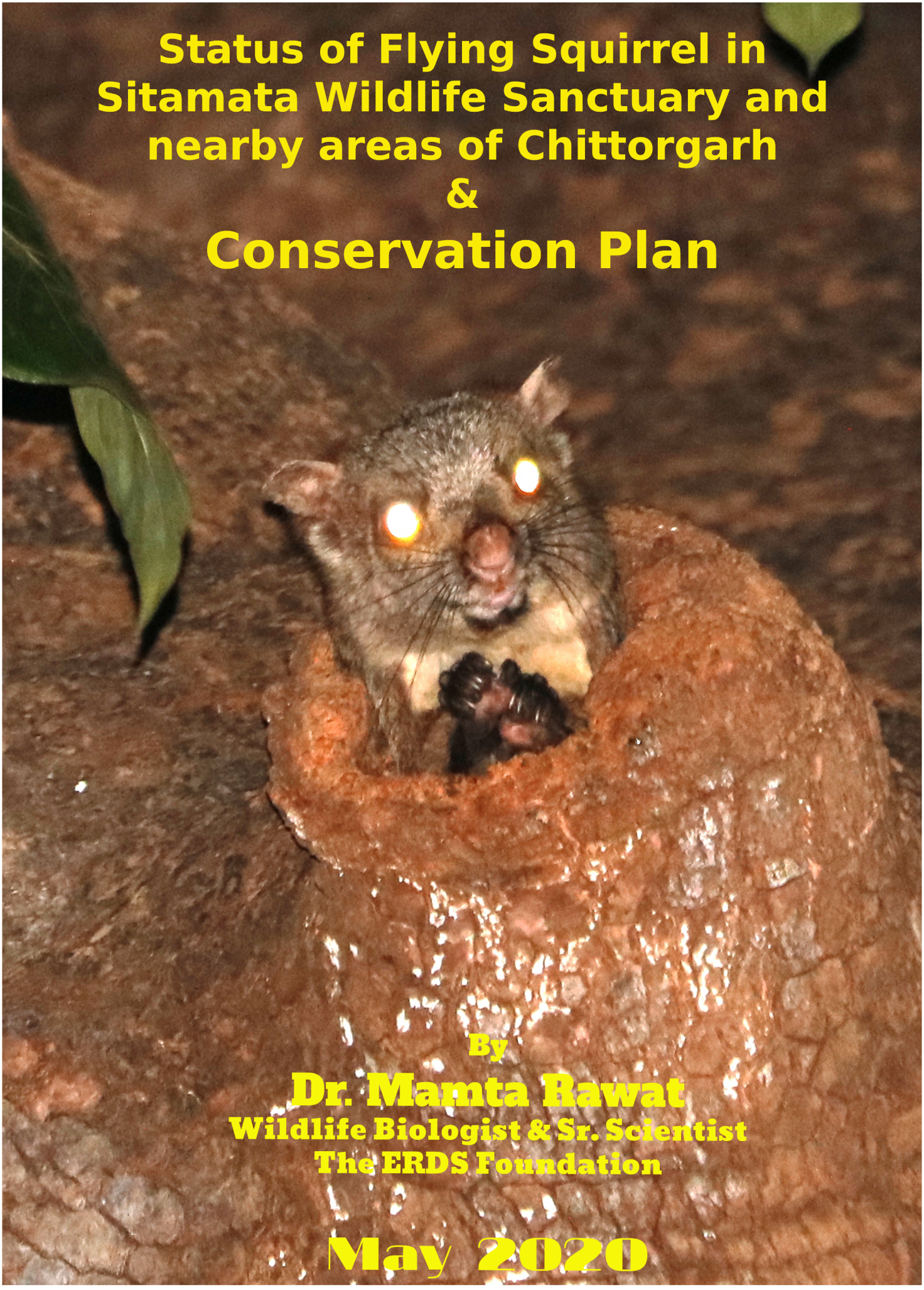
Status of Flying Squirrel in Sitamata Wildlife Sanctuary and nearby areas of Chittorgarh
&
Conservation Plan



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1. Introduction

The Indian Giant Flying Squirrel or Large Brown Flying Squirrel (*Petaurista philippensis*) is the largest of all the squirrels, being slightly larger and heavier than the giant squirrel. *Petaurista* (Rodentia: Sciuridae) comprise a genus of large nocturnal flying squirrels, comprising more than 18 species and inhabits in forests in lowlands and mountains up to 4000 m in elevation across Asia from Pakistan and Kashmir eastward to East and Southeast Asia. They were formerly included in *Petaurista petaurista*, but now have been separated and ranked as a new species according to external characters (Yu *et al.* 2006). The species is distributed in Sri Lanka, India, Myanmar, Thailand, South China and Indonesia (Wilson and Reeder 1993). In India, *P. philippensis* has broader distribution than other species of flying squirrels and recorded in the forests of peninsular part of the country (Nandini 2000, Parter 2005, Koli 2015). In general, people are not much aware about the flying squirrels because of its nocturnal and cryptic habits and also ignored due to difficulty in scientific data collection. Squirrels are easily identified by its slender build, long busy tail and arboreal habitat. Some of them possess the ability to glide and popularly known as "Flying Squirrel".

Petaurista (Rodentia: Sciuridae) is a genus of large nocturnal flying squirrels, comprising more than 18 valid species. *Petaurista philippensis* is a vastly distributed and most studied species among Asian flying squirrels, which was formerly included in *P. petaurista*, but now it has been separated and ranked as a valid species according to external characters

(Yu *et al.,* 2006). Its distribution is confined in Sri Lanka, India, Burma, Thailand, South China (including Hainan and Taiwan) and Indonesia (Wilson and Reeder, 1993; Nandini, 2000a).

South Asia is known for its high diversity of flying squirrels. There are about 17 species belonging to 7 genera (Datta & Nandini, 2005). In India, most of these species are found in the eastern Himalayas and the north-east, at the confluence of two biogeographically significant regions, the Himalayan and the Indo-Malayan regions. Very little is known about many of these species. So far 13 species (confirmed) of flying squirrels are being reported from India (Koli *et al.* 2013a, 2015; Sharma *et al.,* 2013), and mainly concentrated in the Himalayan and Northeast regions, while the Western Ghats holds only two species (*P. philippensis* and *Petinomys fuscocapillus fuscocapillus*). In India, it is known by different vernacular names such as, *Udan Gilhari*, *Udati*, *Khiskoli*, *Haruva*, Rajpankhi, Pankha/Pakhi (South Gujarat), and *Morchitri* in North East Gujarat (Nisha and Dharaiya 2016) etc. In Rajasthan and its adjoining areas, *Udan Pankhi*, *Kali Minki*, *Gulrawari Pankha* (Koli *et al.* 2013a; Sharma and Sharma 2013; Koli 2015). The distribution of this species is restricted and scattered, it has been identified from Gujarat (Nisha and Dharaiya 2016), Andhra Pradesh (Sreekar *et al.* 2012), Karnataka (Kumara and Singh 2004, 2006), Kerala, Tamil Nadu (Umapathy and Kumar 2000; Rajamani 2000; Nandini 2001a), Maharashtra (Nandini 2001b), Madhya Pradesh, southern Rajasthan (Tehsin 1980; Chundawat *et al.* 2002; Sharma 2007; Koli 2012; Koli *et al.* 2013a), Orissa, West Bengal, Bihar and Goa (Ashraf *et al.* 1993; Srinivasulu *et al.* 2004; Molur *et al.* 2005).

Petaurista philippensis has broader distribution than other flying squirrels and its high density was identified in most forests of peninsular part of the country (Wilson and Reeder, 1993; Nandini, 2000a, 2000b; Prater, 1971; Koli *et al.,* 2011). Nandini (2000a, b) surveyed four states (Kerela, Tamilnadu, Karnataka and Goa) of the country to identify its distribution

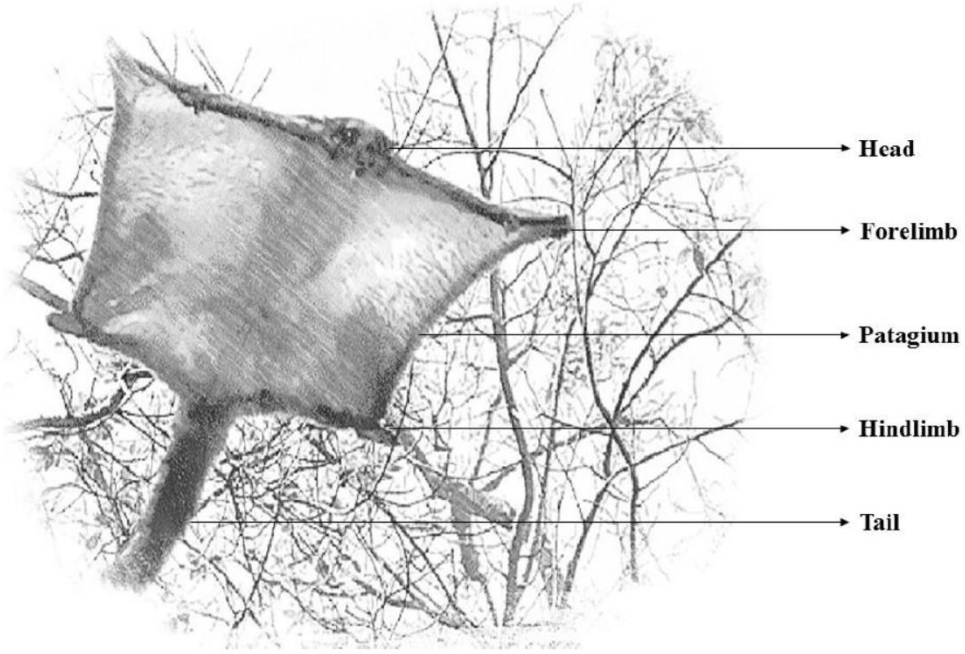
and status hence reported high encounter rate in less protected and moist deciduous forests. Kumara and Singh (2006) assessed its distribution and relative abundance in Karnataka state, along with other giant squirrels. Hunting was identified as a major threat to the flying squirrels in Eastern Himalaya region (Mishra *et al.,* 2006) and south India (Nandini, 2000a, 2000b; Kumara and Singh, 2004; 2006). In 2009, ***call playback method*** was used for census of *P. philippensis* in Western Ghats by Babu and Jayson (2009). Tehsin (1980) and Chundawat *et al.* (2002) reported its occurrence in Sitamata WLS and Phulwari-Ki-Nal WLS respectively, located in western part of the country.

