International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 • Website: www.ijfmr.com • Email: editor@ijfmr.com

Ecological Activities and Gliding Behavior and Conservation Strategies of Flying Squirrels in Sitamata Sanctuary

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ABSTRACT

Research on the Indian Giant Flying Squirrel (Petaurista philippensis) in the Sitamata Wildlife Sanctuary in Rajasthan shows that, although this species is classified as "Least Concern" globally, it is facing local threats. The squirrels rely heavily on the deciduous forests of the sanctuary, especially the Madhuca longifolia (Mahua) tree, for both food and shelter. Studies by Koli et al. reveal that these squirrels are nocturnal and tree-dwelling, and to escape the intense summer heat, they sleep in tree cavities during the day. They also occasionally bask in the sun during winter. Ecological Activities Feeding Habits. The squirrels mainly eat plants, and their diet consists mostly of the pith of the Madhuca longifolia tree, which forms 31-78% of their yearly food intake. they also eat the bark, flowers, fruits, and buds of over 20 plant species such as Terminalia bellirica and Diospyros melanoxylon.

Activity Budget: Research shows they are most active during the early part of the night, particularly between 7:30 PM and 11:30 PM, and have a second smaller activity peak later at night.

About 45.85% of their time is spent resting. Habitat Selection These squirrels prefer areas with tall, old, and thick tree cover, especially those with large trees that have hollows in the mid-canopy for nesting.

Reproduction: Breeding takes place in tree hollows, usually starting in early summer, from January to February. Gliding Behavior

Gliding Mechanics: The squirrels glide between trees using a skin membrane called a patagium. They prefer short glides rather than long ones to move through their habitat. Glide Parameters Observations of 1,203 glides show an average glide ratio of 2.32, which is higher than some other species but lower than others. The average horizontal distance covered during glides was 16.28 meters, while the air distance was 20.08 meters. Seasonal Variation: Gliding activity is more frequent in the summer, which might be linked to increased foraging and breeding activities.These people keep the bones, hair, and Skeletons of dead squirrels in their homes. Some even cut the bones into pieces and tie them around the necks of weak children to increase their weight. The flying squirrel has also been greatly affected by highways running through the forest. For the survival and protection of this species in Rajasthan, efforts should be made to stop the cutting of Mahua, Bahera and Kadamba trees. Sita Mata Sanctuary was once considered for relocating some lions, but the availability of prey was considered too low. Also, the area was too close to humans. The sanctuary also has ancient places like the Valmiki Ashram (the birthplace of Luv and Kush, the twin sons of Sita and Lord Rama), the Hanuman and Sitamata temples, and other sites of historical and mythical importance. Another interesting place in the sanctuary, 5 km from Tikhi Magri, is Lakhiya Bhata, where drawings of prehistoric animals are carved on rocks. A fair is held at the

Sita Mata temple in the sanctuary every July. the Aravalli hills as our jeep drove along a narrow dirt road toward the Sita Mata Wildlife Sanctuary.

Habitat Protection: The survival of the species depends on protecting old Mahua trees, as they are vital for food and shelter. Mitigation of Threats: The population is declining due to habitat loss caused by logging, road construction, and agricultural expansion.

Community Involvement: Educating local tribal communities, such as the Bhils, about the ecological role of the species is important to reduce hunting, as they sometimes use the squirrel's bones or hair for traditional medicine. Population Management: Creating habitat corridors between isolated and scattered populations inside the sanctuary has been suggested as a way to improve their chances of survival. in Sitamata the Indian Giant Flying Squirrel is mostly found in dense forest areas like the Arampura forest within the sanctuary.

However, they are facing challenges due to increasing human settlements, road construction (such as NH 76), and, notably, local hunting, which has led to their disappearance from certain regions.

Keywords: Flying squirrels, biomechanics gliding, jumping, Glaucomys sabrinus, kinetics, substrate reaction forces

INTRODUCTION

Sitamata is an unexplored wildlife sanctuary located in the Kanthal region, covered with teak forests. It lies at the meeting point of three distinct landforms: the Aravalli, Vindhya, and Malwa regions. This area in arid Rajasthan is known for its lush green valleys, rivers, and special wildlife. Kanthal Pradesh, which was once known for the natural beauty and lifestyle of the Vagad, Mewar, and Malwa regions, is now called Pratapgarh. It forms the north-western edge of the teak forests on the Malwa plateau, between the Aravalli and Vindhyan mountain ranges. This area is unique and has a lot of different plant and animal life.

Considering the importance of the biodiversity and the land structure of the forest area, which is 422.95 square kilometers, the Rajasthan government established Sitamata Wildlife Sanctuary on 2 January 1979. Sitamata Wildlife Sanctuar is located at an average height of 280 to 600 meters above sea level The sanctuary includes the “Bhenwa Shikargah,” a hunting ground used by the Maharaja of Pratapgarh. Similarly, the Arampura-Kuntharia area was used by the jagirdars of Dhariyavad for hunting, while the Ranigarh-Dhar forest area was used by the jagirdars of Bansi .in the past, the areahad a lot of wildlife, including tigers, sambar, and chital.

Fig.1 Flying Squirrel

However, their number dropped sharply, and tigers eventually became extinct. Even today, the sanctuary is famous for its rich variety of habitats. These include teak forests, wetlands, rivers, gentle hills, deep valleys, and mixed teak forests. The Indian Giant Flying Squirrel, also known as the Large Brown Flying Squirrel (Petaurista philippensis), is the biggest type of squirrel. It is a bit bigger and heavier than the giant squirrel. Petaurista is a group of big flying squirrels that are active at night. This group has more than 18 different types and lives in forests found in low areas and high mountains up to 4,000 meters in elevation across Asia, from Pakistan and Kashmir all the way to East and Southeast Asia.

People know very little about these squirrels because they are active at night and are hard to spot, and also because it is difficult to collect scientific data on them. Squirrels can be identified by their slender body, long tail, and their habit of living in trees. Some of them have the ability to glide, which is why they are often called "flying squirrels".

the name Sitamata come from a belief in the Ramayana.It is said that when Sita was exiled, she lived in the ashram of sage Valmiki located in this forest. It is believed that she gave birth to Luv and Kush here. Today, the remains of a large banyan tree can still be seen near the Valmiki Ashram, once covering an area of 12 bighas. The local priest mentions that Luv and Kush captured horses for the Ashwamedha yajna here and challenged Ram for a war. It is also believed that the tree where Hanuman was tied is still present. There is a Sita temple on the hill, representing the belief that when Sita entered the earth, the mountain split into two. This place has been considered sacred for a long time, and a festival is held every year on the 'Amavasya of Jyeshtha month' at the Sita Bari temple. People still swing the Luv-Kush cradle in the Valmiki Ashram. The Sita Bari temple is unique in the world as it houses a single statue of Sita Mata. Due to the presence of many mythological sites, the area is called Sitamata Wildlife Sanctuary.

A rock drawing can be found in the forest of Gasitamata. the forests in Sitamata Wildlife Sanctuary are divided into five main types: dense dry deciduous forest, sparse dry deciduous forest, moist deciduous forest, bamboo mixed forest, and grasslands. the presence of perennial rivers along with the surrounding vegetation creates various micro and macro habitats within the sanctuary. Flying squirrels are often seen moving from one Mahua tree to another as the sun sets in the Arampura forest. They rest during the day inside hollows of trees. The best time to spot them is between February and March when the trees have lost their leaves, making it harder for them to hide. the Indian Giant Flying Squirrel can be seen peeking out of a tree cavity. the Chowsingha is found in the Panchguda, Adyghata, Ambarethi, and Pal Forest areas of Sitamata.

These regions have dense bamboo thickets, which provide good cover for the Chowsingha. The animal can hide behind these bushes when threatened. Besides the flying squirrel, two other types of squirrels are present in the sanctuary: the Indian Palm Squirrel and the Five-striped Squirrel. The Indian Palm Squirrel is common in the dense forests of the sanctuary. Among the reptiles, crocodiles, tree frogs, painted frogs, burrowing frogs, tree snakes, and green keelbacks can be seen. It is a popular place in Rajasthan to see flying squirrels. This area is covered with large Mahua, teak, and various tall trees, making it ideal for spotting flying squirrels from 7 pm to 5:30 am. The area receives an average annual rainfall of 756 mm. The temperature in the sanctuary fluctuates between 6 to 14 degrees Celsius in the winter and 32 to 45 degrees Celsius in the summer. Although these squirrels are commonly found in the forests of India, where there are large trees and deciduous forests, the presence of the flying squirrel in Rajasthan, far from the typical geographical areas, is actually quite special.

