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Research Article

Diversity, Distribution and Status of Gliding Squirrels in Protected and Non-protected Areas of the Eastern Himalayas in India

Murali C. Krishna[1], Awadhesh Kumar[1,*], Om Prakash Tripathi[1], John L. Koprowski[2]

[1] *Department of Forestry, North Eastern Regional Institute of Science and Technology (Deemed University), Nirjuli-791109, Arunachal Pradesh, India*
[2] *Wildlife Conservation and Management, School of Natural Resources & the Environment, University of Arizona, Tucson, AZ 85721, USA*

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Abstract

The tropical forests of South and Southeast Asia hold the highest gliding squirrel diversity but our knowledge of species diversity, ecology and major threats is limited. The present study was undertaken in Arunachal Pradesh, Northeast India between June 2011 and March 2015 to address the paucity of data available on gliding squirrels. Based on field and literature surveys, 14 species of gliding squirrels were detected in the state of Arunachal Pradesh. However, species such as *Biswamoyopterus biswasi*, which is reported as endemic to Namdapha National Park, were not detected. The high gliding squirrel diversity in this region could be related to a diversity of forest types and its location between the Himalayas and the Indomalayan region. Encounter rates with four different species revealed that *Petaurista petaurista* was most frequently detected in Namdapha National Park. Major threats include hunting for traditional medicine, cultural purposes or bushmeat, and habitat loss due to forest degradation caused by shifting cultivation. In addition, more intensive studies on population, ecology and conservation status are needed in order to design species and site specific conservation action plans in this region which represents the highest diversity of gliding squirrels globally.

Introduction

The mammalian rodent family Sciuridae holds 285 species (58 genera) of squirrels with different life styles viz., arboreal, ground-dwelling and gliding squirrels (Thorington et al., 2012). Squirrels occupy a variety of ecological niches across world except on Madagascar, Australia and Antarctica (Walker, 1975; Thorington et al., 2005). Among squirrels, gliding squirrels (Petauristinae, Sciuridae, Rodentia) are nocturnal arboreal dwellers capable of gliding leaps by means of the patagia connected principally on each side to their forelegs and hind legs (Nowak, 1991). Globally gliding squirrels comprise 48 species in 15 genera (Corbet and Hill, 1991; Hoffmann et al., 1993; Thorington et al., 1996; McKenna, 1997) that range in size from the pygmy gliding squirrels of the genus *Petaurillus* (24 g) to the giant gliding squirrels (genus *Petaurista*, 1.5 kg, Thorington and Heane, 1981) and occur across North America, Eurasia and Southeast Asia (Hoffmann et al., 1993; Koprowski and Nandini, 2008). Squirrels play key roles in forests which include predator-prey relations, seed dispersal and pollination (Zahler and Dietemann, 1999; Ganesh and Devy, 2006; Fan and Jiang, 2009).

The tropics, particularly the forests of Southeast Asia, are hotspots of squirrel diversity representing 40 species; however, these regions received little scientific study (Koprowski and Nandini, 2008; Thorington et al., 2012). Basic facts such as species richness are not well known with the number of species occurring in India reported between 9 and 12 (Corbet and Hill, 1991; Jackson and Schouten, 2012; Srinivasulu and Srinivasulu, 2012; Thorington et al., 2012; Menon, 2014) and within Arunachal Pradesh region species richness estimates vary from 3 to 9 (Corbet and Hill, 1991; Jackson and Schouten, 2012; Thorington et al., 2012; Menon, 2014). Museum specimens were the primary source for these numbers with little ecological survey. Moreover, throughout the world, forest ecosystems are being altered through anthropogenic activities such as tree felling, mineral extraction, road networks, agriculture, and settlement (Harris, 1984; Hunter, 1900; Terborgh, 1992; Myers, 1996). Moreover, gliding squirrels in Asia continue to suffer strong pressure due to habitat destruction, mainly because of clear-cutting of primary forests (Muul and Lim, 1978). Tree

*Corresponding author
Email address: tpileatus@gmail.com (Awadhesh Kumar)

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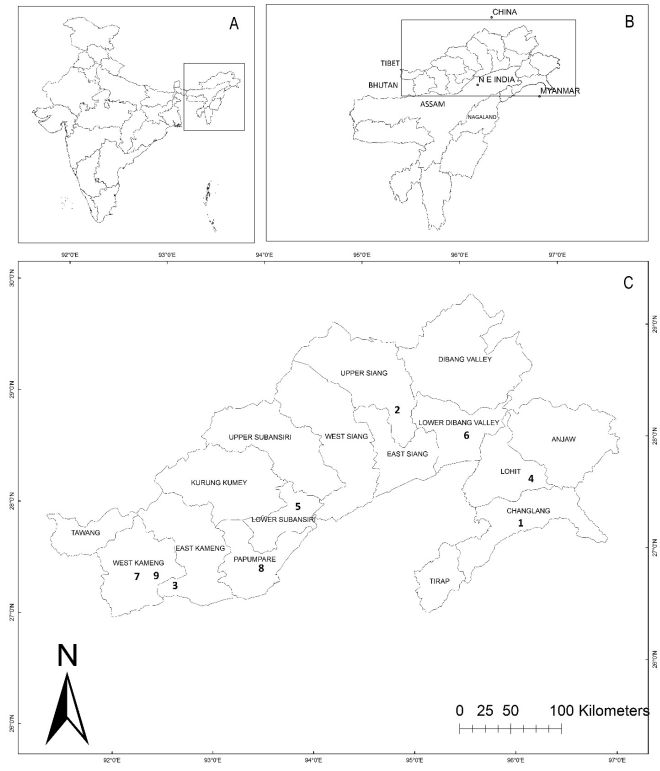

Figure 1 – Map of the study area (A=India, B=Northeast India and C=Arunachal Pradesh) (Numbers in inset include the study sites as per S. No., see. Tab. 1).

and gliding squirrels can serve as excellent indicators of forest health (Koprowski and Nandini, 2008) and can provide insight to these globally rich ecosystems.