In the global context this species is least concern (IUCN, 2016) but later few studies on *P. philippensis* indicate its decreasing status in India due to hunting (Nandini, 2000a, b), anthropogenic disturbances, habitat destruction, and agricultural encroachment (Kumara and Singh, 2004; 2006). Except some reports in southern part of the country, detailed work is lacking. Before drawing a proper conservation action plan for this species, distributional records are essential, hence a proper review of published information was done. Accordingly a survey and first hand data collection was initiated.

Habitat composition and population dynamics of wild animals have a mutual influence on each other. On the one hand, habitat heterogeneity and resource distribution have been found to govern the populations of wild animals, while on the other, animal assemblage has a long-term impact on the surrounding vegetation. The Large Brown Flying Squirrel is one such species which, despite being widely distributed in Indian Subcontinent, from Western Ghat to lower Himalayas and North-eastern Indian state and upto few part of Southern Rajasthan and Gujarat has been less surveyed in southern Rajasthan and Gujarat due to of its elusive behaviour, fragmented population and sporadic records.

1.1 Morphology

The upper part of the body is grizzled brown or claret brown, washed with white hair. Hair present on its back are basally smoke gray followed by seal brown and then white with black tip. Cheek is gray and ear is orange rufous on the distal half. Lower lip is black and eyes are black in colour and round in shape while whiskers are prominent and dark. Forelimbs possess three toes and two sub equal metacarpal pads while hind limbs have four toe pads, a large metatarsal pad and single small supplementary pad present behind the outer toe pad. Tail is bushy and longer than the body length (Koli 2015). Tail is seal brown or light or dark gray with black tips. Female possess six mammae wherein two pectoral and four ventral (Jerdon 1867; Blanford 1891; Wroughton 1911; Xavier *et al.* 1998). Hutton (1949) observed that *P. philippensis* vary in body colour at different age. During early young stage, the tail and feet are jet black, a black band is present across the shoulders. Underside is white and light



Picture credits: Gopi Ramakrishnan

Fig. 1. Different body parts of Indian Giant Flying Squirrel or Large Brown Flying Squirrel (*Petaurista philippensis*).

gray. As it matures, the gray marking on the body become larger till black (Fig. 1). During monsoon season, the fur gets thicker and turns loose in the dry season.

1.2 Distribution

Currently, 15 genera and 44 species of flying squirrels are recognized world over, with the majority (14 of the 15 genera and 42 of the 44 species) occurring in Eurasia, especially Southeast Asia (Thorington and Hoffmann 2005). The only genus to occur outside of Eurasia is *Glaucomys;* this genus is restricted to North America and Mesoamerica (Mexico plus Central America) and comprises 2 species, the northern flying squirrel (*G. sabrinus*) and the southern flying squirrel (*G. volans*) (Thorington *et al.* 2002). Except three species (*Glaucomys volans, Glaucomys sabrinus and Pteromys volans*) all others are distributed in Asia. Thus, ***Asia is a hotspot of flying squirrel diversity***, while southeast part of Asia reach peak in their richness. Highest number of species found in Malaysia (17), Thailand (14), Indonesia (13), Mayanmar (11) and China (10) (Lee and Liao, 1998).

A total of 13 species of flying squirrel are occurring in India, out of which three are endemic to the country. Eastern part of the country contains highest species number follows three in northern part, two in southern part and one in western part subsequently (Koli 2015). Among all the 13 species known to occur in India, *P. phillipensis* is widely distributed in India (Fig. 2).

According to Prater (2005), this species inhabit in all the larger forests of the peninsula south of the Ganges. In southern Rajasthan, its distribution is found confined only in *Madhuca longifolia* groves and belts (Sharma 2007; Koli *et al.* 2013a; Sharma and Sharma 2013). Recently, Sreekar *et al.* (2012) reported its occurrence in highly disturbed and degraded forest of Andhra Pradesh. It is encountered up to maximum 2050 m elevation, but the high

encounter rate is recorded at 50–500 m elevation (Koli *et al.* 2013a; Nandini 2001a).

Fig. 2. Global Distribution of *Petaurista philippensis.*

1.3 Biology

P. philippensis is mainly nocturnal, spending the daytime asleep in tree cavities and comes out at dusk, while retires before dawn (Prater 2005). Due to high fluctuations in air temperature over the year in tropical forests, their behaviour is also change in different season. During the summer season, the species is seen to be sleep out, on its back, from its hiding sites in the day time to rid itself from high temperature (Prater 2005; Bhatnagar *et al.* 2010a). While, during winter the species basks in the sunlight for thermoregulation (Koli *et al.* 2012). It generally uses tall trees for its gliding and feeding activities and prefers the mid canopy of the forest (Kumara and Singh 2006). In both wet and dry forests, Kumara and Singh (2006) observed *P. Philippensis* used most trees of 16–20 m tall, while Nandini (2001a) sighted it mostly on trees with 22.59 m ± 0.62 SE height.

Animals use natural and primary cavity nests of large and old trees (Koli *et al.* 2013a; Sharma and Sharma 2013). Hutton (1947) located nest height about 18 m above the ground along 1.5 m long and 30 cm diameter of

entrance. Similarly, Koli *et al.* (2013a) identified nest height 22.64 ± 4.56 m (mean ± SD) in southern Rajasthan and Nandini (2001b) noted nest height 18.42 ± 1.79 m along with cavity length 38.4 ± 21.37 cm and cavity width 13.2 ± 2.76 cm subsequently. Major nesting tree species in southern Rajasthan is *M. longifolia* (Koli *et al.* 2013; Sharma and Sharma 2013). On one occasion, Hutton (1947) found *P. philippensis* nest well lined with grass, moss and fur. Gliding of *P. philippensis* is always observed from tree top to lower heights using patagium (Sharma and Sharma 2013; Koli *et al.* 2011). Tail acts in steering (Hutton 1949) and also for balance through the gliding motion (Xavier *et al.* 1998). Koli *et al.* (2011) recorded its mean gliding ratio (2.32), ground speed (6.96 m/s), air speed (7.51 m/s) and gliding angle (25.53). Animal mostly prefers short glides (between 11 and 20 m) than the long ones (Koli *et al.* 2011), however Blanford (1891) had reported its longest glide about 73 m. Gliding of *P. philippensis* is always observed from tree top to lower heights using patagium (Sharma and Sharma 2013; Koli *et al.* 2011). Gliding activity is found higher in the summer season than monsoon and winter seasons, while in the night, early period (1930–2330 h) is found most active time for gliding (Koli *et al.* 2011).

1.4 Feeding

P. philippensis is chiefly herbivore and its feeding consists flower, fruit, bark, leaf, pith, lichen (Zacharias and Bhardwaj 1997; Sharma 2007; Nandini and Parthasarathy 2008; Bhatnagar *et al.* 2010b; Koli 2012; Koli *et al.* 2013b), shoots and nuts (Sterndale 1884). Some records on beetles, larvae (Blanford 1891) and termites have been also recorded (Sharma and Sharma 2013). In tropical deciduous forests of western India, pith is most preferred (almost 78% of the diet) plant part (Bhatnagar *et al.* 2010b; Koli *et al.* 2013b), while in the Rainforests of Western Ghats, fruits accounted about 48% of its diet (Nandini and Parthasarathy 2008). The sound of the animal is weak, soft, monotonous and quickly repeated. Sometimes it grunts like a ‘‘guinea-pig’’ (Sterndale 1884). It has a loud alarm call and made sharp chattering cry among many squirrels (Prater 2005). For *P.*

philippensis census in Western Ghats, ***call playback method*** was used by Babu and Jayson (2009), while Koli and Bhatnagar (2014) suggested that mid-night and late night are optimum time for its census in tropical deciduous forests.

1.5 Breeding

Data on the reproductive biology is scarce. Many observations consider the early summer season as its breeding period. Mating takes place in January and February months (Zacharias and Bhardwaj 1997). Zacharias and Bhardwaj (1997) observed a killed specimen of *P. philippensis* with fully grown embryos in the March–April. Breeding occurs in tree holes (Blanford 1891). After birth of young ones, the nest hole is occupied solely by the mother and its offspring (Prater 2005). Hutton (1947) had taken a baby flying squirrel from its nest was blind and just more than a foot long. Its head was out of all proportion to the rest body. Flat tail was five inches long. The parachute was undeveloped ending at the elbow, not to the wrists.

1.6 Threats

Globally *P. philippensis* is considered Least Concern, but recent studies indicate its decreasing status in India due to habitat destruction, degradation, tree felling, shifting cultivation, forest fires, increasing human settlement, accidental mortality due to collision with vehicles (Molur *et al.* 2005), anthropogenic disturbances, agricultural encroachment, monoculture plantation (Kumara and Singh 2004, 2006; Koli *et al.* 2013a), construction of national highways, myths (Sharma and Sharma 2013) and hunting (Nandini 2001a; Kumara and Singh 2006; Koli *et al.* 2013a; Sharma and Sharma 2013). Animals hunt for local consumption, medicinal purpose, socio-cultural traditions and myths (Molur *et al.* 2005; Koli *et al.* 2013a). Molur *et al.* (2005) predicted that *P. philippensis* has lost its habitat about 20 % from last 20 years and similar trend expected for next 20 years due to these reasons.