Fig. Flying squirrel's night view

It is a brown-colored species that is skilled at gliding between branches. It can be seen in the forests of southern Rajasthan. It leaves its tree at evening and stays active on the trees until dawn. Out of the 15 species of flying squirrels found in India, only this one is found in Rajasthan. The length of this squirrel is more than 1 meter (approximately 104 cm), with the tail being longer than 50 cm. Its weight ranges between 1 and 2.5 kg. The upper body of adult squirrels is grizzled brown or claret brown with some light white patches. Its parachute-like membrane and front arms are brown. The lower part is light white. Its face is brown and blackish, and its thick tail is longer than the body, ending in black. The color of its feet is black, and there are slight color changes as the squirrel. It can glide smoothly through the branches of trees like banyan, kadamba, and Mahua. this flexible part of the body helps it save energy while moving and also helps it avoid predators while searching for food without getting tired. It increases the distance of its glide by pushing back. When it dives, the membrane attached to its hands and legs opens, helping it change direction. During descent, it first holds the main trunk of the tree with its front hands and then uses its hind hands for support. Its sharp claws help in climbing down and holding on. It generally moves on a fixed path. It can glide up to a maximum of 90 meters, but usually does so for only 10 to 20 meters. It does not move during the rain.

Fig. Sitamata Natural Places

Diet The squirrel's diet includes stems, twigs, leaves, buds, flowers, fruits, and seeds. The pith is the main part of its diet. Mahua, Bahera (Terminalia bellirica), Terminalia tomentosa, and Timru (Diospyros melanoxylon) are some of its preferred food sources. this species is nocturnal and leaves its nest after 7 in the evening and returns by 6 in the morning. During winter, it can be seen basking in the sun near its burrow during the day. Its maximum activity is between 6 to 11 pm and 2 to 6 am. When light falls on it, it stays still. At night, it communicates with other squirrels through sounds. During the breeding season, it forms pairs through vocal communication. Their calls can be heard most at midnight or early in the morning before they move into Kotor. To avoid predators, it makes sounds while sitting in dense trees. Their voices are easy to hear in the morning. The time before summer is when they breed. Though this species is listed as endangered in the IUCN Red Data Book, their numbers are slowly going down in western Rajasthan. Hunting by tribal groups, growing cities, and cutting down forests for industry are major threats to their future. Bhil and Garasia tribes hunt them for food, customs, and beliefs.

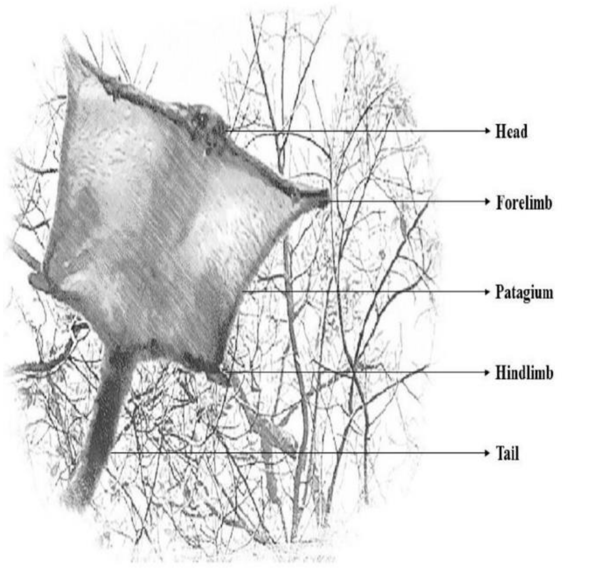
The temple stands as a remarkable testament to India's rich spiritual heritage and architectural legacy. This 1,500-year-old shrine continues to draw pilgrims and history enthusiasts alike, not just for its religious significance but also as a stunning example of early medieval temple architecture in Rajasthan. The temple's ancient water (scared kund) reservoir is believed to have healed properties, adding to the site's mystical charm. Pilgrims often perform rituals here before entering the main shrine. Sitamata Sanctuary is often referred to as the sacred grove of Rajasthan due to its special connection with the Matasita religious belief and its home to unique wild animals such as the flying squirrel and the chowsingha. usually seen as a dry state, is home to a variety of wildlife and vegetation. its feeding is done at night and it hides in a hollow of a Mahua tree during the day. The best time to spot flying squirrels is between February and March, when most Mahua trees shed their leaves and it's easier to see them gliding between the branches of leafless trees.

II: REVIEW OF LETURATURE

The Flying squirrel’s hair on the back starts as smoke gray at the base, then turns seal brown, and finally becomes white with black tips. The cheeks are gray, and the ears have an orange rufous color on the lower half. The lower lip is black, the eyes are black and round, and the whiskers are prominent and dark. The front legs have three toes and two similar-sized metacarpal pads, while the hind legs have four toe pads, a large metatarsal pad, and a small supplementary pad behind the outer toe pad. The tail is thick and longer than the body. The tail is either seal brown, light gray, or dark gray, with black tips. Female flying squirrels have six mammae, two on the chest and four on the belly changes color as it ages. When young, the tail and feet are jet black, and there is a black band across the shoulders. The underside is white or light gray. As it grows older, the gray markings on the body become larger until the entire body is black. During the monsoon season, the fur gets thicker, but it becomes loose during the dry season.

Biology

flying squirrel mostly active at night, spending the day sleeping in tree holes and coming out in the evening. Because the temperature in tropical forests changes a lot throughout the year, their behavior also changes with the seasons. In summer, they sleep on their backs during the day, away from their hiding places, to avoid the heat. In winter, they bask in the sun to stay warm. These animals usually use tall trees for gliding and feeding, and they prefer the mid-level of the forest canopy. In both wet and dry forests, Kumara and Singh found that P. philippensis commonly uses trees between 16 to 20 meters tall. Nandini saw them mostly on trees that were about 22.59 meters tall. The main nesting tree species in southern Rajasthan is M. longifolia. Once, Hutton found a P. philippensis nest lined with grass, moss, and fur. Gliding is observed when they jump from tree tops to lower places using their patagium. Their tail helps them steer and also helps with balance during gliding recorded the average gliding ratio as 2.32, ground speed of 6.96 meters per second, air speed of 7.51 meters per second, and gliding angle of 25.53 degrees. These animals mostly prefer short glides, between 11 and 20 meters, rather than long ones. However, Blanford recorded a glide of up to 73 meters. Gliding is always done from tree tops to lower heights using the patagium. Gliding activity is highest in the summer compared to the monsoon and winter seasons. The most active time for gliding is during the early night, between 7:30 PM and 11:30 PM. there is a full plan in place to help protect the Fig. Different body parts of Indian Giant Flying Squirrel or Large Brown Flying Squirrel flying squirrels in the Sita Mata Sanctuary.



Picture credits: Gopi Ramakrishnan

Breeding There is not much information on the reproductive biology of P. philippensis. many observations suggest that breeding occurs during early summer. Mating takes place in January and February a dead specimen with fully developed embryos in March or April. Breeding happens in tree holes. After the young are born, the mother and her babies occupy the nest hole alone. a baby flying squirrel that was blind and only about a foot long. Its head was much bigger than the rest of its body. The tail was flat and about five inches long. The patagium was not fully developed, ending at the elbow, not the wrists.

Fig.Sitamata Natural Road for Tracking

Threats

Globally, P. philippensis is considered to be of Least Concern, but recent studies show that in India, its population is declining. this is due to habitat destruction, degradation, cutting down trees, shifting

agriculture, forest fires, increasing human populations, accidental deaths from vehicle collisions, human disturbances, agricultural encroachment, and monoculture plantations. The construction of national highways, myths, and hunting also pose threats. People hunt them for local use, medicinal purposes, and cultural or traditional beliefs predicted that P. philippensis has already lost about 20% of its habitat over the past 20 years, and similar losses are expected in the next 20 years due to these reasons.
This is part of a4 month survey aimed at estimating the population of the Large Brown Flying Squirrel, understanding its behavior, and suggesting ways to help it survive long-term in Sitamata Wildlife Sanctuary.The main goals of this survey are to all identify the areas where the flying squirrel lives in the sanctuary. to conduct a detailed count of the population to study how the squirrels interact with the plants, trees, shrubs, and the land and weather, along with photos to support these findings to record the behavior of the flying squirrel to produce clear evidence and a map showing where the squirrels are found to suggest ways to protect this species and ensure survival.