The state, Arunachal Pradesh, lies in the northeast portion of India and is contiguous with Southeast Asia. Three new species of gliding squirrels were discovered in Arunachal Pradesh in the last decade (Choudhury, 2007, 2009, 2013b). However, to date, no systematic studies on flying squirrels have been conducted in this part of the Indo-Malayan region. Therefore, we conducted the present study to provide information on species diversity, distribution, status and local threats of gliding squirrels in this unique region.

Materials and methods

Study Area

Arunachal Pradesh (26°28′ N, 97°30′ E, area 83.743 km^2), is situated in the north-easternmost part of India and is surrounded by Bhutan to the west, China to the north, Myanmar to the east and Assam and Nagaland states of India to the south (Fig. 1). About 80% of the total geographical area of the state is forested (FSI, 2015). The Eastern Himalaya is recognized as a global diversity hotspot (Mittermeier et al., 1999) and Arunachal Pradesh is thought to be the most biodiversity-rich and is among the 200 globally most important eco-regions (Olson and Dinerstein, 1998). The state harbours the world's northernmost tropical rainforests (Proctor et al., 1998) and is home to over 100 mammal species (Datta, 2007). The wide altitudinal range (100 to 6000 m) has resulted in varied types of forest (tropical to alpine). The state has 11 Wildlife Sanctuaries and 2 National Parks (Envis, 2012). The present study was undertaken in 9 protected areas, in addition to non-protected areas which are under the unclassified state forest category (Tab. 1).

Survey Methods

Reconnaissance Survey

The survey was initiated in June of 2011 and continued until March 2015. Prior to spotlight surveys, the villages around the protected areas were visited. Experienced hunters, forest officials and traditional healers were shown images of gliding squirrels and were asked about their presence/absence in the area. Based on their knowledge, localities were identified and selected for further direct field survey for gliding squirrels using recce sampling (see Walsh and White, 1999). In this method, pre-existing trails were surveyed to minimize cutting of vegetation. Trail length varied between sites ranging between 500 m–11 km (Tab. 2).

Spotlighting Surveys

During recce sampling, spotlighting was used to detect gliding squirrels in the survey areas. Animals were located by scanning the canopy with red lights. We walked at a pace of 8–10 m per minute. Two spotlights (6 V, solar powered; yellow lights) and National Geographic 5× night-vision binoculars were used to observe the animals (Lee et al., 1993; Krishna et al., 2014). The animals were photographed and videos were taken whenever possible to identify the species. A handheld Garmin GPS was used to collect the location data. As most of the survey areas lack electricity, the lights were charged using solar panels and thus the lights did not last long. This is a reason for short and swift surveys in the study areas. Based on the surveys, we estimated encounter rates for each species. Encounter rate was calculated as the number of gliding squirrels sighted per km of trail travelled per species (Nandini and Parthasarathy, 2008).

Identification and threat assessment

The species were identified by using several field guides and reference books including Corbet and Hill (1991); Thorington et al. (2012); Jackson and Schouten (2012); Menon (2003, 2014). Also, the skins of dead animals were photographed and collected whenever possible during surveys in houses of local people. Furthermore, skins were compared to those of the preserved specimens from Zoological Survey of India, Kolkata. In order to avoid confusion, we followed the nomenclature as provided in Thorington et al. (2012), except in the cases of the species *Petaurista nigra*, *Petaurista mishmiensis* and *Petaurista siangensis*, which are not mentioned in the book. We used these names following the papers published by Choudhury (2007, 2009, 2013a,b). The literature was thoroughly surveyed using Google Scholar, Zoological Survey of India publications, and the volumes of the Bombay Natural History Society, and offline collections were also reviewed whenever possible using Biodiversity Heritage Library (http://www.biodiversitylibrary.org/). In addition, we consulted many researchers who work in the field of wildlife in Arunachal Pradesh and collected photographs and location data of gliding squirrel.

We conducted informal interviews with hunters and traditional healers to learn the cultural and ethno-zoological use of the species from 11 different villages of the state. We also enquired on the methods of hunting. Interviews were conducted in the evenings when people were

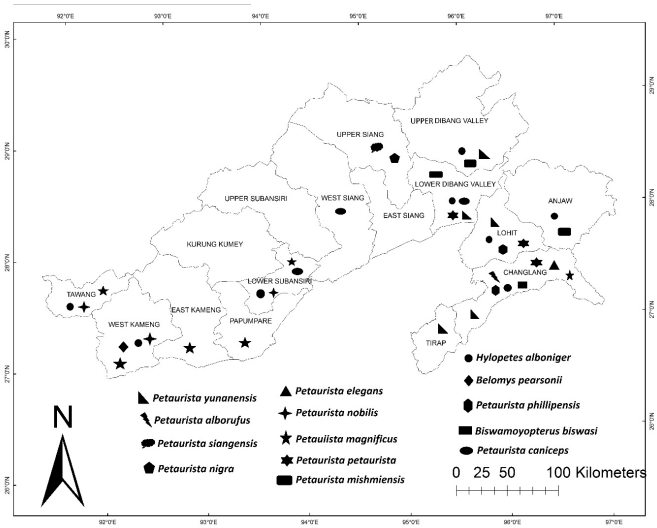

Figure 2 – Distribution of gliding squirrel species in Arunachal Pradesh, Eastern Himalaya.

free from domestic work. Also, we visited fringe villages of protected areas to check the presence of squirrel skins in as many parts of the state as possible. All skins were photographed for identification.