2. Objective

The present study was sanctioned vide Work Order No. एफ ( ) स्टोर/ उवसं/वजी/2019-20/564 dated 13.02.2020 to 11th May 2020, a part of 4 month long survey for population estimation, behavioural characteristics and suggesting conservation measures for long term survival of Large Brown Flying Squirrel in Sitamata WL Sanctuary, with below mentioned objectives:

- To demarcate all the flying squirrel habitats in sanctuary
- Detailed census
- Their associations in term of trees, herbs, shrubs, geology, geography and climate with photographic evidence
- Documentations of behavioural characteristics
- Conclusive evidences and flying squirrel maps
- Suggestive measures for species conservation

3. Methodology

3.1 Study Area This study was done in the Sitamata wildlife sanctuary of Rajasthan, located at the trijunction of Aravalli & Vindhyan Hill Ranges and Malwa Plateau, which harbours its unique and diverse biodiversity. Sitamata Wildlife Sanctuary (SWLS) lies in the districts of Chittorgarh, Pratapgarh and Udaipur in the south west region of Rajasthan State. It extend to 422.95 km^2 and is situated between 24° 04´ - 24° 23´ N latitude and 74° 25´ - 74° 40´ E longitude. It includes 359.60 km^2 Reserved forest and 63.35 km^2 Protected forest. It is important mainly because it forms the north-western limit of Teak-bamboo forests and the fauna occurring there in. It is exceptional for diversity and interspersion of habitats, which includes area of teak stands, wetlands, perennial streams, gentle undulating mountains, natural deep gorges and fine grooves of mixed woodlands. The location of this sanctuary being at the inter junction of the Aravalli, Vindyan hill ranges, and Malwa Plateau makes it zoo-geographically important and more unique as floral and faunal elements of both ranges could occur.

The PA covers the older formations like Pre-Aravalli gneisses, Aravalli and Vindhyans with basalt in composition and consisting essentially of basic plagioclase and pyrovene. Magnesite and limonite are present as accessories in the rock. The influence of the Malva Plateau the Deccan trap has led to interappean beds at place, which consists of silicaceous limestones and charty rocks with some fossils.

The soil varies from clayey, clayey-loam to gravelly depending upon topography and mixed with pebbles and boulders. Black cotton soil is found in patches lying upon the old formations. The soil depth is fairly good and varies from 30cms to few metres. The tract is hilly interspersed with network of streams and rivers. The slopes are gentle except at very few places. The terrain is hilly and rugged with an altitudes ranging from 280m to 600m. The general slope of the land is from north-west to south-

east. In general the topography presents a picture of tangled wilderness of ridges, plateaus, valleys with network of streams and at places fairly wide plains (FES Report, 2010).

The climate is sub-tropical characterized by distinct winter, summer and monsoon season. The winter commences from November and becomes cold in December –January with the minimum temperature of 6°C. Summer starts from mid March and the heat becomes intense in April with the maximum temperature of 45°C. Rainy season is from mid June and continues up to mid September. Sometimes winter showers also occur in January-February. The average rainfall is 756 mm with maximum up to 951 mm and minimum 517mm. All showers coming in a mean of 30 rainy days.

The forest found in this PA is classified as II- Dry tropical forests, which is further diversified into group 5- Tropical dry deciduous forest with 5A- Southern tropical dry deciduous forest (including C1-dry teak bearing forest) and 5B- Northern tropical dry deciduous forest (including C2 – northern dry mixed deciduous forest) (Champion and Seth 1968). The network of rivers (Jakham, the Karmoi and the Sitamata) and accompanied riparian vegetation is main characteristic of this sanctuary. All this have resulted in diverse micro and macro habitats that are home to quite a few conservation significant floral species like *Sterculia urens, Dendrocalamus strictus, Chlorophytum tuberosum Buchanania lanzan, Desmostachya bipinnata, Gloriosa superba* and Vanda orchid, and faunal species *viz.* Starred Tortoise, Marsh crocodile or Mugger, Long-bill Vulture, White-rump Vulture, Scavenger Vulture, Pangolin, Ratel, Four horned antelope and Leopard.

The forest is interspersed with about 30 villages and their agriculture field that creates a typical mosaic. The agricultural activities coupled with the heavy biotic pressure of domestic livestock, illicit cutting of wood, timber and bamboo and other MFP collection including encroachments, both

inside and the periphery exerts enormous pressure on the PA. Further, though it is endowed with rich natural resources, it is affected by natural calamities and hazards like drought, fire, flood and storm, with drought being a common phenomenon.

3.2 Field Survey Methods

Flying squirrels are arboreal and nocturnal in habit, which makes them more elusive and secretive in behaviour. Always remain in foliage and use to feed on forest canopy; it is very tough to detect it during feeding time in night. It generally feeds on pith, bark of young twigs, seldom on leaves, flower buds, flowers and fruits of varieties of trees in the study area. Designing a proper survey protocol is a unique way to start a systematic population estimation work. Being a large, undulating and dense forest area of sanctuary, entire area was divided into sampling grids. A proper survey of all secondary source of information (published research papers, reports, personal communication with few experts who have are doing similar work in NE India and South India on the same species and interaction with forest staff) was done before planning for field survey. Generally this elusive animal comes out from its hiding place (generally in tree hollow) after half an hour of sunset, spotting them at this stage was a challenging task. The unique feeding behaviour of this animal was reported in many research papers were taken as a tool for survey during the day time, because it used to drop the half eaten twigs, without bark twigs and nibbled leaves on the forest floor. This was taken a main survey method and all probable locations were searched with the help of local trekkers as well as escorted by forest staff. Looking at the biting and grinding signs on the twigs, presence of Large Brown Flying Squirrel (LBFS) was marked (Nandini 2001a; Kumara and Singh 2006; Koli *et al.* 2013a; Sharma and Sharma 2013). Later in the late evening many such sites were randomly revisited for direct sightings. The number of such sites indicates the occurrence and intensity of use by a species in that area. During our reconnaissance survey, we observed direct sighting of flying squirrels at only 12 locations (Table 1), whereas at 61 places we were able

to get positive signs of presence of these elusive flying squirrels during day time (Table 2). This was mainly due to the inaccessible terrain in night. Hence, we opted for the occupancy framework by sampling all such positive signs of flying squirrel movement and feeding, which is a reliable source for assessment of population status of shy, nocturnal and elusive animals (Kumara and Suganthasakthivel, 2011).

Table 1: Direct Sighting locations of Indian Giant Flying Squirrel.

S. No.	Coordinates		Places
	latitude	longitude	
1.	24.24828	74.42861	Mayda
2.	24.22245	24.22245	Aarampura
3.	24.22245	74.43194	Aarampura
4.	24.20882	24.20882	Reecharipal
5.	24.20176	74.55555	Reecharipal
6.	24.16062	74.57944	Down side Jakham Dam
7.	24.15446	74.58055	Down side Jakham Dam
8.	24.23284	74.48722	Near Rana
9.	24.26859	74.50444	Chail River to Valmiki Ashram
10.	24.26532	74.50500	Chail River to Valmiki Ashram
11.	24.26418	74.50416	Chail River to Valmiki Ashram
12.	24.29600	74.57166	Near Peepli Khera

Table 2: Confirmed positive sign locations of Indian Giant Flying Squirrel.

S. No.	Coordinates		Chauki	Places	Range
	latitude	longitude			
1.	24.23608	74.52014	Dum duma gate	Keli gaon	Bari sadri
2.	24.2099	74.48278	Dholiya	Jammogra	Dariyawad
3.	24.24308	74.51775	Dum duma gate	Keli gaon	Bari sadri
4.	24.24808	74.43375	Dholiya	Sitawadi	Dariyawad
5.	24.24835	74.42867	Dholiya	Sitawadi	Dariyawad
6.	24.24851	74.42886	Dholiya	Sitawadi	Dariyawad
7.	24.30581	74.48553	Dum duma gate	Cheli nadhi	Bari sadri
8.	24.32476	74.56423	Dum duma gate	Cheli nadhi	Bari sadri
9.	24.26854	74.50441	Dum duma gate	Cheli nadhi	Bari sadri
10.	24.26417	74.50425	Dum duma gate	Cheli nadhi	Bari sadri
11.	24.27012	74.50388	Dum duma gate	Cheli nadhi	Bari sadri
12.	24.2653	74.50499	Dum duma gate	Cheli nadhi	Bari sadri
13.	24.26593	74.50549	Dum duma gate	Cheli nadhi	Bari sadri
14.	24.2328	74.48852	Dum duma gate	Sita mata river	Bari sadri
15.	24.29494	74.56921	Sangri kheda	Kala bhata	Bari sadri
16.	24.29572	74.56918	Sangri kheda	Kala bhata	Bari sadri

