al. 2013). The need for proper nutrition while in danger of injury or death leads to a compromise between the risk of predation and starvation, which affects the amount of time per day the squirrels are active (Dall & Boyd 2002). For species conservation and understanding of their ecology, it is imperative to have better knowledge of the factors that affect species activity (Michalski et al. 2006). Such factors include competition (Wasserberg et al. 2006), available resources (Lambert et al. 2009), predation (Borowski & Owadowska 2010), temperature (Chappell 1980), season (Manfredi et al. 2011), lunar luminosity (Lucherini et al. 2009) and disturbance due to human activities (Theuerkauf & Rouys 2008).

SKFS is a nocturnal mammal and during the day time it roosts in the holes of trees (Niethammer 1990, Roberts 1997). Night-time activity is highly significant for many animal species' survival but documenting factors that affect nocturnal activity is highly challenging (Jinelle et al. 2013). The activity patterns in various squirrel species are well-documented, e.g. for grizzled giant squirrel *Ratufa macroura* (Rao et al. 2015), fox squirrels *Sciurus niger* (Wassmer & Refinetti 2016), white-tailed antelope squirrel *Ammospermophilus leucurus* (Chappell & Bartholomew 1981), European souslik *Spermophilus citellus* (Everts et al. 2004), etc. The SKFS is insufiniently studied throughout its entire range; the occurrence of this species has been confirmed beyond the distribution range presented by the IUCN (Pasha & Suhail 1997). The present study was conducted in the Musk Deer National Park (MDNP) with the primary objective to obtain data on its distribution range and understand the diel activity pattern of the SKFS with prevailing environmental factors in the MDNP.

Materials and Methods

Study area

The current study was conducted in the Musk Deer National Park (MDNP) (Fig. 1). The MDNP (34.731055, 74.786675) is located in the Neelum Valley of AJK and spreads over 528.15 km^2 (Ahmad et al. 2016). In winter, the temperatures fall to 0^{o}C, while in summer, they reach up to 30°C (Dar 2003). During summer, the area receives very little rainfall, while in winter, heavy snowfall occurs. The abundant plant community is represented by *Pinus wallichiana, Abies pindrow, Picea smithiana, Juglans regia, Cedrus deodara* and *Betula utilis.* The mammalian species found in the park territory include the black bear (*Ursus thibetinus*), Himalayan brown bear (*Ursus arctos*), wolf (*Canis lupus*), red fox (*Vulpes vulpes*), leopard cat (*Prionailurus bengalensis*), snow leopard (*Panthera uncia*), yellow-throated marten (*Martes flavigula*), stone marten (*Martes foina*), Kashmir langur (*Semnopithecus ajax*) Kashmir musk deer (*Moschus cupreus*), Kashmir marmot (*Marmota caudata*), Indian pika (*Ochotona roylei*), SKFS and the wood mouse (*Apodemus rusiges*) (Ahmad 2015).

Survey technique

Camera trapping is a modern technique and is widely used to study wild animal species populations and behavior studies (Long & Zielinski 2008, O'Connell et al. 2011, Rovero et al. 2013). A camera trapping study was carried out during the period 10 May – 26 June 2014 in MDNP to document the distribution and activity pattern of SKFS. The study area was divided into 20 unequal size watershed-based blocks to ensure the spatial distribution of cameras. Forty ReconyxTM (HC500 HyperfireTM and PC900 Hy-