Results

Diversity and Status

Findings of the current study are based on the surveyed area of 10 districts of the state including 6 wildlife sanctuaries, 2 National Parks (NNP) and an Orchid Sanctuary. We documented that 14 species of gliding squirrels occur in Arunachal Pradesh (Fig. 2–5). The recently discovered Mishmi Hills giant gliding squirrel (*Petaurista mishmiensis*) was confirmed through our surveys by secondary evidence (a tail portion) at Hunli (28°19′ N 95°57′ E) in Lower Dibang Valley District of the state, along with photographs of the species. The only known resident species that we did not detect was the Namdapha gliding squirrel (*Biswamoyopterus biswasi*); however, this species is a rare endemic to Namdapha National Park. Of 14 candidate species suspected to be resident, the presence of 12 species were documented through surveys and specimens. Highest species richness occurred in Namdapha National Park (Tab. 2; Fig. 3–6). Encounter rates of 4 different species were estimated. Highest encounter rates were observed for *P. petaurista* (1.1 individuals/km) and *H. alboniger* (0.6 individuals/km) in Namdapha National Park. Encounter rates of other species are reported in Tab. 2.

Species encountered in the current study

1. **Particolored Gliding Squirrel (*Hylopetes alboniger*)**
   - **Distribution within the state:** West Kameng, Tawang, Lower Subansiri, Lower Dibang Valley, Upper Dibang Valley, Anjaw and Changlang.
   - **Presence of the species in protected areas:** Eaglenest WLS, Sessa Orchid Sanctuary, Mehao WLS, Kamlang WLS, Namdapha NP, Pakke WLS and Mouling NP.
   - **Elevation range of occurrence:** 100–2300 m.
   - **Evidence:** Direct sightings, calls as well as through interviews with the hunters and forest officials.
   - **IUCN status:** Least Concerned.
   - **Local status:** Near Threatened (Molur et al., 2005); II(II) (Sharma et al., 2015).
   - **Global threats:** Habitat loss, overharvesting, natural predators.
   - **Local threats observed in present study:** Hunted as a part of bushmeat collection along with diurnal tree squirrels. Also, in Eastern Arunachal Pradesh, the meat is used for treatment of alimentary canal disorders.
   - **Other remarks:** Observed along with *P. petaurista* in NNP and is likely sympatric with the species. Detected in tropical lowland, subtropical and broadleaved forests and around the human habitations. This species probably is spread throughout the state.
   - **Literature:** Prater (1974); Menon (2003); Srinivasulu et al. (2004); Molur et al. (2005); Pradhan et al. (2011); Krishna et al. (2013).

2. **Grey Headed Gliding Squirrel (*Petaurista caniceps*)**

Table 1 – Details on location and forest types of protected Areas (PAs) of Arunachal Pradesh, India, where the study was conducted.

S. No.	Name of PA	District	Location	Elevation (m asl)	Area (km^2)	Classified area	Forest type & Dominant tree species	References
NATIONAL PARKS (NP)								
1.	Namdapha	Changlang	27°31′ N 96°37′ E	200–4571	1985.23	NP, TR	Tropical Wet Evergreen forests in the lowlands, temperate and alpine forest in higher reaches. *Diptercarpus, Alnus nepalensis, Anthocephalus, Artocarpus, Castanopsis, Mangifera sylvatica*	Ghosh (1987); Proctor et al. (1998); Datta et al. (2003); Nath et al. (2005)
2.	Mouling	Upper Siang	28°33′ N 94°46′ E	500–4000	483.00	NP	Tropical Semi Evergreen, Moist deciduous, Temperate Broad leaved Forests along with Temperate conifer Forests and sub-alpine forests.	Singh et al. (2005)
WILDLIFE SANCTUARIES (WLS)								
3.	Pakke	East Kameng	27°6′ N 92°33′ E	150–2500	861.95	WLS, TR, ER	Tropical semi-evergreen to evergreen with patches of secondary jhum forests. *Polyalthia simiarum, Pterospermum acerifolium, Sterculia alata, Stereospermum chelonioides, Ailanthus grandis, Mesua ferrea* and *Duabanga grandiflora* are major dominant species.	Varma et al. (2008); Champion and Seth (1986); Lyngdoh et al. (2011)
4.	Kamlang	Lohit	27°44′ N 94°39′ E	550–4000	783.00	WLS	Wet evergreen to semi evergreen, broad leaved forest and temperate forests.	Rao and Chowla (2006); Krishna et al. (2015)
5.	Talle Valley	Lower Subansiri	27°32′ N 93°53′ E	1200–3000	370.00	WLS	Sub-tropical broad leafed, wet temperate broad leafed and temperate conifer types. Dominant species are *Quercus sp., Acer, Magnolia, Rhododendron, Betula, Chimanobambusa callosa* etc.	
6.	Mehao	Dibang Valley	28°5′ N 93°30′ E	400–3600	281.50	WLS	Tropical wet evergreen forests in the low elevations, followed by Subtropical broadleaved forests higher up and temperate forests and coniferous forests occur even higher up. The highest elevations of the sanctuary are dominated by subalpine moist scrub.	Krishna et al. (2012)
7.	Eagle Nest	West Kameng	27°5′ N 92°24′ E	500–3200	217.00	WLS	Semi-evergreen and Evergreen forest in the foothill areas and Temperate to Coniferous forest at higher elevation. Further, the forest may be classified as: i) Tropical Evergreen and Semi evergreen forest, ii) Sub-tropical broad-leaved hill forests and iii) East Himalayan dry temperate coniferous forest *Rhododendrons, Acer, Quercus, Pinus sp.*, etc. are dominating species.	Kaul and Haridasan (1987); Datta (1999)
8.	Itanagar	Papum Pare	27°5′ N 93°30′ E	300–1000	140.30	WLS	Tropical Semi Evergreen, Tropical Evergreen and Secondary forests.	Aiyadurai et al. (2003)
ORCHID SANCTUARY (ORS)								
9.	Sessa Orchid Sanct.	West Kameng	27°9′ N 92°33′ E	600–3100	100.00	ORS	Tropical, Sub-tropical and Alpine forests.	Kaul and Haridasan (1987); Varma et al. (2008)

