Journal of Wildlife and Ecology. (2019). 3(2):22-29

Research Paper **Open Access**

Gliding performance of the small Indian gliding squirrel *Hylopetes fimbriatus* in Azad Jammu and Kashmir, Pakistan

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Peer Reviewed

Citation: Rauf, K., S. Nazer, M. Faiz, M. Altaf. 2019. Gliding performance of the small Indian gliding squirrel *Hylopetes fimbriatus* in Azad Jammu and Kashmir, Pakistan. Journal of Wildlife and Ecology. 3: 22-29.

Received: 11, 03, 2019
Accepted: 07, 05, 2019
Published: 01, 06, 2019

Competing interests: The authors have declared that no competing interests exist.

Funding: Authors have no source of funding for this work.

Availability of data: Authors have included all data in the manuscript that were collected during the field survey.

ABSTRACT

Gliding squirrels are recorded from whole world, while ten species in *Hylopetes* found whole South East Asia. The population of gliding squirrels is decreasing due to habitat destruction. The purpose of the study was to know the gliding behavior of the *H. fimbriatus Hylopetes fimbriatus* within Bagh forest of Azad Jammu and Kashmir, Pakistan. The data were composed on 100 glides experiment at nights. The mean height of launching (10.35±4.7m) and landing trees (6.4969±2.8357) were studied. Gliding variables measured were vertical drop (mean= 10.06±3.1255m), horizontal distance (mean= 3.0787±1.2291 m) and glide angle (mean= 49.2±13.75892°). In conclusion, gliding behavior of *Hylopetes fimbriatus* appears to be different than earlier studies on other species. Environmental aspect may have a major role in shaping glide passageways. Even though during this study noted the many of gliding aspects to decide the gliding capability of *H. fimbriatus*, other features i.e. body weight, wing load, forest structure, habitat composition, anthropogenic factors, distribution of food resources and climatic factors should also be measured for a enhanced knowledge of the gliding behavior of species in the wild.

Key Words: Glide, Squirrel, Gliding variables, Height of launch

INTRODUCTION

Corbet and hill (1992) identify ten species in *Hylopetes* found in whole South East Asia, while Roberts (1997) identifies only eight species. They can be distinguished from genus *Petaurista* by their smaller ordinary size and comparatively shorter but wider tail, which has the furs spreading sideways in shape. The tail, therefore, enlarges significantly to the jump or gliding surface when the animal is leaping.

Skull and physique length normally less than 300mm, adapted to slipping, with flexible membrane connected to margin but no membrane from heel to base of tail. Cranium with tympanic bullae not especially flattened and with last premolar not less than first molar and with lower cheek teeth cuspidate. Dorsal hair grizzled black and pinkish buff. Tail with broad black tip and flattened ventro-dorsally with furs radiating external like a barb (Roberts, 1997). During collection through the "Zoological Survey of India" (ZSI) around the town of Islamabad (formerly Anatnag) in the main valley of Kashmir (N33 ^{o}42'E75^{o} 09'), Chakraborty (1981) composed five specimens of *Hylopetes baberi* as a different species.

Roberts (1997) observed a specimen from Nijrow, Kohistan in Afghanistan, which, because of its relatively greater size called as *Sciuropterus baberi*. Ellerman and Morrison-Scot (1951) in their list treated as a subspecies *H. fimbriatus baberi*. It is noted that *H. fimbriatus* was known and14camping trips in the Kaghan valley and other areas where *H. fimbriatus* noted, found this flying squirrel to be known than *petaurista* and had many opportunities to measure it without constantly suspecting that faunas identical in appearance, sharing the same habitation and with same vocalizations, might be two distinct species. New in section was therefore made in 1993 of all specimens from BNHM Collected special type specimens of craniums.

This proof did not support the criteria used by Chakraborty (1981) for assigning full definite rank. Basically he argued that larger size, as encountered by cranium occipital nasal length, and a small modification in size between the crest zone of 1st molar and 4th premolar were adequate basis for separation, whilst conceding sympatric of populace of both *baberi* and *fimbriatus*, and from his comprehensive explanation of *baberi*, conceding also same pelage characteristics. Corbet and Hill (1992) admit *H. baberi* as a full species, but Roberts (1997) does not, and in Roberts (1997) view unless it can be showed that there is generative separation between these two same and definitely sympatric populaces, there is no base for retaining *baberi*, equal as an identifiable subspecies. Specimen of Kashmir, in the eastern part of *Hylopetes fimbriatus*, array is as greater as or bigger than the magnitudes given for *baberi* in the key provided by Corbat and Hill (1992).