III: Methodology

By measuring take-off and landing forces, we aim to quantify the advantages they gain from their unique body structure. The results will be influenced by the compliance of the surface. Previous studies used rigid force measuring devices, while others explored the effects of surface compliance. Demes et al. found that when using compliant apparatus, take-off forces were higher than landing forces in seven primate species, which contradicted earlier studies that used rigid platforms. Some of the take-off force is used to bend the flexible branch before the jump, whereas the reaction force on landing is reduced as allowing more time for deceleration. Bonser also showed that the landing forces for starlings were lower than their take-off forces, suggesting that the birds use their wings to slow down during landing, and that additional energy is used to bend the compliant perch during take-off.
Generate higher take-off forces when jumping from narrow and flexible branches, and they face their highest impact forces when landing on rigid tree trunks. made compliant, so we expect take-off forces to be higher than landing ones over short distances. At greater distances, the squirrels will be affected by gravity, and their landing force will likely increase unless they use their body shape to slow down aerodynamically. Therefore, if landing forces continue to increase at long distances, our hypothesis that gliding evolved primarily to enable control of landing speed can be rejected However, primates do not seem to take advantage of this, supporting the idea that they do not intentionally recover this energy. Therefore, we do not expect flying squirrels to benefit from the rebound of our instrumented branch either. However, they have been observed using a bounding gait before launching with both fore- and hind-feet together at the end of a platform before taking off. This movement is probably used to increase take-off speed and thus achieve a longer glide. The northern flying squirrel, Glaucomys sabrinus, is the larger of the two species found in North America, although still much smaller than some species found in Southeast Asia. Flight is made possible by the presence of patagia, a characteristic that has evolved independently in multiple animal groups, with the earliest known example dating back to the Mesozoic era.
Flying squirrels can actively change the shape of their lift-generating surface by moving their limbs during flight. The body structure of flying squirrels was compared with that of tree squirrels to see what physical changes are linked to their ability to glide (Thorington and Heaney, 1981). Longer legs allow more energy to be used when taking off, giving them a better horizontal range. Compared to other squirrels of similar size, flying squirrels have much longer forelimbs, a feature that almost certainly

helped them become more aerodynamic while gliding. This is further enhanced by the styliform cartilage, a flexible part of the wrist that extends upward, forming part of the lift surface during flight. It works with the manus, or hand, which points downward towards the squirrel's body, creating a wing tip similar to a winglet designed by NASA. This structure helps reduce induced drag by spreading and guiding vortices away from the patagia. Smaller flying squirrels are generally more maneuverable and agile, while larger ones must glide faster to achieve the same glide ratio.

Materials and methods

All the animals were born in the same week and were around 27 months old. The body mass, wing span, and wing area of each animal are listed in Table. Other squirrels from the colony were used for different studies and were not available. The colony has been kept for five years on a diet that includes pecans, walnuts, sunflower seeds, mushrooms, and birdseed. They live in a large, temperature-controlled room (20°C) with a 12-
hour light and 12-hour dark cycle.

There are plenty of branches and enough space for the animals to jump and glide. At first, measurements were taken in the squirrel lab, but longer glides were measured in a barn on the university farm that is 7 meters by 14 meters by 7 meters.

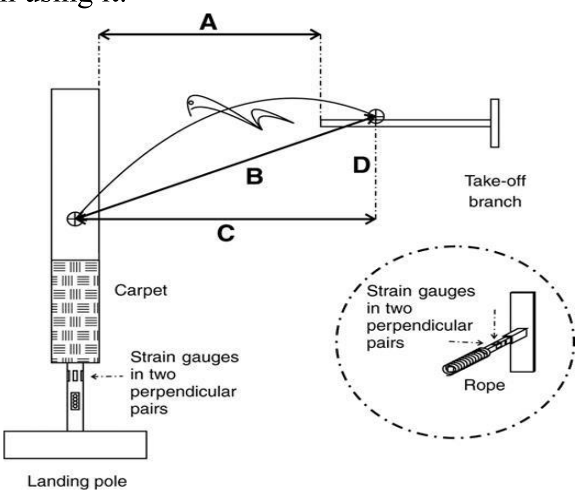
					Take-off force (bw)			Landing force (bw)
Squirrel ID	Wing span (cm)	Wing area (cm^2)	Leap distance (m)	Mass on day of testing	Count	Mean ± s.d.	Count	Mean ± s.d.
YF1	28.0	511	0.5	272 g	9	3.70±1.99	-	-
			1	274 g	6	4.64±1.17	6	3.47±0.37
			1.5	267 g	10	4.36±1.64	10	4.88±0.35
			2	256.5*	7	5.57±1.53	7	7.58±0.96
			2.5	256.5*	5	5.91±1.49	5	6.16±0.54
YF2	27.5	500	0.5	200	8	2.56±1.28	-	-
			1	201	10	5.21±2.47	10	3.56±0.30
			1.5	198	11	3.30±1.70	11	4.28±0.21
YM	25.9	554	0.5	259	9	3.38±0.96	-	-
			1	260	4	6.97±1.23	4	3.79±0.44

Table . Summary table of all the measured forces generated by northern flying squirrels during leaping and landing YF stands for young female, YM for young male, and bw means body weight. There were

79 take-offs, but only 53 landings because data for the shortest jumps of 0.5 meters wasn't collected. Only one squirrel, YF1, used the barn setup, but it wouldn't land on the force pole when the distance was more than 2.5 meters. Unfortunately, due to reasons outside our control, YF2 only cooperated at 0.5, 1, and 1.5 meters, while YM only cooperated at 0.5 and 1 meters.

Squirrels seemed to lose a lot of weight before the tests at these distances. The reason for this weight loss isn't clear, but it might be because the testing environment was very hot and humid inside the barn, compared to the temperature-controlled lab. Apparatus Flying squirrels typically land on tree trunks, which allows for different contact points, so we used a vertical landing pole based on the. the squirrels were used to this pole for several months before the experiments and used it regularly. The pole was made of two parts: a 1.52-meter-long PVC tube (114 mm in diameter) covered with carpet and marked every 10 cm (for calibration and image analysis), attached 80 cm up a 2.41-meter-long galvanized steel tube (23 mm in diameter). The steel tube was fixed to a concrete base, and had four strain gauges (FLA-2-11-3L, TML, Tokyo, Japan) equally spaced around its circumference and aligned vertically. A half-bridge circuit was used for each tension/compression pair to measure forces in both directions relative to the squirrel's movement. The pole was found to be compliant, with a compliance of 1.5 mm per Newton at the free end, which decreased gradually down to 0.2 mm per Newton near the fixed end, and the resonant frequency was 2.2 Hz.for the take-off branch, we designed a horizontal cantilevered beam to mimic a tree branch, as northern flying squirrels usually launch from a crouched, horizontal position.

Four standard linear strain gauges were placed in two pairs, 50 mm from the fixed end of a 10 mm square aluminum bar. These were connected in a half-bridge circuit. Alignment was easier because the gauge width was almost the same as the 10 mm width of the aluminum bar, though it wasn't critical as any cross-talk was eliminated during calibration. The aluminum branch was covered with tightly wound rope to simulate the surface of a tree branch. The strain gauges were protected using polystyrene foam, covered with plastic. A 4 cm x 9 cm timber block was fixed vertically on the wall and had mounting holes every 10 cm to allow height adjustments for the launch branch. The design ensured the compliance was similar to the landing pole measured at 1.9 mm per Newton at the free end and decreasing to almost 0 mm per Newton at the fixed end. The resonant frequency of the take-off branch was 17.3 Hz. The signals from the strain gauges on both devices were amplified using AD524 chips or equivalent, and the sampling rate was 250 Hz. No acclimation was needed for the take-off pole since, unlike the landing pole, squirrels had no choice in using it.



It includes the tools used to measure the forces when squirrels take off and land. There's a pole covered with carpet for landing, a branch wrapped in rope for take-off, and the positions of the strain gauges on each. It also shows the measurements made to analyze the results, compared to the path a squirrel might take. (A) The fixed horizontal distance between the end of the take-off branch and the vertical landing pole. (B) The total distance covered during the glide, calculated from the exact horizontal distance (C) and the drop (D).