Table 2 – Areas Surveyed and Encounter rates of gliding squirrel species between August 2011 and February 2014.

S. No.	Species	Protected areas	No. of trails walked	Trail lengths (Min, Max)	Total Walk (km)	Encounter rates/km	Survey Months
1.	Particolored Gliding Squirrel (*H. alboniger*)	Namdapha National Park	14	500 m (Min) 2 km (Max)	114.5	0.9	August 2011 to December 2014 (Multiple Surveys)
		Mehao WLS & Surrounding areas	3	1 km	27	0.6	December 2012
		Talle WLS	3	4 km (Min) 11 km (Max)	44	0.4	February 2013 March 2014
		Sessa Orchid Sanctuary & Surrounding Areas	3	1 km (Min) 5 km (Max)	24	0.4	March 2013
		Pakke WLS	2	6 km	12	0.7	August 2013
2.	Hodgson's Gliding Squirrel (*P. magnificus*)	Talle WLS	3	11 km	22	0.4	February 2013 & March 2014
		Sessa Orchid Sanctuary & Surrounding Areas	3	1 km (Min) 5 km (Max)	24	0.6	March 2013
3.	Red Giant Gliding Squirrel (*P. petaurista*)	Namdapha National Park	14	500 m (Min) 2 km (Max)	114.5	1.1	August 2011 to December 2014 (Multiple Surveys)
4.	Bhutan Giant Gliding Squirrel (*P. nobilis*)	Sessa Orchid Sanctuary & Surrounding Areas	3	1 km (Min) 5 km (Max)	24	0.3	March 2013

Distribution within the state: West Kameng, Lower Dibang Valley and Lower Subansiri.
Presence of the species in protected areas: Talle WLS and Mehao WLS.
Elevation range of occurrence: 1900–2300 m.
Evidence: Direct sightings, photographic evidence.
IUCN status: Least Concerned. (But kept as a synonym under *P. elegans*).
Local status: II(II) (Sharma et al., 2015).
Global threats: Habitat loss and developmental activities.
Local threats observed in present study: None. However, the species is hunted for bushmeat in a few areas of the state.
Other remarks: The species was sighted in *Quercus* spp. and *Rhododendron* spp. dominated forest areas in Talle WLS only during three surveys and is probably uncommon.
Literature: Prater (1974); Srinivasulu et al. (2004); Molur et al. (2005); Krishna and Kumar (2015).

3. **Spotted Giant Gliding Squirrel (*Petaurista elegans*)**
Distribution within the state: Changlang.
Presence of the species in protected areas: Namdapha NP.
Elevation range of occurrence: $\leqslant$ 1600 m.
Evidence: Specimen at ZSI Kolkata.
IUCN status: Least Concerned.
Local status: II(II) (Sharma et al., 2015).
Global threats: Habitat loss.
Local threats observed in present study: Conversion of forest to agriculture lands and habitat loss.
Other remarks: This species was not sighted during the field surveys and is only documented through a specimen deposited at ZSI, Kolkata of the subspecies *P. e. sybilla*, collected from Gandhigram of Namdapha National Park, Arunachal Pradesh in 1985 by S. Biswas (Reg. No. 23717). This species is probably restricted to easternmost part of the state bordering Myanmar.
Literature: Prater (1974); Srinivasulu et al. (2004); Molur et al. (2005); Pradhan et al. (2011).

4. **Hodgson's Giant Gliding Squirrel (*Petaurista magnificus*)**
Distribution within the state: West Kameng, East Kameng, Lower Subansiri, Papumpare, Lower Dibang Valley and Changlang.
Presence of the species in protected areas: Eaglenest WLS, Sessa Orchid Sanctuary, Itanagar WLS, Talle WLS, Mouling NP and Mehao WLS.
Elevation range of occurrence: 100–2300 m.
Evidence: Direct sightings, rescued individual at Itanagar Zoo and pelts.
IUCN status: Least Concern.
Local status: Vulnerable (Molur et al., 2005); II(II) (Sharma et al., 2015).
Global threats: Habitat loss and degradation.
Local threats observed in present study: Hunting for bushmeat and trophy hunting. The skins are dried and displayed as trophies.
Other remarks: This species inhabit habitat types ranging from tropical, sub-tropical and broad leaved forests at different elevations. This species probably is spread throughout the state as records appear from almost all regions of the state.
Literature: Prater (1974); Srinivasulu et al. (2004); Molur et al. (2005); Pradhan et al. (2011).