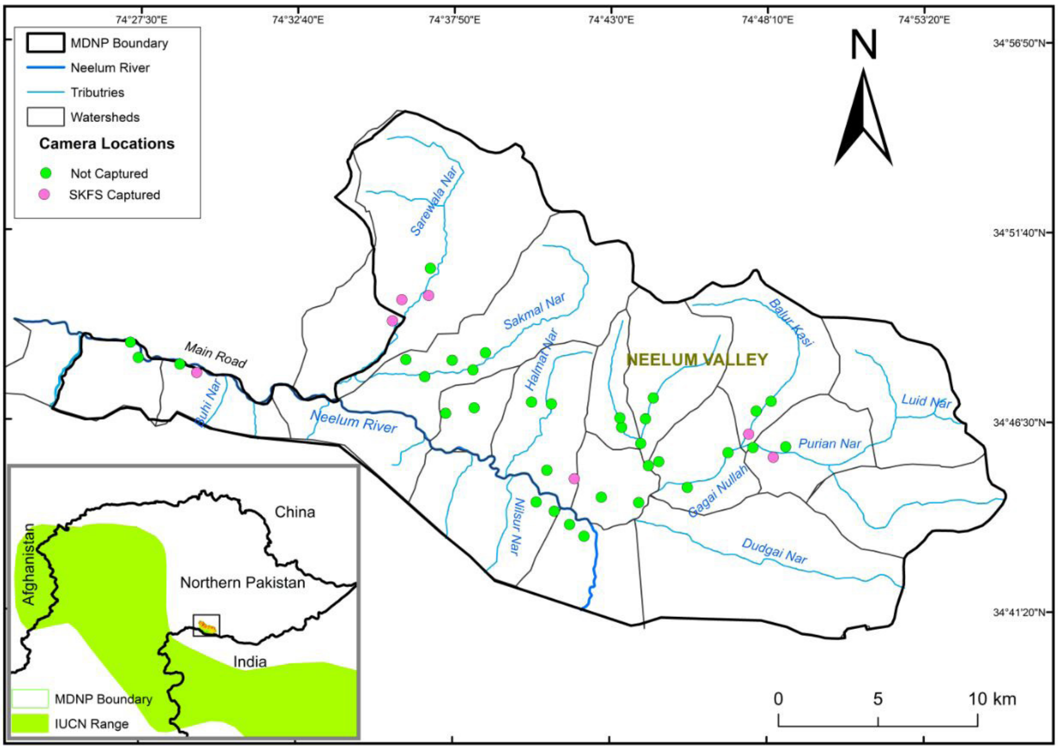

Fig. 1. Map of the study area along with camera stations and SKFS photo-capture locations.

Table 1. Categorisation of different moon phases and their duration during the study period in MDNP. Legend: *Crescent moon*: appears between the new moon and the first quarter. *Gibbous moon*: appears between the first quarter and full moon or full and third quarter moon. *Half moon*: when half of the moon is illuminated. *Full moon*: when the moon is fully illuminated.

No	Moon phases	Merged phases	Length of phases (days)
1	New moon, waning and waxing moon	Crescent moon	19
2	Waning and waxing gibbous moon	Gibbous moon	19
3	First and third quarter moon	Half moon	6
4	Full moon	Full moon	3

perfireTM) motion-triggered trail cameras were set up in various blocks at different locations (Fig. 1). To cover the maximum area of the park, a minimum of one-kilometer aerial distance was maintained between two adjacent sampling locations.

Cameras were deployed at sites near the wild animal sign such as burrows, scrap, scat, pugmark or near tracks used by humans. Of the total deployed cameras, 38 were mounted on metal pipes, while the remaining two cameras were mounted on trees. Each camera was fixed at a height of about 45-50 cm above the ground. Vegetation in front of the camera sensor was removed as it could trigger the camera (Jackson et al. 2006). Castor scent bait was spread on a stone at each camera (Ahmad et al. 2016, Rehman et al. 2021) to increase capture possibility (Guil et al. 2010). Camera settings were fixed in such a way as to take three successive pictures after a gap of one second each time cameras were triggered. Time and date were set to be stamped each time the camera was activated. The installed cameras remained functional in the field for a total of 1025 trap nights. On average, each camera remained active for a total of 28 trap nights (Minimum = 14 trap nights and Maximum = 36 trap nights).

Data analysis

Map showing camera installation and species distribution were projected in Arc GIS10.3 (Geographic Information System). The moon phases during the study period were categorised into four phases based on the shape appearance (Table 1). The duration of each moon phase during the study period was also documented.

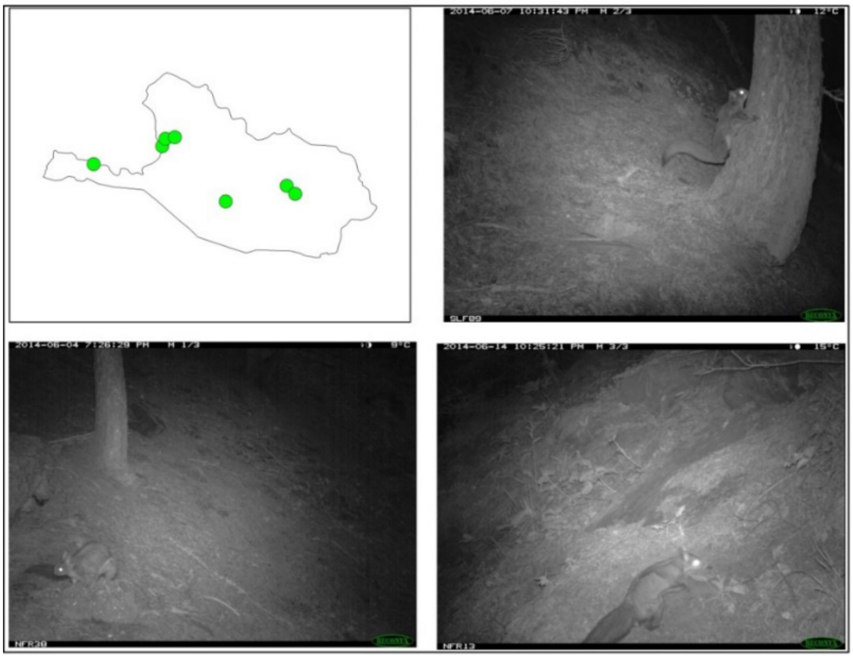

Fig. 2. Photo-captured record and spatial distribution of SKFS in MDNP.