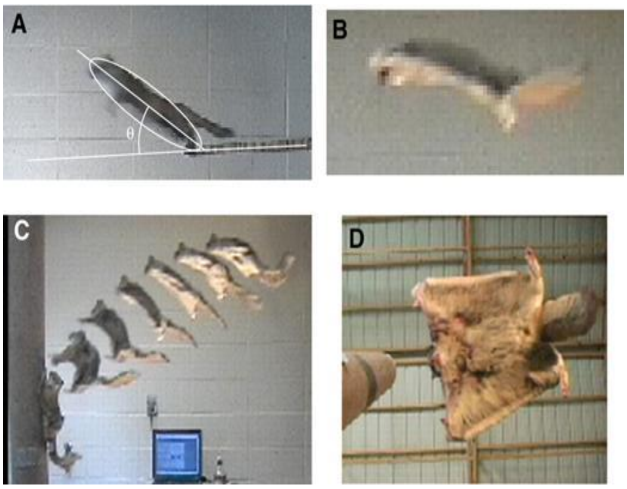
Experimental design

The take off branch was adjusted as the experiment progressed so that the angle between the tip of the branch and the base of the landing pole stayed roughly the same, about 55 degrees. This was done because it wasn't possible with the equipment we had to set up short jumps at high altitudes, and the squirrels couldn't reach the landing pole unless they had enough starting height. Each animal was released one at a time on the instrumented branch and started running, usually stopping and then jumping to the instrumented landing pole. The horizontal distance was increased step by step, starting from 0.5 meters, to find the point where the leap-to-glide change happens. Below this point, squirrels just leap around, but above it, flying squirrels get an aerodynamic advantage. It was thought that studying this range of tree-dwelling movement would be more important for understanding how flying squirrels first started to differ from other squirrels.

there digital video cameras were used to record the jumps. One camera was placed to capture the take-off angle, another to capture the landing angle from the side, and the third to get a view from below of the landing. In the large squirrel barn, it wasn't possible to place a camera level with the take-off branch, so the images taken were from angles that were not perfectly horizontal. A small amount of trigonometric correction was needed to adjust the vertical distances measured from the take-off footage. Calibration Since strain gauges can be affected by changes in the environment, temperature was recorded using two I-buttons (Maxim Integrated Products, Sunnyvale, CA, USA), fixed to the top and bottom of the 4 cm by 9 cm wooden board. This recorded temperature every hour this daily check of the calibration was especially important because testing was done in two different environments: a temperature-controlled lab and a hot, humid metal barn. only the landing forces were measured by turning the strain gauge outputs into force measurements. A static calibration was done daily by applying forces to different points on the pole. Steady signals were used to create calibration graphs that helped determine the force constant, k, where $F = kx$; F is the force in newtons and x is the measured strain signal in volts. Forces between 1 and 10 times the squirrel's body weight were applied, resulting in good linearity across the full range of the pole. (On average, the square of the Pearson product moment correlation coefficient was 1.00 along the line and 0.99 across the expected direction of motion.) The position of the animal on the instrumented poles was taken into account, and a linear equation was used to apply the correct calibration at any point. The cross-talk from the strain gauges was 13% and 17% for parallel and transverse forces, respectively. Cross-talk here means the unwanted signal measured by one pair of strain gauges when a force is applied at a different angle. The equipment had a good enough frequency response to capture the quick movements of the squirrels. The effect of temperature on the calibration wasn't significant, as even though it varied greatly between the two test areas, the calibration graphs remained consistent through out the study. Results processing Even though both the take- off branch and the landing pole could measure forces in two directions, neither could measure forces along their length.

To solve this, video footage from the side cameras was used to determine the angle at which forces were applied, allowing the force vector to be calculated in 3D from the two measured components. This method was acceptable for landing forces because the squirrels landed at angles that were almost perpendicular to the pole. For the middle data point at a range of 1.5 meters, a trigonometric calculation showed that a 5-degree change in the landing angle would cause a 10% change in the resulting force. During take-off, the squirrels were consistent in their behavior, always moving toward the free end of the branch and jumping in the same direction. However, the shallow take-off angles mean that a 5-degree measurement error leads to a significant 39% change in the median resulting force at 1.5 meters. Therefore, resultant take-off forces had to be calculated by integrating the strain gauge outputs over time, so that the measured take-off velocity could be used to determine the acceleration. This acceleration was then multiplied by the known mass of each flying squirrel to calculate the resulting force. The frame rate of the side take-off camera was 30 frames per second, allowing an estimate of velocity between the first two frames after the foot left the branch by measuring the change in the center of mass position. The resultant force calculated this way is the total force needed to accelerate the squirrel to its actual take-off velocity, based on its known acceleration profile. This method doesn't account for losses from deforming the branch but is completely independent of the accuracy of the take-off angle measurement. the video recordings were converted into digital format using edge-detection software, which followed the shape of the squirrel in each image from a camera positioned to the side (LabView – National Instruments, Austin, TX, USA). The tail was not included in this shape, as it makes up a small part of the squirrel's total weight and often lies flat and moves quickly outside the image plane. The center of the area inside the squirrel's side shape was used as a rough estimate of its center of mass. This center could be followed from one image to the next, allowing both where the squirrel landed on the pole and the angle at which it hit to be determined. This made it possible to calculate the reaction force for each landing squirrel.

To find the take-off angle of the squirrel, principal components analysis was used in the LabView tracking program to find the best-fitting ellipse around the squirrel's shape in each image. the take off was angle then calculated as the angle between the longest axis of this ellipse and the branch in the last image before the squirrel left the branch. This same program was also used to estimate changes in pitch during the landing movement shown in Fig. 2C. A separate program was created in NI Labview to measure the wing span and wing area of each squirrel from images taken from below during a glide. Side images were used together with these to make sure only the frames where the squirrel was aligned with a calibration bar were used for the measurements.



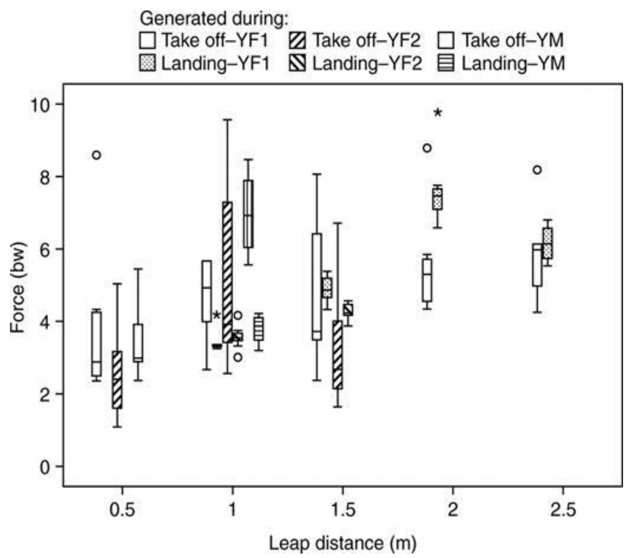
Video stills showing the squirrels in different postures they were observed.

(A) The forelimbs moving outwards before the hindlimbs leave the branch during take-off, and how the take-off angle, Î¸, is calculated as the angle between the branch and the main body shape of the squirrel (excluding the tail). (B) Normal gliding flight, (C) landing from the side, and (D) a front view of landing on the pole on the left. In C, the last few frames of a landing sequence are combined into one image to show the landing behavior, but the second-to-last frame was removed for clarity. In this short jump of 1 meter, the squirrel first moves upwards and flattens its body and tail against the direction it is moving. Just before landing, the head tilts back while the limbs are all moved forward and the tail is turned back to be parallel with the ground.