5. **Bhutan Giant Gliding Squirrel (*Petaurista nobilis*)**
Distribution within the state: West Kameng, Lower Dibang Valley and Lower Subansiri.
Presence of the species in protected areas: Eaglenest WLS and Talle WLS.
Elevation range of occurrence: 800–2300 m.
Evidence: Direct sightings and pelts.
IUCN status: Near Threatened.
Local status: Endangered (Molur et al., 2005); II(II) (Sharma et al., 2015).
Global threats: Habitat loss and degradation.
Local threats observed in present study: Hunting for bushmeat and trophy hunting. The skins are dried and displayed as trophies.
Other remarks: This species is distributed in subtropical and broadleaf forests of the state, which extends known distribution. The species was previously thought to occur only in the easternmost part of the state; however, we documented that the distribution extends westward to central Arunachal Pradesh.
Literature: Choudhury (2003); Menon (2003); Srinivasulu et al. (2004); Molur et al. (2005); Pradhan et al. (2011); Thorington et al. (2012); Datta et al. (2015).

6. **Red Giant Gliding Squirrel (*Petaurista petaurista*)**
Distribution within the state: Anjaw, Lower Dibang Valley, Lohit, Changlang.
Presence of the species in protected areas: Namdapha NP, Kamlang WLS and Mehao WLS.
Elevation range of occurrence: 100–1500 m.
Evidence: Direct sightings.
IUCN status: Least Concern.
Local status: Near Threatened (Molur et al., 2005); II(II) (Sharma et al., 2015).
Global threats: Habitat loss, degradation and hunting.
Local threats observed as per present study: The urine is thought to cure kidney stones and thus the species is hunted for medicinal purposes.
Other remarks: Commonly seen in Namdapha NP in the lower reaches dominated by tropical forests.
Literature: (Prater, 1974; Menon, 2003; Srinivasulu et al., 2004; Molur et al., 2005; Pradhan et al., 2011; Menon, 2014).

7. **Hairy-footed Gliding Squirrel (*Belomys pearsonii*)**
Distribution within the state: West Kameng and West Siang.
Presence of the species in protected areas: Pakke WLS possibly.
Elevation range of occurrence: 1500–2400 m.
Evidence: Dead specimens.
IUCN status: Least Concern.
Local status: Vulnerable (Molur et al., 2005); II(II) (Sharma et al., 2015).

Global threats: Shifting cultivation, forest fires, monoculture plantations, and overharvest.
Local threats observed in present study: Hunting for bushmeat and natural predation possibly.
Other remarks: None.
Literature: (Menon, 2003; Srinivasulu et al., 2004; Molur et al., 2005; Pradhan et al., 2011; De et al., 2006).

8. **Mishmi Hill Giant Gliding Squirrel (*Petaurista mishmiensis*)**
Distribution within the state: Lower Dibang Valley, Upper Dibang Valley and Anjaw.
Presence of the species in protected areas: Mehao WLS .
Elevation range of occurrence: 1200 –1900 m.
Evidence: Direct sightings, photographic records and pelts.
IUCN status: Not assessed.
Local status: Not assessed.
Global threats: Not assessed.
Local threats observed in present study: Highway construction and hunting.
Other remarks: The species was observed to inhabit areas dominated by *Rhododendron* spp. and *Quercus* spp. Many birdwatchers have sighted this species around Mayudia area of Mehao WLS.
Literature: Choudhury (2009).

9. **Mechuka Giant Gliding Squirrel (*Petaurista nigra*)**
Distribution within the state: Upper Siang.
Presence of the species in protected areas: Mouling NP.
Elevation range of occurrence: $\leq$ 1800 m.
Evidence: Photographs and specimen at ZSI Kolkata .
IUCN status: Not assessed.
Local status: Not assessed.
Global threats: Not assessed.
Local threats observed in present study: Hunting for bushmeat.
Other remarks: None.
Literature: Choudhury (2007).

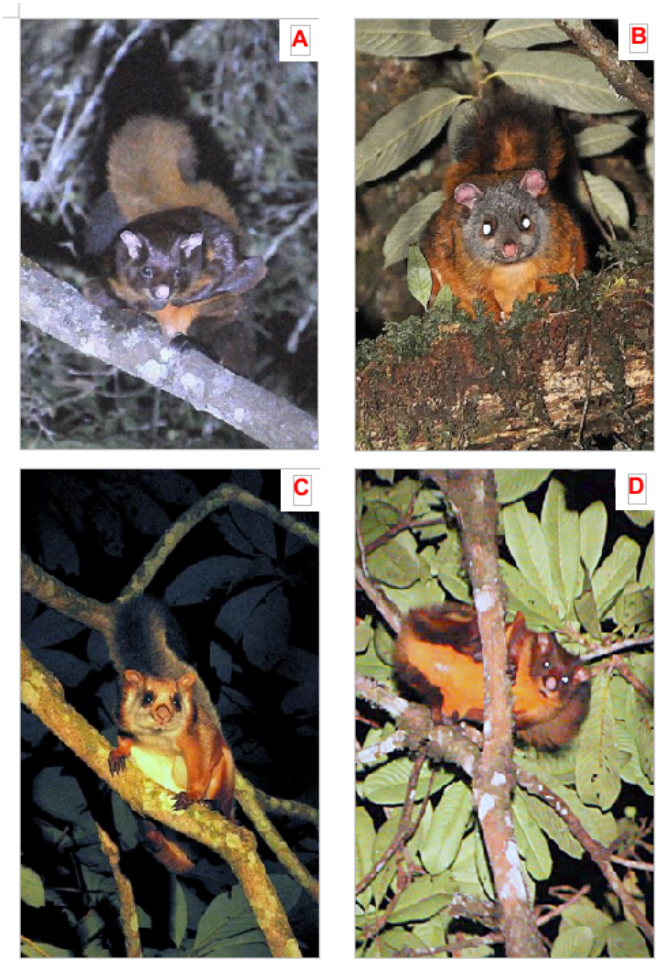

Figure 3 – A) *Petaurista magnificus*; (B) *Petaurista caniceps*; (C) *Petaurista petaurista*; (D) *Petaurista nobilis.*

10. **Indian Giant Gliding Squirrel (*Petaurista philippensis*)**
Distribution within the state: Kurung kumey, Changlang, Lohit.
Presence of the species in protected areas: Namdapha NP.
Elevation range of occurrence: 200–500 m.
Evidence: Pelts.
IUCN status: Least Concern.
Local status: Near Threatened (Molur et al., 2005); II(II) (Sharma et al., 2015).
Global threats: Overharvest.
Local threats observed in present study: Hunting for bushmeat and trophy hunting.
Other remarks: None.
Literature: Choudhury (2013a).