17.	24.29652	74.57263	Sangri kheda	Kala bhata	Bari sadri
18.	24.296	74.57154	Sangri kheda	Kala bhata	Bari sadri
19.	24.24835	74.42867	Dabela	Sitawadi	Dariyawad
20.	24.15568	74.47138	Dholiya	Dholiya	Dariyawad
21.	24.1893	74.46822	Dholiya	Dholiya	Dariyawad
22.	24.21057	74.48384	Dholiya	Jammogra	Dariyawad
23.	24.23035	74.49093	Rana	Rana	Dariyawad
24.	24.23266	74.48724	Rana	Rana	Dariyawad
25.	24.2333	74.489	Rana	Rana	Dariyawad
26.	24.18663	74.52294	Pal	kala khet	Jakham
27.	24.20092	74.50561	Pal	Mandela	Jakham
28.	24.18828	74.52178	Pal	kala khet	Jakham
29.	24.21109	74.54411	Pal	Mogi amba	Jakham
30.	24.21109	74.54302	Pal	Mogi amba	Jakham
31.	24.19546	74.55675	Pal	Mogi amba	Jakham
32.	24.2024	74.55704	Pal	Mogi amba	Jakham
33.	24.20017	74.55636	Pal	Mogi amba	Jakham
34.	24.20724	74.55606	Pal	Mogi amba	Jakham
35.	24.19326	74.55687	Pal	Mogi amba	Jakham
36.	24.1925	74.55735	Pal	Mogi amba	Jakham
37.	24.19113	74.55817	Pal	Mogi amba	Jakham
38.	24.20866	74.55543	Pal	Mogi amba	Jakham
39.	24.19688	74.55719	Pal	Mogi amba	Jakham
40.	24.20022	74.55633	Pal	Mogi amba	Jakham
41.	24.20174	74.55561	Pal	Mogi amba	Jakham
42.	24.15694	74.59883	Anoppura	jar mahadev	Jakham
43.	24.15582	74.5994	Anoppura	jar mahadev	Jakham
44.	24.15576	74.5996	Anoppura	jar mahadev	Jakham
45.	24.15571	74.59995	Anoppura	jar mahadev	Jakham
46.	24.15572	74.5994	Anoppura	jar mahadev	Jakham
47.	24.16053	74.57928	Anoppura	jakham river	Jakham
48.	24.1615	74.57909	Anoppura	jakham river	Jakham
49.	24.1626	74.58241	Anoppura	jakham river	Jakham
50.	24.15714	74.57922	Anoppura	jakham river	Jakham
51.	24.15468	74.57901	Anoppura	jakham river	Jakham
52.	24.15454	74.5805	Anoppura	jakham river	Jakham
53.	24.15337	74.58028	Anoppura	jakham river	Jakham
54.	24.16324	74.57431	Anoppura	jakham river	Jakham
55.	24.16351	74.58403	Anoppura	jakham river	Jakham
56.	24.11776	74.60673	Anoppura	anoppura	Jakham
57.	24.07508	74.57899	Pipliya	ponga talab	Jakham
58.	24.07188	74.56291	Pipliya	ponga talab	Jakham
59.	24.10522	74.53594	Pipliya	guwal mata	Jakham
60.	24.10522	74.53583	Pipliya	guwal mata	Jakham
61.	24.10519	74.53456	Pipliya	guwal mata	Jakham

During surveys many areas inside sanctuary and nearby villages were scanned to identify the preferred habitats of flying squirrels. Presence of flying squirrels was identified with the help of local people, forest personals and tribes. Description of animal, photograph and their vernacular names of Flying Squirrel in Sitamata WL Sanctuary area (Udan Pankhi, Udan biladi, Udani Minki, Kali Minki, etc) were used to detect its probable presence and to confirm animal presence. Additional information were collected from fecal matter and feeding remains of flying squirrels during day time, because both are often encountered near active dens of the flying squirrels (Sharma, 2007). Nocturnal surveys were also done on foot between 19:30 to 23:00 h on natural and new trails using spot lights and binoculars to observe the animals in the same areas. *P. philippensis* displays a distinctive red eye shine in the flash of beam light. This identification feature was used to detect its presence in the night. Besides this, gliding in tree or between trees and calling of the animals were also helpful in locating the flying squirrels. Sites where the presence of flying squirrels was confirmed were recorded using a global positioning system (GPS) (Table 1 & 2). Repeated walks were not made on the same trails. Encounter rate was considered as relative abundance and calculated as number of animals observed/ travelled km. During the surveys, we also collected information on the species occurrence in the past, reasons of squirrels hunting, socio-cultural influence on hunting and hunting practices by interviewing the local tribes.

During the study period, nesting trees of flying squirrels were also identified with the help of local tribes and described by tree species, tree height (m), nest/cavity height (m), diameter at breast height (DBH) (cm), canopy cover (m2), type of cavity (natural/artificial), and distance to nearest trail or road (m). Pearson product moment correlation (r) was used to estimate correlations between nest height to nest tree height, DBH and canopy cover (Nandini 2001a; Kumara and Singh 2006; Koli *et al.* 2013a; Sharma and Sharma 2013).

Flying squirrel observations: Trails were walked at every study site primarily between 1900 and 0100 hrs of the night. Spotlighting was the primary method of locating flying squirrels. This method is widely used in the study of other nocturnal arboreal mammals (Rajamani 2001, Goldingay 1990) and has been established as effective in detecting arboreal mammals (Laurence & Laurence 1995). One modified torch fitted with a halogen bulb and connected to a 12V battery was used as additive to flashlights and headlights (Nandini 2001a; Kumara and Singh 2006; Koli *et al.* 2013a; Sharma and Sharma 2013).

All strata of the vegetation were scanned from different angles and squirrels were detected by eye-shine and then identified by the use of 8 x 50 or 10 x 50 binoculars. Only confirmed sightings were used for analysis. Sightings when the animal moved away from the light too quickly or was too far away to be identified accurately were not taken into account. *P. philippensis* was also detected by its vocalisations, which are loud calls that are usually repeated monotonously (Prater 1971). The observer was familiar with the call (due to previous field experience with the species) and the call could be identified as being that of *P. philippensis* with accuracy. Nocturnal calls that were not the call of *P. philippensis* were not recorded (Kumara and Singh 2006; Sharma and Sharma 2013).

For each squirrel sighted, the following characteristics were recorded: time of the sighting, the species, number of individuals, mode of detection of the animal (either by call or sight or movement), location of the animal on the tree, diameter of substrate used, and height of the animal on the tree. Details of behaviour (categorised into pre-determined behaviours), size and colour of the animal sighted were also noted. Other variables measured during the walk were the wind, rain and moon conditions.

Playback experiment: This is one of the best methods to do a rapid survey of nocturnal elusive arboreal animals. Playing call of squirrel, predator call

(calls of natural predator of flying squirrels like call of Spot-bellied Eagle-Owl , Brown Fish Owl and Indian Eagle Owl) as well as other call to alert the feeding squirrel in canopy, later the same was spotted with the help of high beam torch light. Fleshing eyes and confirmation through binocular or glide reported as presence of squirrel.

Measurement of Vegetation parameters: The trees that the flying squirrels were sighted on were marked and a vegetation plot of radius 12.6 m was laid around these trees during daytime to characterize parameters of the habitats used by flying squirrels. The distance to each of the trees from the centre tree (sighting tree) was recorded. The girth at breast height, height, and life stage condition (trees characterized as being dead or alive) of all the trees within this 12.6 m radius were measured. The following characteristics of the centre tree were recorded: girth at breast height, height, phenology, canopy contiguity to nearest trees, presence or absence of hollows and the perpendicular distance of the tree to nearest road or trail. The presence of vegetation (cover) was recorded in height intervals of 5m within a radius of 5m around the tree. The altitude, GPS location, topography and slope of the plot were also recorded.

In areas where no flying squirrels were encountered the same habitat parameters were recorded in random plots laid along the path walked in order to measure the parameters in the general habitat. Random plots were not laid within habitats where flying squirrels were sighted as the aim of collection of such habitat parameters was not to compare features of the habitat within a site, but to compare habitat characteristics across sites (to compare sites where flying squirrels were sighted with sites where they were not sighted). For every walk, forest type, the altitude (with an altimeter) and location of the walk (with a GPS) were recorded.

Population estimation:

The Sitamata WL Sanctuary boundary was overlaid with 2 sq. km grid study on the 'geographical information system' platform using ArcGIS for systematic random sampling protocol. Total 122 such grids were placed on map and out of these 122 grids, total 65 grids selected for field survey. The 2 sq. km grid size was chosen based on the largest known home range of the species with similar forest structure, which was estimated to be ~2 km2. Each 2 sq. km grid was further divided into four sub-grids, which were used to finding the most frequently visited tree groves. Tree grove survey was conducted in 65 grids (Figure 3). The fieldwork was carried out during the dry season from February to April 2020.

Flying Squirrel Activity Tree Survey: We uploaded the shapefile of the grid cells to a handheld GPS (GARMIN-eTrex™) using DNR Garmin™ application. Using this, the grid cells were located on the field. Once a grid cell was located, we selected the existing grove of most frequently visited tree species by Flying Squirrels in this region. For this help from local forest staff was also taken into consideration. Almost all such tree groves were visited during field survey and signs of activity noted. We turned the track mode on to record the path in GPS and walked slowly by searching for nearby trees of same species. We sampled 73 grids and during the walk, and recorded the geo-coordinates for all detections of signs handheld GPS receiver (Figure 1). We also determined the GBH of tree, distance between nearby trees from the central tree, canopy cover as well as any human activity sign as it is considered to be one of the influencing factors for flying squirrels in all the published literature.

Vegetation structure and anthropogenic variables: To assess the environmental and anthropogenic variables, we laid 10*10 m quadrats on a diagonal line near the central tree of probable flying squirrel tree grive. Plant species having minimum 50 cm girth were considered as potential trees w.r.t. feeding trees for flying squirrels, and height of the trees was measured using a random ocular estimation. The girth at breast height (GBH) for

each tree stem more than 50 cm was measured. Taxonomic identification of the species was done after noting down vernacular name of trees with the help of accompanying forest guard and later confirmed from standard flora books. We also recorded the count of dung piles of livestock in such sites, if any. On the GIS platform, we measured the distance of the grid corner to the forest boundary and the nearest village.