A calculation was done to find out how much of the squirrel's body weight was supported during each glide, compared to a ballistic trajectory (the path an object would take with the same speed and angle, but without any drag or lift). In a simple free fall, gravity pulls down, but any lift force works against that. The total force acting on the body is: where Mb is mass (kg), a is the resulting acceleration (m sâ"2), g is the acceleration due to gravity (9.814 m sâ"2), and L is the lift force (N). The percentage of body weight supported is simply the lift force divided by the animal's weight. Measured take-off angle, Î¸, velocity, v (m sâ"1), and jump duration, t (s), are enough to calculate the vertical drop, y (m), using the standard kinematic equation below:

2.Therefore, by combining equation 1 and equation 2, we get an expression for the overall lift force during the glide:

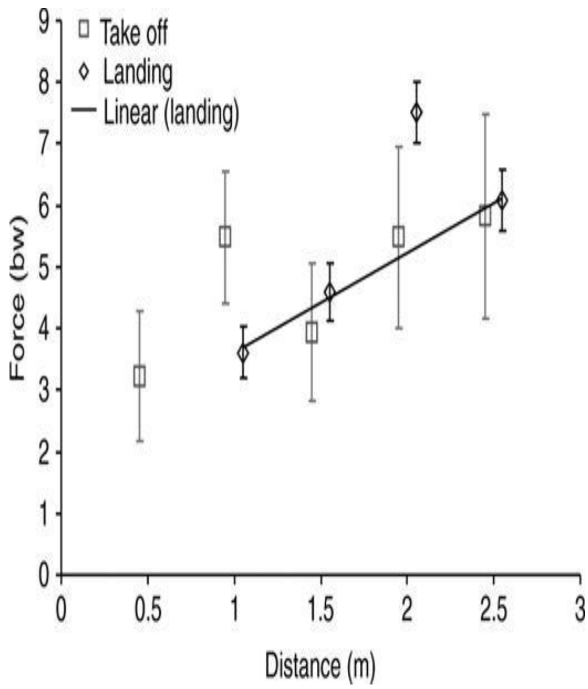
3.Jumps observed, general mixed model, and other statistics



A box plot compares the landing forces with the take-off forces for three flying squirrels two young females (YF1 and YF2) and one young male (YM) at each horizontal distance, from the end of the take-off branch to the landing pole. Asterisks and circles represent values that fall outside the interquartile range, with asterisks indicating those that are statistically far away. A summary of the take-off and landing forces, expressed as a multiple of body weight, is provided in Table there was a lot of variation in both take-off and landing forces for each squirrel at each distance. Take-off forces, when adjusted for body weight, increased significantly with the leap distance (Fig. 3; r=0.323, P=0.004). The same box plot also shows a strong positive link between landing forces and horizontal distance (r=0.816,

International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

$P<0.001$). the general mixed model confirms that normalised take-off forces were significantly affected by the distance ($F_{5,11.5}=45.182$, $P<0.001$), but not by the identity of the squirrel ($P=0.602$).
A paired sample t-test comparing landing force with its corresponding take-off force for each jump was not significant ($t_{51}=0.374$, $P=0.710$). The standard deviations of the mean forces for each animal at each distance are listed in Table 1. The standard deviation in take-off forces at each range is greater than that for landing forces. Excluding the 0.5 m range, where there is no landing force data, the standard deviation in take-off force ranges from 1.37 to 6.10 body weights, compared to only 0.04 to 0.92 body weights for landing forces.



A graph showing the output from the mixed model statistics of mean take-off and landing forces at each horizontal range. The error bars show the 95%confidence intervals. When a few jumps at 2 meters are ignored, and the squirrel consistently lands on the more rigid part of the pole, the square of the Pearson product moment correlation coefficient (the r^2 value) increases from 0.61 to 0.99.
Landing force is positively correlated with the angle of descent ($r = 0.740$, $P < 0.001$). Allstrain gauge outputs were recorded at the same time, allowing the duration of each glide to be measured.
we recorded 79 take-offs and 53 corresponding landings, and the number of jumps each animal did at each distance is in Table. No landing force data were collected for the shortest jumps of 0.5 meters, but other than that, all take-off forces had a matching landing force. Only one squirrel, a young female, performed in the barn but she didn't jump to the force pole from distances greater than 2.5 meters, landing instead on the ground beyond the instrumented pole. This was the only animal that participated in all the tested distances. Unfortunately, a second young female only cooperated at 0.5, 1, and 1.5 meters, and the young male only at 0.5 and 1 meters. Because of the missing data points, we couldn't use the typical multivariate ANOVA, so we used a general mixed model (Krueger and Tian, 2004) for both take-off and landing forces, with distance as a fixed factor and squirrel ID as a random factor. Unless stated otherwise, all correlation statistics use Pearson's product moment correlation.

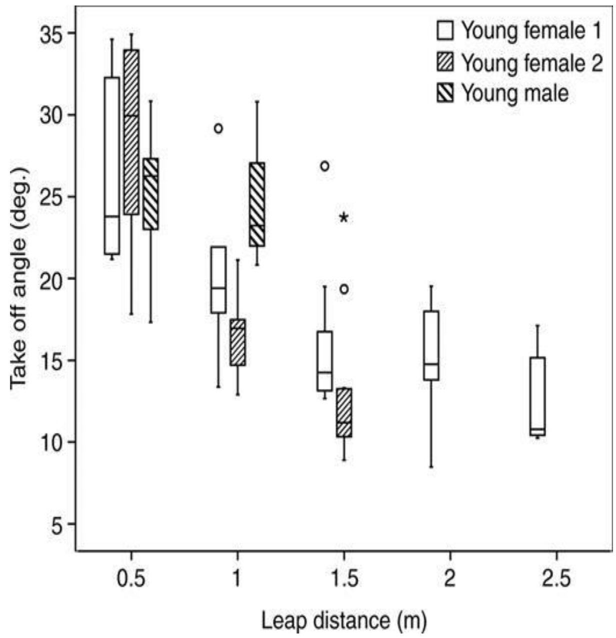
The still image from side camera shows the consistent take-off, gliding, and landing postures of the squirrels (Fig.) during take-offs, the forelimbs were moved out before the feet left the ground, allowing the squirrel to quickly assume the gliding position. During gliding, all limbs were raised, forming a curved wing shape held at a small positive angle of attack. The tail was flat on the back, likely to create lift. Before landing, the squirrel tilted upwards, keeping the body and tail aligned and flat against the direction of motion. Just before landing, the head tilted back while the limbs moved forward and the tail turned back to be parallel with the ground. In the example landing sequence (Fig. 2C), the body's pitch angle changed from about 22.5 degrees relative to the horizontal to 90 degrees just before landing. In the barn, the squirrels had a steeper approach and didn't pitch up much before landing. The head still tilted back, but the tail was turned for ward toward the vertical.

As a result of the lower angle of attack, the front limbs hit the pole first, causing the body to rotate quickly onto the hind limbs due to the change from linear to angular motion. Occasionally, the tail was curved so that the inside of the curve faced the landing pole. In some jumps, the squirrels clearly banked or turned in the second-to-last frames to adjust for misalignment with the pole, and in one case, a subject landed on the side of the pole. Since it was simple to calculate the forces for these jumps as well, these results were also included in our analysis Landing forces were also dependent on distance ($F_{4,9.5}$=409.341, $P<0.001$), but not on the specific squirrel ($P=0.548$). The means and 95% confidence intervals from this model are shown in Fig. 4. All landing and take-off forces were not related to one another ($r=0.094$, $P=0.507$).

There is a strong positive correlation ($r = 0.923$, $P < 0.001$) between glide distance and glide duration. The mean glide velocity, calculated based on the straight-line distance from take-off to landing, and not the actual path, is strongly positively correlated ($r = 0.951$, $P < 0.001$) with the horizontal range. This speed reached 4.5 meters per second over a horizontal range of 2.5 meters. the average take-off angle for each squirrel at each distance is negatively correlated with the range ($r = -0.684$, $P < 0.001$) (Fig. 5). shows the percentage of body weight supported by lift during gliding as a function of horizontal range.

The average value for each squirrel at each range is plotted against the horizontal range, with error bars showing plus and minus one standard deviation. At ranges of 1.5 meters and above, the squirrel was able to support approximately 40% of its weight through gliding, but not when jumping shorter distances. The advantage gained from gliding increases with range ($r = 0.609$, $P < 0.001$). Landing force was found to be significantly correlated with the impact position on the pole ($r = -0.713$, $P < 0.001$). Glide angles increased sharply with horizontal range until they reached about 45 degrees beyond 2.5 meters (Fig. 7), the angle that distinguishes gliding from parachuting.