11. **Mebo Giant Gliding Squirrel (*Petaurista siangensis*)**
Distribution within the state: Upper Siang.
Presence of the species in protected areas: None.
Elevation range of occurrence: 1500 m.
Evidence: None.
IUCN status: Not assessed.
Local status: Not assessed.
Global threats: Not assessed.
Local threats observed as per present study: Not assessed.
Other remarks: The species is described based on the dead specimen. However, molecular studies are required to confirm it as a new species.
Literature: Choudhury (2013b).

12. **Red and White Giant Gliding Squirrel (*Petaurista alborufus*)**
Distribution within the state: Changlang.
Presence of the species in protected areas: Namdapha NP.
Elevation range of occurrence: 200–500 m.
Evidence: Photographs.
IUCN status: Least Concern.
Local status: Not assessed.
Global threats: Not assessed.
Local threats observed in present study: Natural predation.
Other remarks: None.
Literature: Choudhury (2013a).

13. **Namdapha Gliding Squirrel (*Biswamoyopterus biswasi*)**
Distribution within the state: Changlang .
Presence of the species in protected areas: Namdapha National Park (NP).
Elevation range of occurrence: 100–300 m.
Evidence: Museum specimen at ZSI, Kolkata.
IUCN status: Critically Endangered.
Local status: Not assessed.
Global threats: Narrow range increases susceptibility to natural calamities; overharvest.
Local threats observed in present study: Possible hunting and bushmeat collection.
Other remarks: The species is often mistaken for the sympatric *P. petaurista* in Namdapha National Park. The species is very rare and has not been sighted since its discovery in 1981. Moreover, the species is described based on a dead specimen. It is thought to inhabit areas dominated by *Mesua ferrea* trees in the park.
Literature: Saha (1981); Krishna and Kumar (2015).

14. **Yunnan Giant Gliding Squirrel (*Petaurista yunanensis*)**
Distribution within the state: Lower and Upper Dibang Valley, Changlang, Lohit, Tirap and Anjaw.
Presence of the species in protected areas: Namdapha NP and Mehao WLS.
Elevation range of occurrence: 200–500 m.
Evidence: None.
IUCN status: Not assessed.
Local status: Not assessed.
Global threats: Not assessed.
Local threats observed in present study: Hunting for bushmeat.
Other remarks: None.
Literature: Choudhury (2013a).

Threats

Altogether we collected 32 interviews (21 hunters and 11 traditional healers) throughout the study area to understand hunting methods and use of these species. Through interviews, we learned that hunters used air guns and catapults to kill gliding squirrels. Spotlights were used to locate the squirrels in the night. Two species *P. petaurista* and *H. alboniger* were used in traditional medicine and for cultural and religious

Figure 4 – (A) *Hylopetes alboniger*; (B) *Biswamoyopterus biswasi*; (C) *Petaurista nigra* (B and C are specimens from ZSI Kolkata, India).

purposes that include sacrificing the animal. The remaining species are hunted for bushmeat and the skins are displayed as trophies. In Lower Dibang Valley district of the state, gliding squirrels are hunted along with other rodents during the months of March and November immediately pre and post-harvest of crops, and the hunted squirrels are used as a source of bushmeat. In general, throughout the survey area, squirrels were not the primary game species among tribes. Habitat loss was observed as major threat apart from hunting. The major cause for habitat loss in the state is due to shifting cultivation practices along with highway and dam constructions.

Discussion

Diversity

The tropics, especially the regions of South and Southeast Asia, harbour the greatest gliding squirrel diversity that includes many endangered species; however, these species are underrepresented in the literature (Koprowski and Nandini, 2008). Arunachal Pradesh, as a portion of Indian Eastern Himalaya and a global biodiversity hotspot, is inhabited by many gliding squirrels. However, data on diversity, distribution and threats to species are sparse and most of the studies related to diversity are based on the checklists of what occurred historically and through literature or through Conservation Assessment and Management Plan reports (CAMP) (Srinivasulu et al., 2004; Molur et al., 2005; Pradhan et al., 2011).