As its title indicates it is a smaller squirrel than *P. petaurista*, having a relatively smaller tail, further upright conspicuous ears and a comparatively larger skull. Being nocturnal they have similar very enormous eyes as *P. petaurista* however the muzzle is more pointy and elongated. The auricles are nearly hairless

by the external margin severely concave to the tip, so that the pinna naturally bands backward. The physique fur is smaller and fewer some luxuriant than in *P. petaurista*. The abdomen fur is milky white in color changing to dull grayish buff. The dorsal hair is dull pinkish buff color miscellaneous with black furs, consequently that the common appearance is grizzled. There is frequently a distinguishing 'V' formed pattern of black furs through the shoulders. Such as previously showed the tail is extensive at its base with the furs radiating outward to form flattened exterior dorsa ventrally. Its tapers to a point and has abroad black tip, being a sandy red color in its proximal areas (Roberts, 1997).

As in all flying squirrels, there is a broad flap of flexible skin stretching from the wrist of forelimb to the posterior feet. When leaping, this covering flap is also extended and tightened by cartilaginous wrist spur related to that found in *P. petaurista*. Nevertheless the spur measures approximately 40 to 42 mm (70mm in *petaurista*). Female *Hylopetes* have 6 mammae (Roberts, 1997).

The naked palms of front and back feet are pinkish brown and totally the digits are armed with very severe claws. The outer surface of front and back feet is enclosed with dark brown furs and like *P. petaurista* there are five toes on the back foot and four on the fore foot, composed with vestigial thumb. The incisor teeth are layered with bright red enamel. The vibrissae are elongate, up to 83mm and black in color. Average sizes of thirteen specimens from Pakistan are as follows: head and physique length 285mm (range 235-300mm), tail 310mm (range 252-355mm), with the back foot 62mm (range 52-70mm), and the auricle 44mm (range 37-48mm). One specimen from Gilgit weighed 680gm and another from Nathia Gali weigh up 510 gm (Roberts, 1997)**.** Not a single study signifies the gliding behaviour of *P. Petaurista* from India and thus, there is need to well understand their favorite of small-habitat for safe gliding in local environment. We started this study in Azad Jammu and Kashmir Pakistan, to well understand the gliding behavior of *Hylopetes fimbriatus,* which might be helpful in future for species conservation and park management.

MATERIALS AND METHODS

Study area: Bagh is present 80 km from district Muzaffarabad. Muzaffarabad is a capital of Azad Jammu and Kashmir, Pakistan. Bagh is linked to Muzaffarabad by two roads,one via Sudhan Gali and the other through Kohala. It is located 160 Kilometers from Islamabad. Islamabad is the capital of Pakistan. The total area of the district Bagh is 770 square kilometers. Topographically, the district is quite mountainous with lush green pine forests on the mountain slopes leading into the valleys. The altitude of Bagh is 3405 feet (DRU, 2007).

Collection of gliding data*: H. fimbriatus* was noticed through eye and sounds. At any time a *H. fimbriatus* was in view and behavior was noticed. A space of 10 to 15m was retained during the study. *H. fimbriatus* in this region was good addicted to human being as there are people around the forest. Although *H. fimbriatus* was not tagged, *H. fimbriatus* can be known at least 6 to 14 adult individuals. The data composed were not divided consist on the different sexes as it was not easy to distinguish females and males in the existing field circumstances. Data was

collected for 8 days/month over a time of whole year. During the study 100 glides were documented and also, data were composed by chance when the glides were occurred during the path. For every glide, five variables were noted:

1. Height of launch (m)
2. Height of landing (m)
3. Vertical drop (m)
4. Horizontal distance (m)
5. Glide angle (^{o}).

Stopwatch was utilized to note the precise time of *H. fimbriatus* gliding. Direct glide distance, vertical drop and gliding angle were calculated (Stafford *et al*., 2002; Koli *et al*., 2011).

Statistical analysis: ANOVA tests were used to analyze the data using SPSS 16.0.

RESULTS AND DISCUSSION

Different glide features data are mentioned (Table 1) i.e. gliding angle (°), horizontal distance (m), vertical drop (m), height of launch (m) and height of landing (m). Heights of launch, landing and horizontal space were calculated using a gauge tape and stopwatch was utilized for measuring time. Vertical drop was calculated as the variation between heights of launch and landing. Direct gliding angle and glide distance were measured by drawing launching, landing and horizontal distance on paper. The glide time was 2.52±1.335m. The height of launching (i.e. 10.35±4.7m) and landing (i.e. 6.4969±2.8357m) were also observed. Gliding variables i.e. mean vertical drop, mean horizontal distance and mean glide angle were calculated as 10.06±3.1255m, 3.0787±1.2291m and 49.2±13.75892° respectively. *H. fimbriatus* favored "J-shaped" glide pathways which was 60 percent (n=60) of the whole glides, 23 percent (n =23) "S-shaped" glide pathways as well as only 17 percent (n =17) of glides included "straight" or "horizontal" glides. This was feasible due to variation in type of forest, structure of forest and height of the tree. There was significant difference in gliding preference (Kruskal–Wallis ANOVA, F = 816.69 with p–value 0.000) (Table 2).