After this point, glide angles gradually decreased, as indicated by a strong negative correlation between the 17 longest jumps ($r = -0.816$, $P < 0.001$). At this point, only one animal was still performing, but it did not land on the pole. Instead, it glided past the pole and landed on the floor

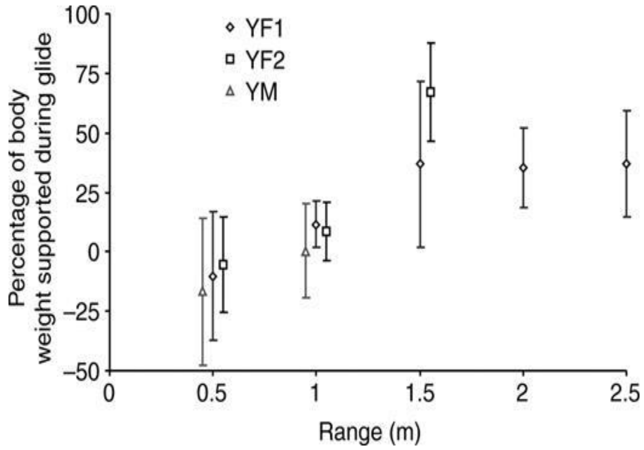


The average take-off angle for each individual flying squirrel based on the horizontal distance they travelled during a jump (labelled C in Fig. 3). This suggests that the squirrels are thinking ahead, which may mean they are considering where they will land. Asterisk and circles, see Fig. Discussion in this study, we measured the take-off and landing forces of northern flying squirrels as they moved between different surfaces.

We also carried out a detailed analysis of videos of their movements. To our knowledge, no such data has been published before, and we believe our results offer a better understanding of how gliding has evolved in these animals. We connect our observations, where possible, to the following four hypotheses explaining why flying squirrels have diverged from other tree squirrels: (1) to make foraging less energy-intensive; (2) to cover more area in a given time without considering the effort of moving; (3) to improve their ability to escape from predators; and (4) to have better control over where they land. the take-off, landing and gliding performance are discussed separately. Take-off Flying squirrels produced take-off forces ranging from 1.08 to 9.57 body weights.

The amount of force was related to the distance the animal travelled (Fig. 3). It makes sense that squirrels use more force to jump further, as ballistic theory says they need higher speed to cover greater distances. However, there is a maximum force the squirrel can generate. Our results suggest this maximum might be about 10 body weights, which is similar to the force used in occasional high jumps at shorter distances. (These occasional jumps show that flying squirrels may jump more powerfully when surprised.) the highest take-off angle recorded was 35 degrees, which happened at the shortest jump distance of 0.5 m.

this was short enough that the landing position was often higher than the take-off position. The take-off angle decreased as the jump distance increased (Fig. 5). However, this might have been influenced by another factor, the height of the branch. With enough height, the animal can take off at a shallower angle, which helps generate more horizontal speed

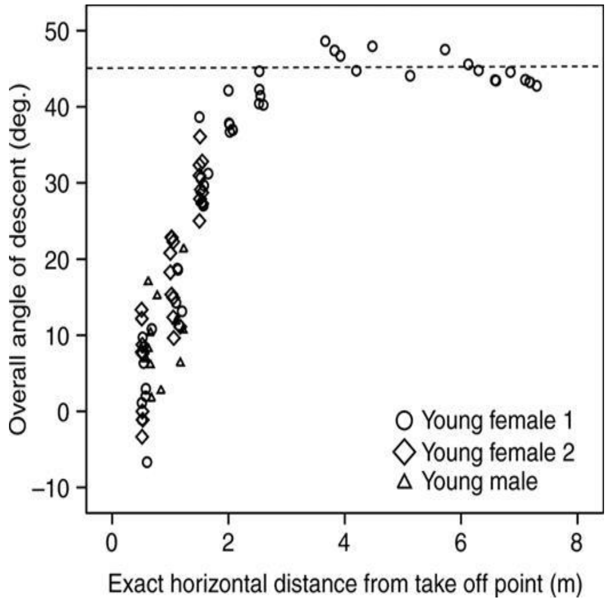


Percentage of body weight supported by lift during gliding as a function of horizontal range in flying squirrels (young females YF1 and YF2, and young male YM).
value are means for each squirrel at each range ± 1 standard deviation. overall velocities of the squirrels increased with range. The animals usually ran and jumped immediately after release on to the branch, but occasionally it was necessary to startle them. It is unknown if the apparent levelling off of glide angle that we observed for longer jumps is a general trend because we did not obtain results for longer leaps.

Gliding performance

Squirrels used lower glide angles in the lab, but angles near 45° (parachuting) for the longer ranges of 2 m and above in the barn.
This may have been a behavioural change due to unfamiliarity, and is based on only one squirrel at these ranges. In a study describing the kinematics of two southern flying squirrels *Glaucomys volans*, glides from both animals were shorter and significantly steeper after moving to a new test arena (Bishop, 2006). However, our measured glide angles improved with increasing range (Fig. 7) and are comparable with similar distance results from two field studies of northern flying squirrels (Vernes, 2001; Scheibe et al., 2006), so it is more likely a consequence of the need for this species (the larger of the two North American species) to reach a higher velocity before it is able to exhibit superior aerodynamic performance. Average glide velocities measured in this study increased with range as would be expected. Observations of the Japanese giant flying squirrel on long glides (Ando and Shiraishi, 1993) sometimes showed an initial steep descent with the glide angle decreasing with increasing velocity, until both became constant. Likewise, northern flying squirrels dropped steeply prior to gliding, and often even managed to gain altitude slightly, just before landing (Vernes, 2001). The squirrels in this study may have initiated a similar behaviour, but the possible ranges were too short for the effect to be noticed. This would help to explain why field observations of northern flying squirrels have reported significantly better glide ratios. In Alaska, USA, Scheibe et al. evaluated 168 glides from 82 different squirrels with mean glide distances of 12.46 m and 14.39 m in successive years, and corresponding mean glide angles were 41.31° and 36.31° (Scheibe et al., 2006). Vernes reports a mean angle of descent of just 26.8° for glides which were longer, averaging 16.4 m (Vernes, 2001). Gliding behaviour is therefore likely to be optimised for significantly longer ranges than were possible in this study.
A scatter plot shows how the glide angle increases with horizontal range until it reaches about 45 degrees, marked by a broken line. After this point, the glide ratio starts to improve a bit. High take-off angles and the limited time squirrels spend in the air are why glide angles are low for short ranges. Glide

angle has a strong negative link with range above 4 meters (r = -0.816, P < 0.001), where higher glide speeds help northern flying squirrels achieve better lift to drag ratios. Adult bodies weigh less than three ounces (about 454 grams) and measure four to eight inches. in length. Their bushy tails add another four inches (about ten centimeters), giving them a total length of about twelve inches. Their fur is silky and blends greyish and chestnut colors with a dense, soft grey undercoat and a light-colored belly. They have a small, round head, large ears, and long whiskers. Their small size, beautiful fur, big black-eyed appearance, and ability to glide make them unique and beautiful members of the rodent family.



In Sitamata Wildlife Sanctuary, located in Rajasthan, at the meeting point of the Aravalli and Vindhyan mountain ranges and the Malwa Plateau.its unique and diverse wildlife. The sanctuary covers parts of the districts of Chittorgarh, Pratapgarh, and Udaipur. Its total area is 422.95 km², of which 359.60 km² is reserved forest and 63.35 km² is protected forest. It is a significant area as it marks the northern edge of the teak-bamboo forests and is home to a variety of wildlife. The sanctuary has a mix of habitats, including teak forests, wetlands, streams, hills, deep gorges, and mixed woodlands.Its location between different geographical formations makes it very important for the study of plants and animals found in the region. these rocks are mainly made up of basic plagioclase and pyroclastics, with some magnesite and limonite. The influence of the Malwa Plateau and the Deccan traps has created layers of silicaceous limestone and cherty rocks with some fossils. The soil type varies from clayey and loamy to gravelly, depending on the terrain, and often mixes with pebbles and boulders. Black cotton soil appears in some parts on these older formations. The soil depth is good, ranging from 30 centimeters to several meters. The area is hilly with many streams and rivers. The slopes are gentle except in some places. The overall terrain is hilly and rugged, with elevations ranging from 280 meters to 600 meters. The land slopes from the north-west to the south-east, creating a landscape of ridges, plateaus, valleys, and streams, with wide plains in some areas. The climate is sub-tropical with clear seasons: winter, summer, and monsoon. Winter begins in November and gets cold in December and January, with the lowest temperature sometimes reaching 6°C. Summer starts around mid-March, and the heat becomes very strong in April, with temperatures up to 45°C. The monsoon season runs from mid-June to mid-September. Occasionally, there are winter rains between January and February. The average rainfall is 756 mm, with the highest being up to 951 mm and the lowest around 517 mm. These rains generally happen over about 30 days.