Results

SKFS Distribution in MDNP

Unfortunately, four out of 40 cameras were lost, and the remaining cameras were operating in different watersheds of MDNP for 1,025 trap nights. During this period, about 85 thousand photos were obtained, including false images of humans, livestock, birds and mammals. Fourteen species of mammals (large, medium and small size) were photo-captured at different camera stations at an elevation range from 2,269 to 3,044 m a.s.l. (mean 2,786 m). SKFS were photo-captured 11 times at a total of 7 camera stations and a total of 30 photos were obtained. The species was photo-captured, primarily in the western border and the center of the park (Fig. 2). In the current study, the SKFS presence was confirmed about 38 km away from the nearest IUCN range of the species (Fig. 1).

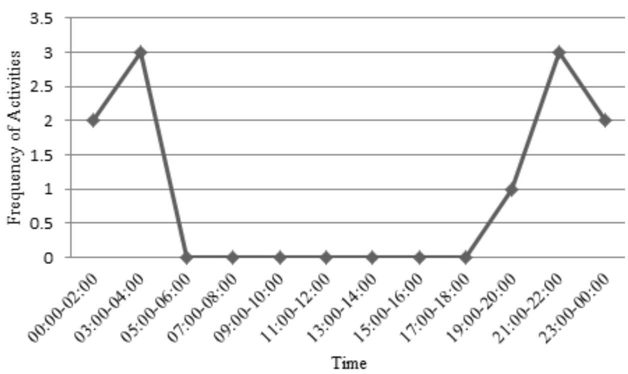

Fig. 3. Numbers of activity of SKFS recorded per 2-hour intervals in MDNP.

Activity Pattern

The photo-captured history of SKFS in the study area shows nocturnal activity throughout the study. Time-wise activity data of the species was arranged and numbers of the species activity after each two hours interval were plotted. The capture history of the species shows that SKFS became active at 20:00 hours (hrs) and remained active till 03:00 hrs in the morning. No activity was recorded between 05:00–06:00 to 17:00–18:00 hrs. The frequency of the recorded data was found to be highest between 03:00–04:00 and 21:00–22:00 hrs, indicating peak activity of the SKFS (Fig. 3).

Assumed effect of environmental factors on the activity of SKFS

The photo-captured records of the SKFS showed that the moon phase, temperature and rainfall probably affected its activity in the study area. The activity appeared to be high during the gibbous moon (55 %), followed by the crescent moon (27 %) and the full moon (18 %). Based on the photo-captured history, we assumed that SKFS in MDNP remained more active at a temperature range between 7–15°C (mean 10°C). Likewise, the species was found highly active during rain and vice versa (Table 2).

Table 2. Activity of SKFS recorded in MDNP to various environmental variables.

No	Date	Location		Altitude (m)	Time (Hrs)	Temperature °C	Moon phases	Precipitation (mm)
		Latitude	**Longitude**					
1	27 May 2014	34.831930	74.616810	3,006	03:00	7	Crescent moon	0
2	04 June 2014				20:00	9	Crescent moon	0
3	28 May 2014	34.769450	74.792710	2,611	22:00	13	Crescent moon	0
4	13 June 2014				03:00	8	Full moon	0
5	06 June 2014	34.829990	74.602090	3,044	23:00	8	Gibbous moon	0
6	07 June 2014				23:00	12	Gibbous moon	0
7	11 June 2014				01:00	8	Gibbous moon	0
8	12 June 2014	34.758980	74.806230	2,651	22:00	10	Gibbous moon	0
9	13 June 2014	34.749000	74.697110	2,444	02:00	7	Full moon	0
10	14 June 2014	34.796500	74.489620	2,269	22:00	15	Gibbous moon	0
11	15 June 2014	34.820410	74.596980	2,911	03:00	11	Gibbous moon	0
Mean				**2,786**		10		

Discussion

Camera trapping is an essential modern technique used in documenting wild mammals' presence, distribution, geographical range and activity budget within a given area (Surridge et al. 1999, Jeganathan et al. 2002). In MDNP, where dense forest makes it difficult to document nocturnal species' presence, distribution and activity patterns like SKFS, the camera trapping technique provided an excellent opportunity to acquire the desired goals. Through camera trapping, the SKFS were photo-captured at seven sampling locations in the park's densely forested areas (dominated by silver fir, herbs and shrubs). The present study revealed that SKFS inhabits the area in MDNP at an elevation from 2,269-3,044 m a.s.l. Similarly, Corbet & Hill (1992) described that SKFS is distributed in the Himalayan moist temperate forest between elevations of 1350 to 3050 m a.s.l., while Abbasi et al. (2010) reported that SKFS resides at elevations higher than 1356 m a.s.l. in the moist temperate forests, with an extended distribution range of 1981 m a.s.l..