Table 1: Gliding variables with explanation (Stafford *et al.*, 2002; Koli *et al*., 2011).

Sr. No.	Gliding aspects	Definition
1	Height of launch (m)	The point on tree from which the glide is initiated by the flying squirrel.
2	Height of landing (m)	The point of landing on tree at the end of glide.
3	Vertical drop (m)	Total height of landing tree minus the height of point of landing.
4	Horizontal distance (m)	Horizontally distance between the points of launching and landing.
5	Gliding angle (°)	Angle between horizontal distance and air distance.

Table 2: Statistical analysis of gliding variables.

Gliding aspects	**Mean**	**Min**	**Max**
Glide duration (Second)	2.52±1.335	1	5
Height of launching (m)	10.35±4.7	3.96	21.3
Height of landing (m)	6.4969±2.8357	2.43	12.49
Vertical drop (m)	10.06±3.1255	4.87	15.24
Horizontal drop (m)	3.0787±1.2291	0.91	6.7
Glide angle (angle °)	49.2±13.75892	12	75

Table 3: Types of glide during study observed in *H. fimbriatus*.

Types of glides	**No. of observation**
S-shaped glide	23
J-shaped glide	60
horizontal glide	17

During the study 100 glides was observed. Various parameters were noted e.g. height of launch, landing, horizontal drops as well as glide angle. Only one the longest glide of 30m was noted in this research, as observed by govern by Ando and Shiraishi (1993) where longest glide was observed as 115 m. Other important features impacting glide distance are tree structure and height with denser forest and smaller trees creates trouble for lengthy glides. *H. fimbriatus* liked "J-shaped" glide as compared to other glides e.g. "S-shaped" and "horizontal". In "S-shaped glide" pathways, *H. fimbriatus* jump from tree by obliging their legs backwards in order to get further vertical height prior to ingoing the downward glide pathway and generally, that types of glides were noted in usual distant glides. In the case of "J-shaped glide" pathways, the *H. fimbriatus* dives from branch losing height quickly, and then draws out of the glide to a more horizontal glide angle that types of glides were noted for distant glides. A "straight" or "horizontal" glide pathway was the least noted where the *H. fimbriatus* jumps from its rest on at about the glide angle for the majority of the glides. By increasing their gliding angle *H. fimbriatus* may have increased their gliding speed (Table 3). Further detail is present in Table 4.

Conclusion: Gliding behavior of *Hylopetes fimbriatus* shown to be different than previously documented studies on other gliding squirrels. Environmental aspects may have a basic role in shaping glide passageways. Even though during this research noted the many of gliding aspects to decide the gliding capability of *H. fimbriatus*, other features i.e. body weight, wing load, forest structure, habitat composition, anthropogenic factors, distribution of food resources and climatic factors should also be measured for a enhanced knowledge of the gliding behavior of species in the wild.

Acknowledgements: All authors are thankful for all people who help me during research in field.

Availability of data: We have included all data in the manuscript that were collected during the field survey.

Authors' contributions: Rauf has designed project, collected data and written this article; Altaf and Nazer supervised this project and Faiz helped in manuscript write up. All authors critically analysis this article and approved as final.

Table 4: Comparison on different gliding aspects of gliding squirrels studied globally.

Species	Sample size	Maximum glide distance (m)	Vertical drop (m)	Source
P.leucogenys	202	160	-	Imaizumi, 1983
P. petaurista	_	115	-	Ando and Shiraishi 1993, Stafford *et al.,* 2002
P. petaurista	100	150	7.4	Scholey, 1986
G.volans	_	38.5	7.5	Koli *et al.,* 2011
G. sabrinus	100	50	1.8	Nowak, 1991; Scheibe and Robins, 1998
Glaucomys sp.	100	90	1.9	Wells-Gosling, 1985; Vernes, 2001
H.Lepidus	_	6–20	-	Wells-Gosling, 1985
H. alboniger	_	135>110	-	Nowak, 1991
P.volansorii	31	52.8	-	Krishna *et al*., 2013
P. petaurista	71	104.3	11.9M 10.8F	Ansari *et al.,* 2007; Suzuki *et al.,* 2012
P.breviceps	_	42	12.7	Goldingay 2014
P.gracilis	_	60	15.2	Jackson, 2000
P.norfolcensis	85	47	11.7	Goldingay and Taylor, 2009
G.variegates	222	-	-	Byrnes *et al*., 2011

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