The forests in this area are classified as II - dry tropical forests, further divided into group 5 - tropical dry deciduous forests, including 5A - southern tropical dry deciduous forest and 5B - northern tropical dry deciduous forest. The agricultural activities along with the high pressure from domestic livestock, illegal cutting of wood, bamboo, and other forest products, and encroachments both inside and around the sanctuary are putting a lot of stress on the area. Although the area is rich in natural resources, it often faces natural disasters like drought, fire, flood, and storm, with drought being a common problem.

Field Survey Methods

Flying squirrels are tree-dwelling and active at night, making them hard to spot and study. they usually hide in the canopy and feed on the bark and inner parts of young twigs, sometimes on leaves, flowers, and fruits. Since they are elusive, it's important to design a proper survey plan for an accurate population estimate. Given the large, hilly, and dense nature of the sanctuary, the whole area was divided into sampling grids. Before starting the field survey, a thorough review of existing research, reports, and information from experts working on this species in the Northeast and South of India, along with input from forest staff was done. These squirrels usually come out of their hiding places, like tree hollows, about half an hour after sunset, making them hard to see during that time. However, their unique feeding behavior has been reported in many studies, which was used as a tool for surveying them during the day because they often leave half-eaten twigs without bark and nibbled leaves on the forest floor.

This method was the main way of conducting the survey, and all likely spots were checked with the help of local trekkers and under the supervision of forest staff. By looking at the chewing and grinding marks on the twigs, we identified areas where the Large Brown Flying Squirrel (LBFS) was present. Later, in the late evening, we randomly went back to many of these sites to see the squirrels directly. The number of these sites shows how often and how much a species uses an area. During our initial survey, we saw flying squirrels directly at only 12 places (Table), but we found signs of their presence at 61 other locations during the day. This was because the terrain was hard to access at night. So, we used the occupancy framework, which involves checking all the signs of flying squirrel movement and feeding. This is a good way to assess the population of shy, nocturnal, and hard-to-find animals.

During the survey many areas inside the sanctuary and nearby villages were checked to find out where flying squirrels like to live. The presence of flying squirrels was found with help from local people, forest staff, and tribal communities. Descriptions of the animal, along with photos and local names like Udan Pankhi, Udan biladi, Udani Minki, Kali Minki, etc., were used to figure out where they might be and to confirm their presence. Extra details were also gathered from the droppings and food leftovers of flying squirrels during the day because these are often found near their nests. Nocturnal surveys were carried out on foot between 7:30 PM and 11:00 PM on natural and new trails, using spotlights and binoculars to look for the animals. The species P. philippensis has a unique red eye shine when light shines on it, which was used to identify it at night. Additionally, gliding between trees and hearing their calls were also helpful in spotting them. Where flying squirrels were confirmed to be present were marked using a GPS, and the details were recorded in Table.

The same trails were not revisited again. The number of animals seen per kilometer traveled was used to estimate their population size. During the surveys, information was also collected about the species' past occurrence, reasons for hunting, the influence of local culture on hunting, and the actual hunting practices by speaking with the local tribes.

Nesting

Trees of flying squirrels were identified with the help of local tribes.

The trees were described based on their species, height, the height of the nest or cavity, the diameter of the tree at breast height, the canopy cover, whether the cavity was natural or artificial, and the distance from the nearest trail or road. A Pearson product moment correlation was used to find out if there was a relationship between the height of the nest and the height of the tree, the diameter of the tree, and the canopy cover.

Flying squirrel observations were made at every study site between 8:00 PM and 1:00 AM. the main method used for locating flying squirrel was spotlighting, which is commonly used when studying other nocturnal animals that live in trees. A modified torch with a halogen bulb and a 12V battery was used as an additional light source. all layer of vegetation were scanned from different angles. Squirrels were detected by their eye shine and then identified using 8x50 or 10x50 binoculars. Only confirmed sightings were used for the analysis. Sightings where the animal ran away too quickly or was too far away to be identified accurately were not considered. The species P. philippensis was also identified by its calls, which are loud and repeated in a monotonous way. The observer was familiar with this call due to prior field experience and could identify it accurately. Non-specific calls were not recorded.

For each squirrel spotted, details like the time of sighting, the species, the number of individuals, how the animal was detected (whether by call, sight, or movement), the location on the tree, the diameter of the substrate used, and the height of the animal on the tree were recorded.

Playback experiment: this is one of the most effective ways to quickly check for nocturnal, hard-to-spot tree-dwelling animals. We played sounds like the calls of squirrels and predator calls—such as those of the Spot-bellied Eagle-Owl, Brown Fish Owl, and Indian Eagle Owl—which are natural enemies of flying squirrels. We also played calls that alert feeding squirrels in the canopy. Later, we used a bright flashlight to spot the squirrels. Their eyes would be glowing, and we confirmed their presence either with binoculars or by noting the glide as they moved through the trees.

Measurement of Vegetation Parameters: The trees where flying squirrels were seen were marked, and during the day, we created a vegetation plot with a radius of 12.6 meters around these trees to study the habitat they use. we recorded the distance from each tree to the central tree (the one where the squirrels were seen). We measured the girth at breast height, height, and whether the trees were alive or dead. For the central tree, we noted the girth at breast height, height, the stage of its growth (like flowering or fruiting), how connected its canopy was to nearby trees, if there were any hollows, and how far it was from the nearest road or trail. We also recorded the presence of vegetation in 5-meter height intervals around the tree, within a 5-meter radius. We also noted the elevation, GPS location, topography, and slope of the area.

In areas where no flying squirrels were seen, we recorded the same habitat features in random plots along the path we walked to compare the general habitat characteristics.

random plots in areas where squirrels were found because we were not trying to compare features within one site, but rather across different sites (to compare where squirrels were found with places where they weren't). For each walk, we noted the forest type, elevation using an altimeter, and the location using a GPS.

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

Population Estimation: The Sitamata WL Sanctuary boundary was overlaid with a 2 square kilometer grid study using the geographical information system (GIS) platform, ArcGIS, following a systematic random sampling method. A total of 122 grids were placed on the map, of which 65 were selected for field surveys. The 2 square kilometer grid size was based on the largest known home range of the species, which was estimated to be about 2 square kilometers. Each 2 square kilometer grid was divided into four smaller grids to identify the most frequently used tree groves. Tree grove surveys were conducted in these 65 grids. 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 using the DNR Garmin app. This helped us locate the grid cells in the field. Once we found a grid cell, we selected the most commonly used tree species by flying squirrels in the area, with help from local forest staff. We visited almost all these tree groves during the survey and noted signs of activity. We turned on the track mode on the GPS to record our path and walked slowly, searching for trees of the same species nearby. We sampled 73 grids and recorded the GPS coordinates for all detections using a handheld GPS receiver (see Figure 1). We also measured the girth at breast height (GBH) of the trees, the distance between nearby trees from the central tree, canopy cover, and any signs of human activity, as these are known to influence flying squirrels based on published studies.

Vegetation Structure and Human Influence:

To evaluate environmental and human-related factors, we placed 10*10-meter quadrats along a diagonal line near the central tree of a likely flying squirrel tree grove. Trees with a minimum girth of 50 cm were considered potential feeding trees, and their height was estimated by eye. We measured the GBH for each tree with a girth over 50 cm. Taxonomic identification of the tree species was done by noting the local name with the help of the accompanying forest guard and then confirming from standard flora books. We also recorded the number of livestock dung piles present, if any. On the GIS platform, we measured the distance from the grid corner to the forest boundary and to the nearest village. Y is the chance of something happening, and P is the probability of spotting a species. A '+' means it has a positive effect on the result, a '-' means it has a negative effect, and a '0' means it doesn't affect the result at all.

Statistical analysis

we made a hypothesis based on the biology of large brown flying squirrels and their habitat. we see them and where they live (Table 1). We divided the factors into two groups: ecological factors like tree density, tree variety, trunk size, and food tree density; and human-related factors like livestock droppings and distance from the edge. We also considered how long the trails were, because that could affect how likely we were to find signs of the squirrels.

The specimens from the Yunnan population (mass 150–204 g, head and body length 195–210 mm, tail length 194–213 mm, ear length 33–37 mm, hindfoot length 40–45 mm) are slightly larger than the holotype of P. (H.) leonardi measured on the skin (head and body length 180 mm, tail length 125 mm, hindfoot length 39 mm).