Our camera-trapping record showed that the species was distributed in the central and western parts of the MDNP. The current research has helped redefine this species' global distribution range as its presence was confirmed about 38 km away of the IUCN nearest declared range (Fig. 1). The likely reason for the extention of its range is because the species has been ignored in the past and no proper study has been conducted in and beyond its distribution range. Pasha and Suhail (1997) carried out a similar study in India and reported that the distribution range of the SKFS is extended in India (Ranikhet) up to 300 km. Similarly, Qamar et al. (2012) and Pal et al. (2019) also documented the range extension of woolly flying squirrel (*Eupetaurus cinereus*) in the Himalayas. All these studies indicate that all flying squirrel species are among the least studied species in the Himalayas and the rest of Asia. Based on the results of our study, we believe that the distribution range of SKFS seems to extend over a larger area in the Himalayas and Hindu Kush regions, yet, further studies through modern techniques such as camera trapping and genetic sampling is much needed as the species is nocturnal.

Planning for temporary activities has a significant impact on animal reproduction and survival (Daan & Aschoff 1982). Each animal must allocate time for various activities and temporally distribute those activities over a 24-hours cycle (Ashby 1972). In MDNP the camera-trapping results show that the species were activity between 20:00 to 3:00 hrs. The MDNP hosts several large predators (snow leopard, brown bear, grey wolf, etc.) (Ahmad et al. 2016), which pose a serious predation risk. Consequently, the nocturnal behaviour of SKFS could be considered an anti-predation strategy. Moreover, several settlements are located within, and in the vicinity of the MDNP; therefore, the movement of people for wood collection and livestock grazing aggravates risks for SKFS during day time.

Based on the camera-trapping records of SKFS in our study area, we assume that moon phases, rainfall and temperature probably influence the daily activity of SKFS. It is documented that the concentration of moonlight highly affects the behaviour of various nocturnal mammalian species. For example, during full moon nights, many rodent species tend to stay near vegetation and reduce foraging activity (Price et al. 1984). Additionally, the studies carried out by Skutelsky (1996) and Morrison (1978) showed that some animal species lower their foraging activity during the full moon because moonlight may increase nocturnal predators' visual efficiency (Longland & Price 1991). The photo-captured records in the present study indicated that SKFS in MDNP performed high activity at different moon phases even though most nocturnal prey species are considered lunarphobic (Lang et al. 2006). The presence of thick forest (providing shelter) in MDNP and the gliding ability of the species may be the reason that encourages it to perform activities during the full moon. Illumination also enhances the vision of some prey species to forage efficiently and detect predators (Prugh & Golden, 2014). Rainfall and temperature are also important clues that may affect the activities of animals, causing variation in the detection of predators and prey and affecting the thermoregulation process (Hanya, 2004). SKFS was more active when there was no rainfall; the reduced activity during rain could be due to energetic constraints in high humidity and precipitation (Voigt et al. 2011). The activity pattern of small mammals is highly influenced by temperature (Mcmanus, 1969). Based on the photo-capture records of the species we assume that SKFS activity is highly temperature-dependent in MDNP and displays more activities at a temperature range from 7 to 15°C. At the time of low temperature, the endothermic animals maintain their body temperature and as a result, they loose a greater amount of energy to maintain their body temperature. To reduce energy consumption, possible strategies are to cease or reduce activity or shift them into other periods (Mcmanus, 1969, Fitch & Shirer, 1970). In the study area the maximum temperature recorded during the study period was 38°C but no activity of SKFS was recorded at this temperature. The temperature in the MDNP reaches the upper limits in the daytime during summer, but in the same season, the temperature drops during night time. According to Jinelle et al. (2013), animals shift to nocturnal activity to take advantage of more suitable night-time temperatures and to avoid dangerously hot daytime temperatures.

The current study found that the SKFS mainly occupied the central and western parts of the MDNP at an elevation range of 2,269–3,044 m a.s.l.. This study contributes to rectifying IUCN's previous claim about the range of this species as it has been photo-captured 38 km away from their demarcated range. Most importantly, this study has added pivotal baseline information about the least concerned and least studied species. The camera-trapping result shows the nocturnal behaviour of the species. Based on the species captured records and environmental data, we presume that moon phases do not significantly affect the activity of SKFS in MDNP, while the activities of SKFS in the study area are highly rainfall- and temperature-dependent. There should be more studies to understand SKFS ecology and behaviour better as this could be an important prey species to a diverse group of carnivores residing in its habitat. Environmental education on the ecological role performed by the SKFS should be provided to local communities in order to change the negative perception of locals as they consider it a pest.

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