We observed that gliding squirrels occur throughout the state, especially in Eastern Arunachal Pradesh, where species diversity was highest (14 species); half of these species occur in Namdapha NP. This high diversity might be due to habitat heterogeneity and geographical location (Proctor et al., 1998; Datta et al., 2003). On a whole, the Northeastern region of India harbours 51 Forest habitats that are broadly classified into six major forest types: tropical moist deciduous forests, tropical semi-evergreen forests, tropical wet evergreen forests, subtropical forests, temperate forests and alpine forests. All of these representative forest types occur in Arunachal Pradesh (Hedge, 2000), and the state's location between the Himalayan and Indo-Burmese regions might be the reason for high gliding squirrel diversity. In this study, we confirmed the presence of 11 species. *Petaurista caniceps* and *P. elegans* are considered as distinct species (see Li et al., 2013; Krishna and Kumar, 2015) in the current study along with *P. yunanensis* (Yu et al., 2005). *Biswamoyopterus biswasi* is an endemic, critically endangered species, and occurs in a restricted range in Namdapha NP. Though a few offline reports note their presence in the park, most are the result of confusion with *P. petaurista*, which shares the same habitat (Krishna and Kumar, 2015). Its discovery in the 1980s (Saha, 1981; De et al., 2006) is the only occasion when the species was directly studied (dead specimen), after which it has neither been sighted nor documented (Krishna et al., 2014). *Belomys pearsonii* is distributed in the westernmost part of Arunachal Pradesh (Thorington et al., 2012), but we could not record the species during our surveys. This might be related to the short duration of our surveys, and to the fact that many portions of the state are inaccessible. However, we could trace the presence of the species through hunting reports. *Petaurista elegans* was also not sighted during the study only a specimen collected from Gandhigram region of Namdapha National park is preserved at ZSI, Kolkata (specimen named as *P. sybilla*, Collection No. NM/30). This species might occur in the bordering regions of Myanmar and Arunachal Pradesh.

A few bordering areas of the state were not explored due to border sensitivity issues and risk of night surveys. *Petaurista nobilis*, *P. magnificus* and *H. alboniger* were observed to be distributed widely throughout the state. The recently described species *P. yunanensis* was not observed during the survey but is documented in the mammals of Northeast India (Choudhury, 2013a). The new species *P. mishmiensis* was photographed on several occasions in Mehao Wildlife Sanctuary by several bird watchers and the tails of this hunted species were observed in villages near Hunli in the Upper Dibang Valley. Conspicuous black coloured tails are seen in this species. *Petaurista siangensis* is another new species that was discovered in 2013 by Choudhury (2013b) through skins in Mebo of Upper Siang district. The three new species (*P. mishmiensis*, *P. nigra* and *P. siangensis*) were described based only on skins of dead specimens and confirmation through molecular studies is needed, as the members of genus *Petaurista* show considerable variation in pelage coloration (Thorington et al., 2012; Li et al., 2013).

Status Survey

Few studies exist on the status of gliding squirrels in India, with only two studies from Northeast India, on *P. petaurista* (Radhakrishna et al., 2006; Ray et al., 2006). Encounter rates of *P. petaurista* ranged from 0.85 individuals/km to 0.37 individuals/km in Assam, which is much less than the current study from Namdapha (1.1 individuals/km). The surveys in Namdapha were conducted in areas around forest camps where hunting does not happen, which might be a reason for higher abundance in this region. Another reason for the difference could be due to differences in forest types and duration of study. The studies in

Figure 5 – Skins and Kills – (A) *Petaurista nobilis*; (B) *Petaurista magnificus*; (C) *Hylopetes alboniger*; (D) *Petaurista philippensis*.

Assam were focused on *Nycticebus bengalensis* (Radhakrishna et al., 2006) or did not explore major portions of the study area due to problems with wild elephants (Ray et al., 2006). Similarly, low numbers were detected in Thailand (0.36 individuals/km; Pliosungneon et al., 2010). On the other hand, our results are similar to studies conducted in Taiwan by Lee et al. (1993) (1.21 individuals/km). The encounter rates of most gliding squirrels varied highly among the study sites, which might be due to different forest types and amount of effort invested in surveying along with hunting pressure. However, we do not have ample data to compare our results with other studies. In general, factors like hunting, anthropogenic disturbance, and habitat structure have an impact on the species occurrence. We give details of the encounter rates of gliding squirrels in different parts of the world in Tab. 3 our results generally agree with findings from around the globe.

Threats

Hunting of wildlife is part of the culture of many indigenous communities (Rao et al., 2006) including those in Arunachal Pradesh (Solanki and Chutia, 2004; Aiyadurai et al., 2010; Kumar and Riba, 2015). Squirrels are hunted among the tribal communities in Arunachal Pradesh for bushmeat (personal observation). Hunting of squirrels in Arunachal Pradesh especially of *Ratufa bicolor* and *Dremomys lokriah* occurs for cultural and ethno-zoological use (Dollo et al., 2010; Kumawat et al., 2013; Murali et al., 2014; Singh et al., 2014). In the current study, it was evident that hunting of gliding squirrels was prominent among the tribal communities of the state. In Eastern Arunachal Pradesh, we observed that squirrels, especially *P. petaurista* and *H. alboniger*, were hunted for ethno-zoological use. The tribes refused to share information, however, and informed us that the species were killed historically. Killing of *P. petaurista* for ethno-zoological use was observed in Changlang district, and killing of *H. alboniger* for ethno-zoological use was observed in Anjaw district. A cultural use of *H. alboniger* was observed in east Kameng district of Arunachal Pradesh (see Krishna et al., 2013). Use of rodents in ethno-zoological aspects and for cultural use occurs in other different parts of the world and is not unique to the study area (Azlan et al., 2006; Durojaye, 2008). In Sarawak, Malaysia, tribes hunt the Petauristinae gliding squirrels for ethno-zoological uses; the male squirrel testicles are dried and soaked in oil and applied over the body in the mornings as this is thought to increase a man's libido (Azlan et al., 2006). *Petaurista nobilis* were taken as bycatch in West Kameng district of Arunachal Pradesh, where the species is not the target but is killed when hunters visit the forest to hunt Himalayan black bears (*Ursus thibetanus*).