Covariates	y	*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

The fur is long and fine, with the upper parts being blackish buffy and the hairs having long blackish slaty bases and buffy tips. The underparts are pinkish buffy, with the chest and armpit areas being pure white. The face and the streaks along the sides of the neck are buff. The ears are naked, clearly black, and larger than in most other small flying squirrels (e.g., body size: Hylopetes alboniger > P. (H.) leonardi > Belomys pearsonii, ear length: P. (H.) leonardi = 33–37 mm, Hylopetes alboniger = 24–35 mm, Belomys pearsonii = 22–24 mm). There are no ear tufts. The dorsal surfaces of the hands and feet are blackish, lighter along their inner edges. The tail is flat, very thick, and bushy; its wool hairs are buffy, with long hairs that are glossy blackish (Thomas, 1921). The uropatagium (tail membrane or interfemoral membrane) is less developed than in larger flying squirrels.

Fig. Skin comparison "similar sized + sympatric" or "genetic similarity"

of Pteromys (Hylopetes) leonardi (=Priapomys leonardi) and related species .

IV: Discussion

The seeds collected from the trees, especially Mahua, should be used to grow saplings, which can then be planted in areas where the trees have been lost. Intensive growth of the human population, along with their interference and encroachment into the sanctuary areas, has disturbed the natural habitats of squirrels. Many village sites were also observed where large Mahua trees were present, but the distance between trees was more than 100 meters. This could be a major reason for the absence of LBFS in these areas. Based on the findings of this study, Mahua dominated groves and thickets should be prioritized for conservation and included in the forest conservation plans of the sanctuary.

A Flying squirrel-focused tree nursery should be established. The planting of these species should take place near the current identified locations, as well as in valleys to form a corridor network that helps flying squirrels move around. The largest tree distance was observed to be about 120 meters, so young trees should be planted within these gaps. The survival success rate of these newly introduced trees needs to be increased in the tree groves. Tree augmentation should be done in a way that creates a mix of tree groves and maintains the appropriate distance between trees. Although they occasionally crossed the road, glided, and fed on Mahua and Terminalia species across the road (Dhariyawad road), their movements were largely confined to the sanctuary area.

But it rarely goes beyond a few trees near this road. It is a shy animal and sticks to the trees by the roadside. Whenever a lot of people gather to see it, its emergence time is delayed by up to 12 minutes. Also, it quickly moves towards the tree groves inside the sanctuary. Traffic is one of the reasons for this behavior. Highways cause edge effects around roads, creating disturbances like noise, headlights, and vibrations from vehicles. Roads also break up the forest habitat and limit animal movement. Many mammals avoid these disturbed areas because of vehicles. good planting and conservation of 19 favorite tree species should be done in the form of corridors so that clustered populations can spread and occupy new areas.

the only protected area in Rajasthan where a good population of Large Brown Flying Squirrel is found and breeding occurs. Conservation of this species should be a priority in the sanctuary's management plan. Forest staff should be trained for year-round observation and monitoring of this species along with other wildlife. Year-long scientific studies focusing on conservation are necessary to develop suitable layouts for conservation plans and to improve habitats in the sanctuary.

During surveys, it was noticed that people know little about flying squirrels because of their nocturnal and secretive behavior. The Forest Department should involve local youths from villages within the sanctuary for training and awareness about the wildlife in the area. These youths can be trained as nature guides, and all tourist activities should be conducted through them. These guides can act as the eyes and ears of the sanctuary management and also help stop illegal activities by tourists and religious pilgrims visiting the sanctuary's temples.

Education and Awareness: Awareness campaigns should be launched to highlight the economic, aesthetic, and cultural benefits of saving the flying squirrel. Providing an Alternate Source of Income: Since the tribes depend on the forest directly or indirectly, schemes should be planned to reduce this dependency.

Apiculture: Honey bee rearing is a good option. Since the forest has a lot of flowering trees, bees can collect pollen and produce honey that can be sold as “Pure Forest Honey.” Proper apiculture schemes can be set up around village areas to reduce the need for tribal people to enter the sanctuary.

Tourism Development: The Sitamata WL Sanctuary has a lot of potential as an eco-tourism destination. these programs can boost the local economy and provide alternative income sources for the locals, especially youth, who can be trained as nature guides Nature.

Guide Training Program: Selected youths can be trained and promoted based on their interests as nature guides, trekkers, off-road drivers for tourist vehicles, and hospitality staff at guest houses.

Bird Watching: South Rajasthan is rich in bird diversity. the sanctuary itself has a lot of bird species, so it can be promoted as a birding destination. Bird watching is still not very developed in India, so promoting it can be a good source of income for local youths. Otherwise, they work as laborers or in less productive jobs in nearby cities

Habitat Improvement M. longifolia and T. tomentosa, which are dominant tree species, should be prioritized in conservation planning. Tall and mature trees should be protected from being cut for fuelwood or other uses by locals. If any cutting is observed inside the sanctuary, it should be addressed. If plantin is done, the distance between trees should be maintained to allow for the squirrel's gliding. Minimum distance is10 meters, and maximum up to 60 meters. More of the feeding tree species should be planted in corridor areas (valley areas between two identified sites) to maintain a habitat corridor.

V: Summary and Recommendations

Sitamata WL Sanctuary is known for its elusive flying squirrels. Over the years, estimating the population of this nocturnal animal has been a challenge. The current project was conducted in partnership with the Forest Department to understand the areas occupied by these squirrels and to estimate their population for better management and conservation. The sanctuary area was divided into square grids of 2*2 km², based on the known home range of the Large Brown Flying Squirrel in India. Since these squirrels rarely move more than 2 km from their daytime roosting tree hollow, the 2 km radius was taken from the central "activity tree groove." The project team reviewed various methods used globally for estimating flying squirrel populations.

Because signs of their activity are easier to detect in the early morning, such as typical gnawing on twigs, digging out pith from medium-sized twigs, debarking large twigs, half-gnawed leaves, and fecal pellets were used as indicators of their activity from the previous night. A protocol was created using these signs and surveys were conducted with the help of forest guards, cattle guards, and local villagers. All known sites were visited to find these signs, which were used in the analysis. All the gathered information was used for occupancy-based modeling and population estimation, providing a range of probable minimum and maximum population of the Large Brown Flying Squirrel in the sanctuary. Based on field knowledge, interactions with staff, comparisons of habitat conditions with earlier published works, the project team proposed several key points important for the conservation of the Large Brown Flying Squirrel in the sanctuary.

A total of 12 trees were identified as nesting sites for the Large Brown Flying Squirrel in the sanctuary. Madhuca longifolia was the most common nesting tree, with 8 nests found, while Ficus recemosa and Ficus benghalensis each had 2 nests. The characteristics of these nesting trees were also noted. The Large Brown Flying Squirrel was found to live in natural cavities. All 12 cavities were located in the main trunk or very old side branches, close to the main trunk. Each cavity had only one animal, except at Aarampura, where a female and her one infant shared a single cavity during late March and early April. There was no clear link between the height of the nest cavity and the height of the tree, the diameter of the tree trunk, or the canopy cover. Sitamata Wildlife Sanctuary is known for its flying squirrels

VI. CONCLUSIONS

the take off and landing forces of northern flying squirrels are both linked to the horizontal distance they glide, at least up to 2.5 meters.

The highest take off force measured was 9.57 bodyweights, although the squirrels often used this level of force even for short jumps, probably as a natural response to being startled. Take-off forces were not significantly different from the corresponding landing forces on these flexible surfaces. They are good gliders, spreading out all their limbs to create a wing-like shape, which is kept at a low angle for maximum lift and drag efficiency. The glide angle increases quickly as the horizontal distance increases, up to about 4 meters, then improves gradually, suggesting northern flying squirrels are optimized for much longer glides than were tested in this study. any device that measures force on a flexible surface might show different levels of flexibility along its length.

For example, a cantilever beam starts to act more like a rigid tool near its fixed end. Useful comparisons can only be made between forces measured at points with similar flexibility. If that's not possible, the sample size should be chosen to make sure that the landing positions are randomly spread out. it doesn't seem likely that gliding evolved mainly to reduce the energy needed for travel, even though the lift produced would help in climbing.

The take-off angle decreased with distance but never got close to 45°, the angle for maximum distance, and some of the height was lost due to the aerial maneuvers we saw. The squirrels in this study didn't make any sudden or unpredictable jumps, which casts doubt on the idea that gliding helps in escaping predators. Gliding might have evolved to help squirrels reach more area in a given time. High gliding speeds were measured, and speed increases with distance. However, the development of better landing control is a necessary result of faster flight.

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