Table 1. Predicted species response to each covariate based on our *a priori* hypothesis for Large Brown Flying Squirrel presence in Sitamata WL Sanctuary

Covariates	ψ	P
TR (Tree density)	+	+
FDTR (Food tree density)	+	+
BA (Basal area)	+	+
DIVE (Plant species diversity)	-	0
CATT (Cattle dung density)	-	0
GOAT (Goat dropping density)	-	0
DIST (Distance from the PA boundary)	+	-
KM (Trail length)	+	0

ψ is the probability of occurrence and P is the species detection probability.

'+' signifies a positive effect on the response variable, '–' signifies a negative effect and '0' signifies that the covariate does not affect the response variable.

Statistical analysis

A priori hypothesis: Considering the biology of large brown flying squirrel and habitat conditions, an a priori hypothesis was established to determine the parameters that might influence their detection and occupancy in the grid cells (Table 1). We categorized site-level covariates as ecological variables: tree density (TR), tree diversity (DIVE), basal area

(BA) and food tree density (FDTR); anthropological variables: cattle dung (CATT), goat and sheep droppings (GOAT) and distance from the boundary (DIST). We used trail length (KM) as a covariate for detection probability.

Independent variables: Using plant data from each quadrat we calculated TR and FDTR by dividing the total number of individuals/area sampled × 10,000 and BA using the formula $(GBH)^2/4\pi$. The plant species diversity (DIVE) was represented by Shannon–Wiener's index using the formula:

$$H' = -\Sigma(ni/N)\ln(ni/N),$$

for each grid cell. We listed five species as the most important food species for this study area based on the literature and using our field observations to calculate FDTR. DIST, CATT and GOAT (together as human disturbance factor) were considered as independent variables which may affect habitat selection of LBFS. We considered the variation in trail length to be the influencing factor for detection rate of positive signs under feeding sites (favorite trees for LBFS), as more the visit, probability to get more such signs. Help in identification of trees were taken from pictorial field guide of Mr. Pradip Krishen (2013) and also help were taken from Katiyar and Saharan (2019) regarding the identification through vernacular names being used by locals in the area.

Occupancy and abundance modelling: The detection of positive signs under feeding sites (favorite trees for LBFS) in grid was considered as a spatial replicate, and the fresh sign under such trees in a week long cycle (looking at its site fidelity and tree hollow as roosting site) during rapid survey was considered as a temporal replicate. A binary presence/absence matrix of detection history was constructed for of positive signs under feeding sites (favorite trees for LBFS) and direct sightings. The detection probability, occupancy and abundance were computed using PRESENCE software v.5.3 (USGS, USA). Assuming the population was closed during

sampling, single-season occupancy modelling was used for the estimation of detection probability (P) and proportion of sites occupied (ψ).

Models were first developed to check whether the site covariates affect the detection probability. A null model was developed keeping the detection probability constant $p(\cdot)$ for each site covariate. Then the model was compared with other models (site-covariates) to estimate the detection probability. The models were ranked according to the ΔAIC (Akaike information criterion) value. The lowest ΔAIC value was ranked highest (Burnham and Anderson, 1998), and the average of all the models was calculated to estimate the final occupancy. Generalized linear modelling (GLM) was carried out for the estimation of determinants for the relative abundance of signs under active tree groves. The modelling was performed using R v 3.5.1 software. We estimated the abundance of Large Brown Flying Squirrel for the sampled area using Royle and Nichols model in PRESENCE v5.3 (USGS, USA) using fresh signs, calls and direct sightings. Further, using the estimated abundance in the sampled area, we extrapolated to other areas occupied by the LBFS using occupancy models deduced from favorite tree grove sites.

Results

Sitamata Wildlife Sanctuary is known for its flying squirrels and this survey was restricted to the sanctuary and just adjoining villages in south and eastern side. Entire Sanctuary area was subdivided into 122 grids of 2 km^2 for systematic sampling. A total of 83 such grids were sampled in two cycle of systematic survey, which roughly makes 68% of the total sanctuary area. Almost all probable sites were personally visited by the field team to ascertain the presence or absence of Flying Squirrel. In this, help of local forest guard, local villagers and forest labours were also contacted to locate the probable tree where they have seen them in recent past. Around 223 km of forest treks were covered while walking/bike ride/jeep ride trips in the 83 grids, during which we recorded the "*presence only*" signs or in 68 grids. We recorded a total of 268 clustered tree grooves in 166 sq. km (30 grid cells). The average in-between tree distance range around such "*presence only*" places was 39 sq. m, which ranged between 16 and 73 sq.m^2. Largely, such tree groves were found at 'relatively dense area' within thick vegetation.

Table 3. Detection probabilities for Large Brown Flying Squirrel '*activity tree groves (ATG)'*.

Model	$\hat{p}$ ± SE	AIC_c	ΔAIC_c	w_i	*K*	Naïve occupancy
$\psi(.),p$(KM)	*0.76*± 0.05	229.30	0.01	0.80	3	0.56
$\psi(.),p(.)$	0.81± 0.06	231.62	3.87	0.17	2	

$\hat{p}$, Estimated species detection probability; AIC_c, Akaike information criterion corrected for small-sample bias; ΔAIC_c, Difference in AIC_c values between each model and model with lowest AIC_c, *wi*, AIC_c model weight; K, Number of parameters estimated by the model and KM, Trail length.

The analysis from 83 such sites with two sampling sessions provided an estimated detection probability (p) of 0.76 ± 0.05 for '*activity tree groves*' (Table 3). The distance walked (KM) in each grid and sub-grid influenced the detection probability of ATG, i.e. w_i = 0.90. Subsequent models were run with KM as a function of p. The estimated naïve occupancy was 0.56. The estimated occupancy of ATG was $\psi(.)$, $p(.)$ = 0.52 ± 0.39. Since w_i of the

top model was more than 0.5, we did not sum the AIC_c wt. and considered the top-ranking model as a predictor (Table 4). The occupancy of Large Brown Flying Squirrel was positively correlated with BA: β = 10.23 ± 6.21 and DIST: β = 4.19 ± 1.83, while CATT have a very less influence β = 1.23 ± 0.68 (Table 5). The site occupancy estimates were classified as low (ψ^ = 0.00 – 0.25), medium (ψ^ = 0.25 – 0.50), high (ψ^ = 0.50 – 0.74) and very high (ψ^ = 0.74 – 0.99), and mapped, which shows that 68 out of 83 grids have high probability, while 15 grids show relatively less probability of occupancy as well as remaining 39 from total 122 grids show very less probability presence of LBFS in the Sitamata WL Sanctuary (Fig. 3.).

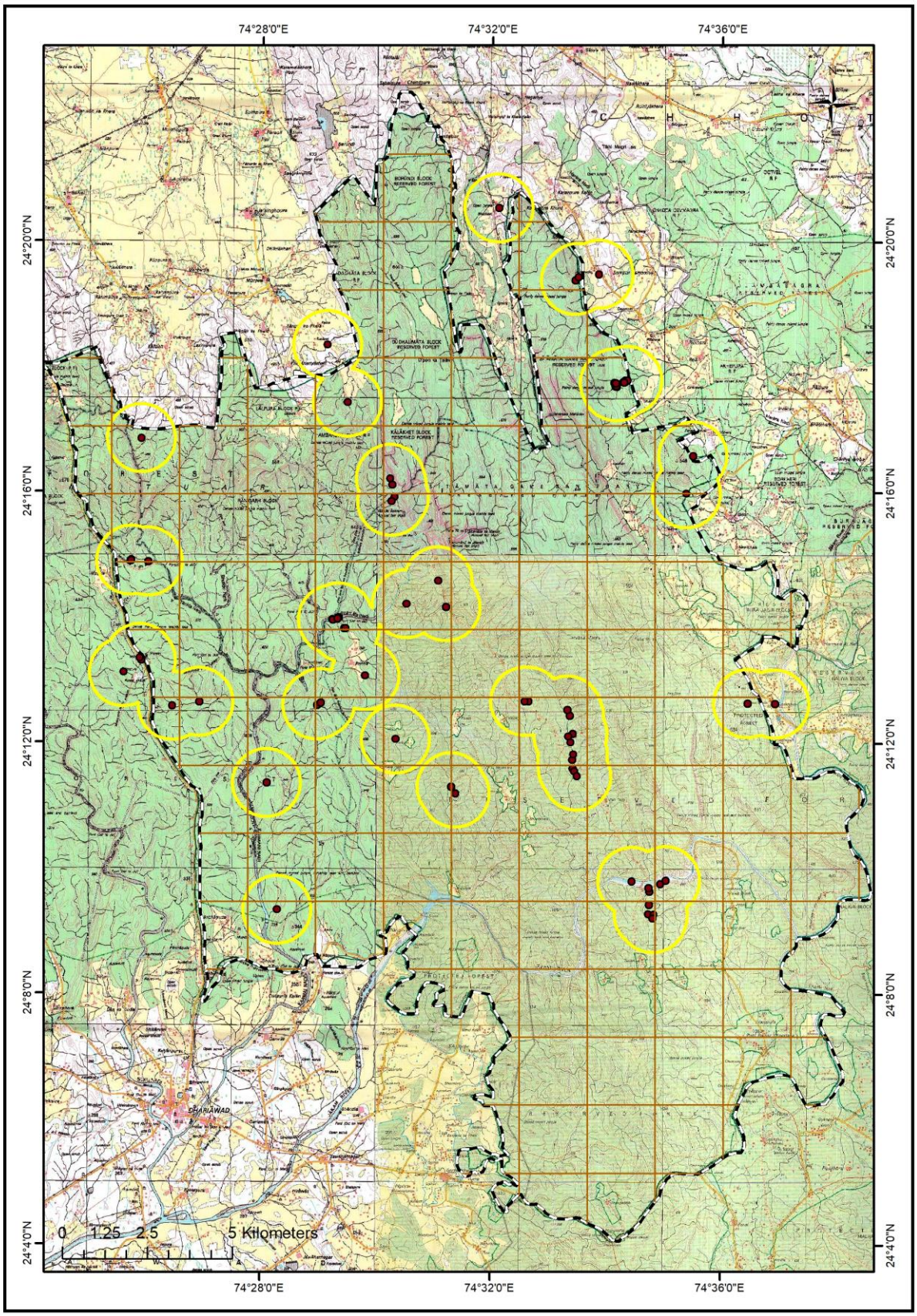


Fig. 3. Area of Sitamata WL Sanctuary, with grids overlaid for survey purpose and Flying Squirrel sighting and presence locations are mapped with 1 km buffer.