The lowland tropical rain forests in Northeast India, particularly Arunachal Pradesh, are the most species rich terrestrial ecosystems. Substantial degradation of these rain forests in and outside of protected areas has led to fragmentation (Kumar et al., 2013) which is a major cause of declining squirrel habitat. Large tracts of jungle are cut to expand agriculture and human settlements along with other infrastructure projects like highway and dam constructions. In the state of Arunachal Pradesh, only 18% of the forest area falls under the protected category, and the remaining areas are considered village and community forests and as un-classified forests. These areas are largely used for agriculture and other uses and thus the forest cover is in decline across the state (see Katti et al., 1992; Datta, 1999). Jhum cultivation or sifting cultivation (Arunachalam et al., 2002) in the state has transformed the majority of the primary forests to secondary forests, which is a severe threat to the species as gliding squirrels require tall trees for nesting and movement as well as feeding as they are arboreal in nature.

Conclusions

Large scale molecular and long-term ecological studies are needed in this region due to the high species diversity and the uncertain taxonomic status of some specimen used to describe new species. Many species still do not fall under the Wildlife (Protection) Act, 1972 of India; thus elevating the conservation status of such species (e.g. *H. alboniger*; *P. caniceps*) is necessary for their strict conservation. Also, educational programs to increase awareness need to be conducted at local levels in order to save nocturnal gliders. Local communities should be notified about the importance of gliding squirrels for ecological purposes and tourism, which can be promoted in those areas where their diversity is high. Wildlife tourism has helped in uplifting of local com-

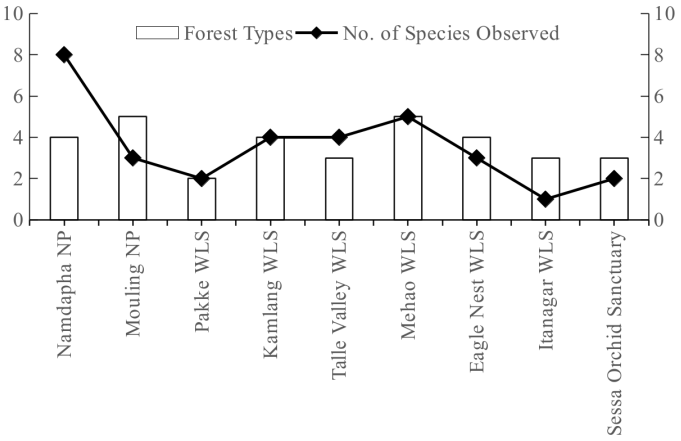

Figure 6 – Number of gliding squirrel species observed in each protected area based on forest type (for forest types see Tab. 1).

Table 3 – Comparative accounts of gliding squirrel encounter rate reported from previous studies.

S. No.	Study site	Species	Encounter rate (individuals/km)	Source
1.	Chitou Experimental Forest	Red giant gliding Squirrel (*P. petaurista*)	0.47 (Conifer Forest) 1.96 (Hardwood forest)	Lee et al. (1993)
2.	Assam and Meghalaya, India	Red giant gliding Squirrel (*P. petaurista*)	0.10–0.77 (Various forest types)	Radhakrishna et al. (2006)
3.	Khao Ang Rue Nai Wildlife Sanctuary, Eastern Thailand	Red giant gliding Squirrel (*P. petaurista*)	0.36 (Primary forest)	Pliosungneon et al. (2010)
4.	Joypore Reserve Forest, Assam, India	Red giant gliding Squirrel (*P. petaurista*)	0.85	Ray et al. (2006)
5.	Namdapha National Park, Arunachal Pradesh, India	Red giant gliding Squirrel (*P. petaurista*)	1.1	Present study
6.	Western Ghats, India	Brown giant gliding squirrel (*Petaurista philippensis*)	0.55	Kumara and Mewa (2004)
7.	Western Ghats, India	Brown giant gliding squirrel (*P. philippensis*)	0.28 (Brahmagiri-Makut) 0.03 (Pushpagiri-Bisale) 0.29 (Sirsi-Honnavara) 1.33 (Nagarahole)	Kumara and Singh (2013)
8.	Western Ghats, India	Brown giant gliding squirrel (*P. philippensis*)	1.5 (Cardamom plantations) 1.29 (Moist deciduous forest) 0.7 (Evergreen forest) 0.3 (Coffee plantations) None (Teak Forest)	Ashraf et al. (1993)
9.	Forest fragments of Western Ghats, India	Brown giant gliding squirrel (*P. philippensis*)	0.1 (forest edges) 3.92 (forest interiors) 5.62 (Coffee plantations)	Nandini and Parthasarathy (2008)
10.	Tropical Deciduous forests, Rajasthan, India	Brown giant gliding squirrel (*P. philippensis*)	0.05	Koli et al. (2013)
11.	Western Ghats, India	Travancore gliding squirrel (*Petinomys fuscocapillus*)	0.18	Kumara and Mewa (2004)
12.	Western Ghats, India	Travancore gliding squirrel (*P. fuscocapillus*)	0.09 (Brahmagiri-Makut) 0.02 (Pushpagiri-Bisale)	Kumara and Mewa (2004)

munities (see Okello et al., 2003), and promoting it would generate income by which the local communities can contribute to a decline in hunting and improve conservation as well. We recommend further studies in those areas where the surveys were not conducted (especially northern parts of the state), as these regions might harbour other species, especially those occurring in the bordering areas of Myanmar and China.

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Supplemental information

Additional Supplemental Information may be found in the online version of this article:

Table S1 Gliding Squirrel diversity in the state of Arunachal Pradesh.
Table S2 Gliding Squirrel diversity in protected areas of Arunachal Pradesh.
Table S3 Local and global threats to gliding squirrels of Arunachal Pradesh.