Table 4. Model for occupancy of Large Brown Flying Squirrel using activity based tree grove detection in Sitamata WL Sanctuary

Model	ψ ^	SE^	AIC_c	ΔAIC_c	w_i	K
ψ (BA + CATT + DIST), p (KM)	0.5218	0.3912	181.92	0	0.6918	5
ψ (BA + CATT), p (KM)	0.5092	0.0621	185.27	1.98	0.335	5
ψ (BA), p (KM)	0.5174	0.0452	193.21	2.12	0.113	4
ψ (DIST), p (KM)	0.4952	0.0412	198.11	23.25	0.011	3
ψ (DIVE), p (KM)	0.5126	0.0391	209.19	28.12	0	2
ψ (CATT), p (KM)	0.4781	0.0441	218.40	32.17	0	2
ψ (GOAT), p (KM)	0.5112	0.0483	226.92	35.32	0	2
ψ (FDTR), p (KM)	0.4723	0.0519	235.27	39.45	0	2
ψ (TR), p (KM)	0.4951	0.0428	247.29	42.47	0	2
ψ (.), p (KM)	0.4268	0.0417	258.14	49.18	0	2

Table 5. Covariates influencing Large Brown Flying Squirrel occupancy in the basis of β-coefficients and standard error

Covariate	β-coefficient	SE^
Basal Area (BA)	10.23	6.21
Distance (DIST)	4.19	1.83
Cattle (CATT)	1.23	0.68

Table 6. Summary of the model selection procedure for covariance influencing relative abundance of Large Brown Flying Squirrel with R^2 and corresponding P values, β-coefficients and associated standard errors

Covariates	R^2	P	AIC_c	ΔAIC_c	K	B-coefficient	SE^
BA	0.1841	0.000	162.32	0	1	0.7814	0.2814
BA+DIST	0.1783	1.611	165.23	1.99	2	0.4281	0.3145
BA+DIST+CATT	0.1845	5.124	166.84	3.84	3	0.2219	0.2549
TR	0.0845	0.000	168.41	4.62	1	0.0021	0.0019
DIVE	0.0489	0.003	169.89	5.29	1	2.4569	1.8928
CATT	0.0395	0.009	171.56	5.86	1	0.0094	0.0081
FDTR	0.0091	0.182	175.12	6.89	1	0.0019	0.0034
DIST	0.0076	0.295	164.28	6.94	1	0.2164	0.4825
GOAT	0.0009	0.762	169.25	7.09	1	0.0007	0.0049
BA+DIST+CATT+GOAT+ TR+FDTR+DIVE	0.2984	1.954	174.36	8.36	7	0.1863	0.5962

Generalized linear modeling (GLM) revealed BA as a significant determinant for relative abundance of LBFS. A model involving only BA (basal area) was found to be the most suitable when compared with combinations of other covariates (AIC_c = 162.32; Table 6). Areas with high probability, active tree groves (ATG) and direct sightings correspond to high BA (β = 0.78 ± 0.28).

A total of 76 ± 14 individuals of Large Brown Flying Squirrel (LBFS) were estimated, with 12 direct sightings of different individuals in 7 separate places and twice with 2 individuals on a single tree as well as once 3 individuals including 1 young one was also sighted. It was found that LBFS lives in tree hollows and have great site fidelity. Its emergence time is always correlated with the sunset timing in the sanctuary. During the study period, one such roosting site of LBFS was monitored for around 45 days at Aarampura Forest Guest House region. The average emergence time was 31 min after the sunset time and this was highly correlated with a value of R^2 = 0.97. The minor flections were the days when large crowd gathered near the tree on road for its sighting. On such days, it peep from the day roost and keep observing the surrounding for a while and after 5-7 min it emerge out and climbs on the upper branches and hide itself in upper canopy of this tree (Fig. 4).

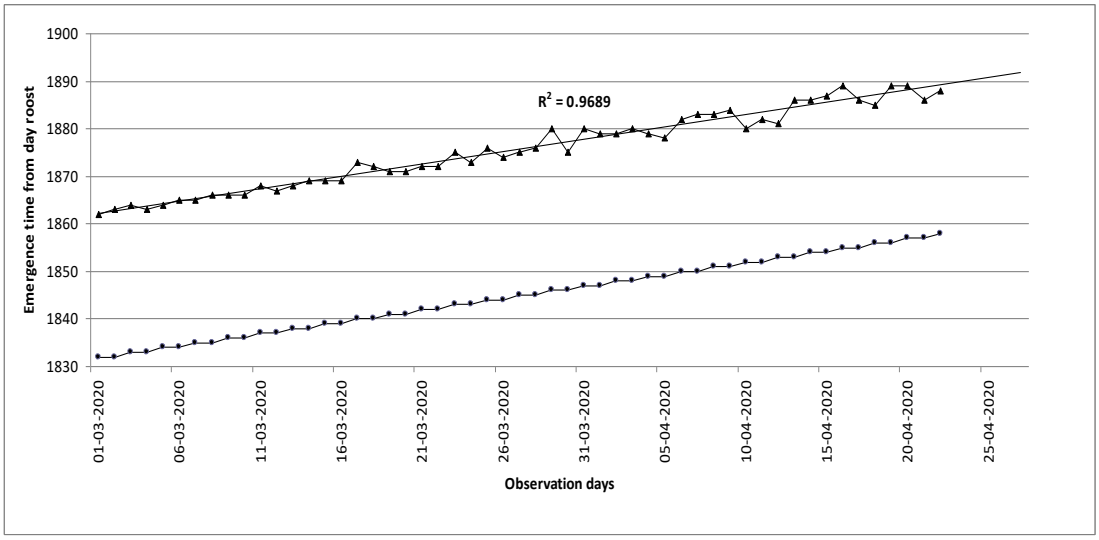


Fig. 4. Emergence time and correlation with sunset in Sitamata WL Sanctuary.

The distance of surrounding tree from "active tree grove" were also measured and it was found that the maximum trees (87%) were found to be upto the distance of 60 metre from the central tree, which was having highest number of LBFS activity signs under its canopy (Fig. 5).

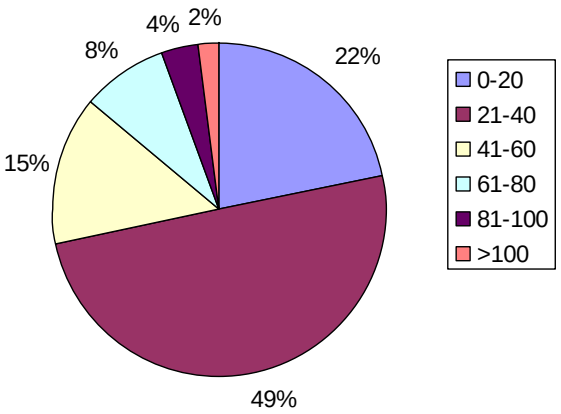


Fig. 5. Distance from "Active Tree Grove" to the nearest tree

The trees found in such 'active tree groves' were also identified and it was found that Mahua tree (*Madhuca longifolia*) was found favorite tree associated with LBFS in early summer with 19% positive signs. Where as another species were as follows: *Terminalia tomentosa* (9%), *Terminalia bellirica* (8%), *Ficus racemosa* (8%), *Ficus religiosa* (8%), *Ficus bengalensis* (6%), *Boswellia serreta* (6%), *Terminalia arjuna* (6%), *Mangifera indica* (6%). These nine species of tree together constitute a total of 76% favored trees during the project duration as well as highest activity signs were also collected

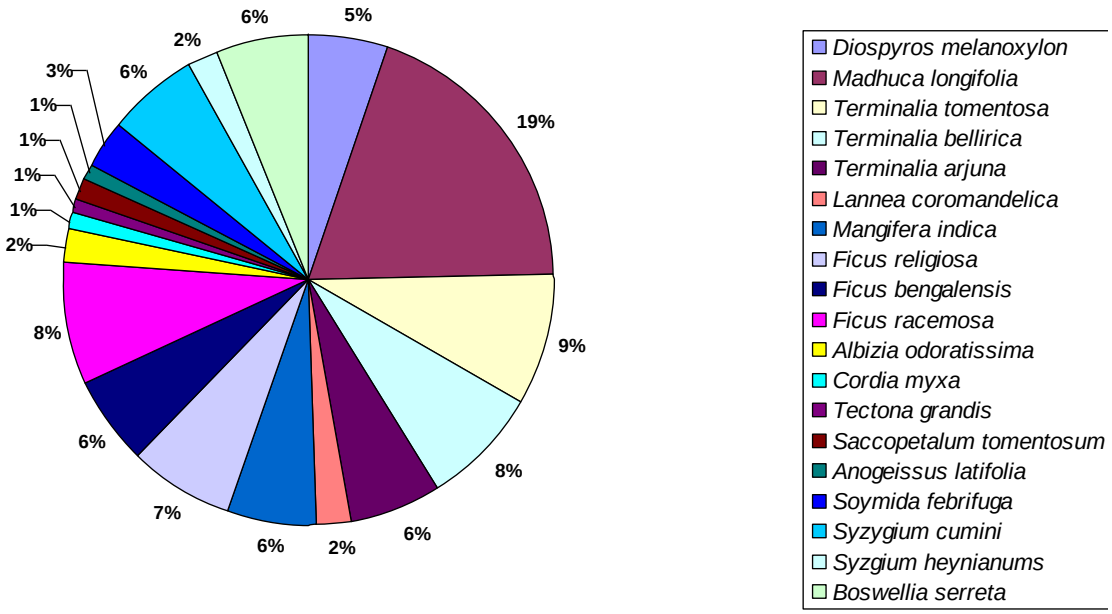


Fig. 6. Most favored tree by Flying Squirrel

from the under canopy of these trees. The other 11 species of trees constituted just 24% of the activity signs. This shows the preference of tree species in the sanctuary area (Fig. 6., Table 7).

Table 7. Most favorite trees by Large Brown Flying Squirrel in Sitamata WL Sanctuary, with vernacular name

S. No.	Common Name	Scientific Name
1	Tendu	*Diospyros melanoxylon*
2	Mahua	*Madhuca longifolia*
3	Asana, saj	*Terminalia tomentosa*
4	Bahera	*Terminalia bellirica*
5	Arjun	*Terminalia arjuna*
6	Indian Ash tree	*Lannea coromandelica*
7	Mango	*Mangifera indica*
8	Peepal	*Ficus religiosa*
9	Bargad	*Ficus bengalensis*
10	Goolar or Fig Tree	*Ficus racemosa*
11	Black siris or kali siris	*Albizia odoratissima*
12	Lasuda	*Cordia myxa*
13	Teak	*Tectona grandis*
14	Umbua or Hoom	*Saccopetalum tomentosum*
15	Axle wood, Dhaora	*Anogeissus latifolia*
16	Rakt rohan, Indian redwood	*Soymida febrifuga*
17	Jamun	*Syzygium cumini*
18	Kath Jamun	*Syzgium heynianum*
19	Salar or Salai guggul	*Boswellia serreta*

A total of 12 trees were confirmed as nesting sites of LBFS in sanctaury. *Madhuca longifolia* was found as the major nesting tree (n = 8), whereas *Ficus recemosa* (n = 2) and *Ficus benghalensis* (n = 2) were another two species with nesting activity.

Characteristics of the nesting trees were also observed. Large Brown Flying Squirrel (*Petaurista philippensis*) was found to be a natural cavity dweller. All these 12 cavities were in main trunk or very old side truck, just close to main truck. Single animal was found in all these day roosting tree hollows (nests) except at Aarampura, where a female and her 1 infant occupied single cavity during late March and early April. No correlation was found between nest cavity height to nest tree height ($r = 0.471$, $P = 0.05$), DBH ($r = 0.164$, $P = 0.05$) and canopy cover ($r = 0.421$, $P = 0.05$).

In the study area, it was also come in observation that flying squirrels are not hunted by local tribes in this sanctuary. For this, research team interacted with more than 23 locals and cattle guards. A kind of trust was built during an open ended interaction session, where they were kept in confidence that their identity will be not revealed to anyone. Only two such incidents came in knowledge where locals were told that once they say few tribal people hunted flying squirrels many years back.

Discussion

Since this project was largely aimed to know that present status and estimation of Large Brown Flying Squirrel population in Sitamata WL Sanctuary, major focus was on the enumeration of methodology for population estimation. It was found that with a proper systematic survey and intensive search in the pre decided grids, can reveal good information about the 'presence only' data of this illusive species. The terrain and topography is very undulating with three major river catchments falls inside the sanctuary, night survey is quite challenging. Therefore majority of field work was conducted during day time. Few attempts were also

tried with 'playback experiment', where downloaded calls of Large Brown Flying Squirrels were played during early night time and any movement in the tree canopy were thoroughly scanned with the help of hand held high beam torch. Along with this, calls of predatory birds (Spot-bellied Eagle-Owl, Brown Fish owl and Indian Eagle Owl) were also played to observe the changes in activity of LBFS. All these experiments were conducted on the sites, where probabilities of sightings were high. Through these experiments, our team was able to record 9 direct sightings in different part of sanctuary.

The overall population of Large Brown Flying Squirrel in Sitamata WL Sanctuary was 76 ± 14 adult individuals, which means that the overall population could be between 64 – 90 individuals in entire sanctuary. During the study time, 12 direct sightings of different individuals in 5 separate places and twice with 2 individuals on a single tree as well as once 3 individuals including 1 young one was also sighted. This was largely restricted in 83 girds of 2*2 km^2, which is about 78% of the sanctuary area. The flying squirrels have great site fidelity and proper attention needs to be given in the areas identified for their conservation.

In the entire sanctuary area, *M. longifolia* identified as a major activity (roosting and nesting) for *P. philippensis*, which is also its most preferred feeding tree species. This tree species also facilitated feeding to young ones of *P. philippensis* during its early life period when it incapable of gliding. *Madhuca longifolia* belts are found in the valleys and deep soil zones along with streams in the valley forests of sanctuary area. Its clustered distribution in sanctuary needs to be properly conserved for flying squirrel population. It was observed that Sitamata WL Sanctuary have good populations of *Madhuca longifolia* trees, but at the same time, the GBH of these trees was more then 180 cm. There was very less young plants of Mahua tree in sanctuary and this makes an interesting point to understand that recruitment of young trees in the sanctuary is very less. This needs

immediate attention as management level. This may be a possible reason for patchy and clustered distribution of *P. philippensis* in sanctuary. Kumara and Singh (2006) also identified restricted distribution of the giant squirrels in the riverine forests of Karnataka state, specifically where the trees were tall and widespread. There was also one interesting observation from this study, 85% activities of Aarampura Guest House site flying squirrels (2 adults and 1 young too observed here) is restricted towards Sanctuary side. Though quite a few time they cross the road, glide and gnawed Mahua and *Terminalia* spp. tree across the road (Dhariyawad road), but it seldom go beyond few tree from this road side. It is a shy animal and restricts its activities towards road side trees. Whenever people gather in large number for its sighting, the emergence time also showed delayed upto 12 min. and also swiftly it glides towards the tree groves inside sanctuary boundary. The traffic movement is also one of the causative factors for such behaviour. Highways generate biotic edge effects nearby vehicle road clearing, disturbance by vehicles including noise, headlights and vibration. Roads also fragmented forest habitats (Goosem, 2007) and restrict movements of animals (Rico *et al.*, 2007) . Often, mammals avoided the disturbed and surrounding altered habitats due to vehicles (Goosem, (2002).

Intensive increasing human population, their interference and encroachment in the sanctuary areas were disturbing squirrels native habitats. Many village sites were also observed, where good large sized Mahua tree were found, but the inter tree distance was more than 100 metre and that could be one of the major reason for absence of LBFS in these village sites. From the present study, it can be suggested that, Mahua (*M. longifolia*) dominated groves and thickets should be given priority for conservation and should be included in forest conservation plans of the sanctuary. Good plantation and conservation of young trees of such 19 favorite trees should be protected in a form of corridors so that the clustered populations of *P. philippensis* can spread and occupy the newer area. This is the only protected area in Rajasthan, where good population

of Large Brown Flying Squirrel is found and breeding. The priority for conservation of this species should be in the management plan of sanctuary. Forest staff should be trained for year long observation and monitoring of this species along with other wildlife.

Year long conservation centric scientific studies on flying squirrels are necessary for preparing suitable layout and outline for conservation plan and sustainable improvement of the habitats in sanctuary. During the surveys, Authors felt that people were not much known about the flying squirrels because of its nocturnal and cryptic habits. Forest Department should involve local youths from the villages (inside sanctuary villages) for training and awareness on wildlife of this area. These youths can be trained as Nature Guide and all tourist activities should be through these nature guide. These guides will be ears and eyes of sanctuary management and can also restrict the unlawful activities done by tourist as well as religious pilgrims of temples of sanctuary.

Conservation Plan

Sitamata Wildlife Sanctuary is famous for its elusive flying squirrels. Over the years the population estimation of this nocturnal animal, always remained a challenge. The current project was executed in collaboration with forest department to know the areas occupied by flying squirrels and well as an estimated population count for better management and conservation of these iconic animals. Sanctuary area was divided into equal sized grids of 2*2 km^2, based on the largest known home range of Large Brown Flying Squirrel in India. The LBFS rarely exceeds beyond 2 km from its day roosting tree hollow, hence 2 km radius was taken from the central 'activity tree groove'. The project team reviewed many methods used world over for population estimation of flying squirrels. Since identification of activity signs were easy to detect during early in the morning time, typical gnawing style of twigs, digging pith out of medium sized twigs, debarking large sized twigs, half gnawed leaves and fecal pellets were taken as a sign of their activity of last night (one or two days old, identified based on the dryness of leaves, twigs and bark). A protocol was prepared from such signs and through survey was done along with forest guards, cattle guards and local villagers. All the known sites were visited for finding the signs and used in the analysis. All such information was used for Occupancy Based Modeling and population was estimated with a range of probable lowest and highest population of LBFS in sanctuary. Based on the field knowledge, interaction with staff, comparison of habitat conditions with the earlier published work, project team is proposing few key points, important for conservation of Large Brown Flying Squirrel in Sanctuary.

1. Since this project was largely aimed to know that present status and estimation of Large Brown Flying Squirrel population in Sitamata WL Sanctuary, major focus was on the enumeration of methodology for population estimation. It was found that with a proper systematic survey and intensive search in the pre decided grids, can

reveal good information about the 'presence only' data of this illusive species. The terrain and topography is very undulating with tree major river catchments falls inside the sanctuary, night survey is quite challenging. Therefore majority of field work was conducted during day time. Few attempts were also tried with 'payback experiment', where downloaded calls of Large Brown Flying Squirrels were played during early night time and any movement in the tree canopy were thoroughly scanned with the help of hand held high beam torch. Along with this, calls of predatory birds were also played to observe the changes in activity of LBFS. All these experiments were conducted on the sites, where probabilities of sightings were high. Through these experiments, our team was able to record 9 direct sightings in different part of sanctuary.

2. **To protect old as well as dead trees:** It has been observed and verified by indirect source of literature that Flying squirrel roosts on old and dead trees as well. Being nocturnal in nature, to rest and sleep they require big holes and burrows during day time. Such trees should be marked (GPS location), shared with FD and proper monitoring of the species to be carried out regularly.
3. Every year, a proper population estimation of Flying Squirrel is required to understand the population trend. The survey timing should be between Feb. to March, as this area comes under deciduous forest, spring and early summer is best time for sightings in this leaf fall time.
4. Sanctuary management should identify the proper team for this work and training is required for survey.
5. In the entire sanctuary area, *M. longifolia* identified as a major activity (roosting and nesting) for *P. philippensis*, which is also its most preferred feeding tree species. This tree species also facilitated feeding to young ones of *P. philippensis* during its early life period when it incapable of gliding. *Madhuca longifolia* belts are found in the valleys and deep soil zones along with streams in the valley forests

of sanctuary area. Its clustered distribution in sanctuary needs to be properly conserved for flying squirrel population.

6. It was observed that Sitamata WL Sanctuary have good populations of *Madhuca longifolia* trees, but at the same time, the GBH of these trees was more then 150 cm. There was very less young plants of Mahua tree in sanctuary and this makes an interesting point to understand that recruitment of young trees in the sanctuary is very less. This needs immediate attention as management level. This may be a possible reason for patchy and clustered distribution of *P. philippensis* in sanctuary. The LBFS was found to be associated largely with 9 species of trees in sanctuary, with highest preference for Mahua tree, and overall 19 such tree species were listed during the project duration.
7. The distribution of flying squirrel was also restricted with the distribution of Mahua and few other associate trees. Interestingly, the girth size of these Mahua trees were found above 180 cm in general, which indicates these are mature tree, where as very less or no young tree (young Mahua tree recruitment in the sanctuary) was noticed. This tree is highly correlated with the presence of flying squirrel.
8. Mahua is one of the recognized Non-Timer Forest Produce in India. At the same time, presence of LBFS is directly correlated with this tree. Hence collection of Mahua flowers can be allowed, but seeds (gully in local language) should be discouraged. It could be one of the reason, that why young trees of Mahua is very less. Therefore complete ban on **collecting *Mahuwa* seeds inside the sanctuary area can be imposed.** Regeneration of Mahua plant is a must, in order to safeguard its roosting site, self re-growth from seeds is a necessary and required process.
9. **Nursery development**: Of the collected seeds fallen from the trees, especially *Mahuwa,* the saplings should be prepared. And further substituted in the lost plantation site.

10. Intensive increasing human population, their interference and encroachment in the sanctuary areas were disturbing squirrels native habitats. Many village sites were also observed, where good large sized Mahua tree were found, but the inter tree distance was more than 100 metre and that could be one of the major reason for absence of LBFS in these village sites. From the present study, it can be suggested that, Mahua (*M. longifolia*) dominated groves and thickets should be given priority for conservation and should be included in forest conservation plans of the sanctuary.
11. **To restore large trees with special reference to *Madhuca longifolia* or *indica*:** Since LBFS is more dependent upon Mahua and other large trees, so restoration, proper protection so that saplings grows profusely in the area, as a main theme of Conservation Plan.
12. A flying squirrel centric tree nursery should be developed. Plantation of these species should be done near the current identified locations, as well as in valleys to form a corridor network for dispersal of flying squirrels. The largest tree distance was noticed around 120 metre, there for young trees should be planted between these gaps and survival success rate needs to be increased for these augmented trees in the tree groves.
13. Tree augmentation should be done in such a manner that a mix tree grove can be created and inter tree distance needs to be maintained.
14. The flying squirrels have great site fidelity and proper attention needs to be given in the areas identified for their conservation. Their largest home range is about 2 km from the tree hollow, where they are roosting during day time. All such roosting trees should be given proper protection.
15. There was also one interesting observation from this study, 85% activities of Aarampura Guest House site flying squirrels (2 adults and 1 young too observed here) is restricted towards Sanctuary side. Though quite a few time they cross the road, glide and gnawed Mahua and *Terminalia* spp. tree across the road (Dhariyawad road),

but it seldom go beyond few tree from this road side. It is a shy animal and restricts its activities towards road side trees. Whenever people gather in large number for its sighting, the emergence time also showed delayed upto 12 min. and also swiftly it glides towards the tree groves inside sanctuary boundary. The traffic movement is also one of the causative factors for such behaviour. Highways generate biotic edge effects nearby vehicle road clearing, disturbance by vehicles including noise, headlights and vibration. Roads also fragmented forest habitats and restrict movements of animals. Often, mammals avoided the disturbed and surrounding altered habitats due to vehicles.

16. Good plantation and conservation of young trees of such 19 favorite trees should be protected in a form of corridors so that the clustered populations of *P. philippensis* can spread and occupy the newer area.
17. This is the only protected area in Rajasthan, where good population of Large Brown Flying Squirrel is found and breeding. The priority for conservation of this species should be in the management plan of sanctuary. Forest staff should be trained for year long observation and monitoring of this species along with other wildlife.
18. Year long conservation centric scientific studies on flying squirrels are necessary for preparing suitable layout and outline for conservation plan and sustainable improvement of the habitats in sanctuary. During the surveys, Authors felt that people were not much known about the flying squirrels because of its nocturnal and cryptic habits.
19. Forest Department should involve local youths from the villages (inside sanctuary villages) for training and awareness on wildlife of this area. These youths can be trained as Nature Guide and all tourist activities should be through these nature guide. These guides will be ears and eyes of sanctuary management and can also restrict the unlawful activities done by tourist as well as religious pilgrims of temples of sanctuary.

20. **Education and Awareness:** Awareness campaign should be driven to spread the economic, aesthetic and cultural benefits of the saving the Flying squirrel.
21. **Providing of alternate source of income:** As the tribes are dependent upon forest and its products directly and indirectly, schemes should be planned and implemented as per so that dependency upon forest products minimizes. For eg.,
    a. **Apiculture:** Honey bee rearing can be a good option for additional course of income. Since forest have great diversity of flowering trees, so bees can visit tress for pollen collection and that same honey can be marketed as "Pure Forest Honey" in market. So proper apiculture scheme can be developed around the village area to minimize the movement of tribal people inside the sanctuary.
    b. **Tourism development:** The entire Sitamata WL Sanctuary has great potential to be developed as eco-tourism destination. Such programs will boost the local economy, alternative income source of locals as well as employment opportunities for youths as Nature Guides.
    c. **Nature guide training program**: Selected youths can be properly trained and depending upon their interest they can be promoted for nature guide, trekker, off road driver for tourist vehicle as well as hospitality services at guest house.
22. **Bird watching**: South Rajasthan is one of the rich bird diversity areas, along with nearby wetlands and village ponds, sanctuary itself holds great diversity of birds, and hence it can be promoted as birding destination. Birding based tourist is yet to catch the pace in India and promotion in this line can be a good source of income for local youths. Otherwise they all are working as laborers or other less productive jobs in the nearby cities.

Conservation Strategies

Habitat Improvement

- *M. longifolia and T. tomentosa* dominant grooves should be given priority in conservation planning.
- Tall and mature trees should be protected from being cut for fuelwood and other requirements by the locals, if any cutting is observed inside sanctuary.
- A suitable amount of distance should be maintained, if plantation is done, between the trees for its gliding. Minimum is 10 metre and maximum upto 60 metre.
- Its feeding tree species should be planted more, especially, between the corridor areas (Valley area between two identified site) habitats so that a corridor could be maintained.
- Habitat loss and deforestation should be checked and prevented.

Monitoring of population

- Firstly, wherever the flying squirrel is known to occurs those habitats needs to be studied and population estimation must be done so that its status could be known whether the population is good or not. This should be done through proper dedicated and trained team of FD staff on regular basis.
- Proper monitoring of the population should be done so that the patchy breeding population could be connected.
- Though, it seems to be a stable population, but if the population is declining then captive breeding could be a good option so that later individuals could be released in the wild for reviving the population.

Strengthening and Enforcement of laws through forest staffs

- Forest field staff should be made aware about its presence and trained properly so that proper conservation measures could be taken.
- Strict law enforcement is required through staff capacity building, vigilance and patrolling.

Awareness

- Local people should be made aware regarding its role in the ecosystem.
- Locals living in and around the areas where flying squirrel is known to occur should be integrated in the conservation planning.
- Myths and taboos associated with the flying squirrel should be broken by interacting with the locals.
- Few Flying Squirrel centric conservation education projects should be started in the schools of this region. So that young generation can be inclined towards the role of these squirrels and the integrity of forest ecosystem well understood at young stage.

Scientific research

- Scanty literature is a proof of the work done on the species being less.
- More scientific studies on its spatial ecology, intra-interspecific interaction, population demography and reproductive behaviour is required.
- Genetic studies can be advantageous for studying the evolutionary significance of the species, as it is the western most distribution of this species world over.
- Wildlife conservation institutions, government and non-government organisations and other stakeholders should work together for its conservation.

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Occasionally it can be seen feeing during day times in less disturbed forest patch. An adult Large Brown Flying Squirrel is feeding on fruits of *Ficus* tree in Sanctuary.

Photo Credit: Gopi Krishnamurthy

Flying from one tree to another during day time.

Photo Credit : Gopi Krishnamurthy

Some vigilant or alert behaviour photos of Large Brown Flying Squirrel in Sanctuary




Fresh leaves and buds gnawed by Large Brown Flying Squirrel in Summer Season