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COMMUNICATION

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COMMUNICATION

Bat diversity in the Banpale forest, Pokhara, Nepal during spring season

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Abstract: Bat research in Nepal is limited and most areas remain to be explored. Sparse research has been conducted in the Banpale forest and to improve the understanding of bat diversity, an updated species checklist was prepared. Trapping surveys using mist nets were conducted at four different locations in the forest from March to May 2018. This survey identified 55 individuals belonging to eight species within eight genera and four families. Trapping locations near less disturbed forest edges and water resources were found to have higher bat diversity compared to highly disturbed areas (e.g., landslides and logging areas). With information from survey and secondary source, we conclude that Banpale forest harbours 10 of the 53 bat species found in Nepal. We recommend adopting practices to conserve the forest from landslides and minimizing illegal logging to conserve bat forest habitats.

Keywords: Checklist, Chiroptera, edge, habitat, logging, trapping.

Nepali: नेपालमा चमेरा अनुसन्धान केहि अध्ययनमा मात्र सीमित छन् र अधिकांश क्षेत्रहरु अन्वेषण गर्नै बाँकी छन् । वनपाले जंगलमा पनि अनुसन्धानका कार्यहरु अत्यन्तै न्यून हुने गरेकाले हामीले यहाँको चमेरा विविधता बुझ्न चमेरा प्रजातिको सूची अद्यावधिक गरेकाछौं । २०१८ मार्च देखि मे महिनामा वनपाले जंगलको चार विभिन्न स्थानमा मिस्टनेट प्रयोग गरेर गरिएको सर्वेक्षणमा हामीले चार परिवार, आठ जेनेरा तथा आठ प्रजातिका जम्मा ५५ वटा चमेराहरू पकड्यौं । यस अनुसन्धानमा पहिरो तथा वनफँडानी भएका क्षेत्रको तुलनामा मानव हस्तक्षेप न्यून भएका वनको किनारा/छेउ र पानीका मुहान नजिक चमेराका प्रजाति बढी भेटिए । प्राथमिक र द्वितीय श्रोत अध्ययन परिणाम अनुसार नेपालमा पाइने कुल ५३ प्रजाति मध्ये वनपालेमा १० वटा चमेरा प्रजाति पाइने पुष्टि भएको छ । यस अध्ययन अनुसार चमेराको वासस्थान बचाउन वनपाले जंगलमा पहिरो विरुद्ध संरक्षणका अभ्यासहरु अपनाउनुपर्ने तथा अवैध वन विनास नियन्त्रण गर्नुपर्ने देखिन्छ ।

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Author contributions: PKB—research design, data collection, data analysis and interpretation, drafting of manuscript, critical review, and revisions at different stages. BS—conceptualization, methodology design, field work, species identification, critical review, draft review and edit. AN—field works and draft review. SK—field works and draft review. PD—field works and draft review.

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INTRODUCTION

Bats (Chiroptera) are highly diverse (Hutson et al. 2001; Voigt & Kingston 2016) and found throughout the globe, except in the Antarctic and a few oceanic Islands (Mickleburgh et al. 2002). They provide many ecological and economic services such as pollination, seed dispersal, agricultural pest suppression, and material & nutrient distribution (Fujita & Tuttle 1991; Kunz et al. 2011). Of the >1400 species of bats found worldwide (Simmons & Cirranello 2021), 148 are reported from southern Asia (Srinivasulu et al. 2021).

Research and conservation efforts in Nepal's mammals are focused on large flagship vertebrates like tigers, rhinoceros, elephants, and snow leopards, and comparatively limited research has been conducted on small mammals such as bats (Acharya et al. 2010; Khanal & Baniya 2018). Thus, there has been limited evaluation of bat species diversity and status in Nepal (Csorba et al. 1999; Hutson et al. 2001; Molur et al. 2002; Acharya & Ruedas 2007; Baral & Shah 2008; Adhikari 2009; Acharya et al. 2010; Jnawali et al. 2011; Pearch 2011; Thapa 2014). Although the latest checklists enumerated 53 bat species from Nepal (Acharya et al. 2010; Thapa 2010), a few identifications were questioned, e.g., *Sphaerias blanfordi* (Thomas, 1891), *Myotis siligorensis* (Horsfield, 1855), and *Rhinolophus subbadius* Blyth, 1844 (Pearch 2011; Thapa 2014). Similarly, species previously identified as *Philetor brachypterus* (Temminck, 1840) from southern Asia was also revised to be *Mirostrellus joffrei* (Thomas, 1915) (Görföl et al. 2020). While many parts of the country are largely unexplored for bat research, recently a few expedition surveys have documented new species, e.g. , Thapa et al. (2012a) recorded *Scotozous dormeri* Dobson, 1875 from Koshi Tappu Wildlife Reserve; Sharma et al. (2019) recorded *Tylonycteris fulvida* (Blyth, 1859) from Kushma, Parbat and Sharma et al. (2021) recorded *Tadarida teniotis* Rafinesque, 1814 from Kali Gandaki canyon. Incorporating species revisions and recent findings, we ensure a current count of 53 valid bat species in Nepal.

Due to favourable climatic and topographical features, Pokhara has several caves, lakes, gorges, forests, and agricultural farms which provide suitable habitats for diverse bat species (Koju & Chalise 2012). A few exploration attempts were made in Pokhara valley in the late 20th century (Abe 1971; Bates & Harrison 1997; Csorba et al. 1999). Since then, other studies were conducted (Acharya 2006; Phuyal & Dhoubhadel 2006; Rajchal 2007; Adhikari 2008; Giri 2009; Bista 2011; Koju & Chalise 2012; Pokhrel & Budha 2014; Sharma 2016, 2019; Baniya 2018; Sharma et al. 2018a,b; Baniya et al. 2019) but most remain unpublished (e.g., in student theses). Adhikari (2008) and Giri (2009) reported 18 bat species, 16 caves, and two roosting sites of *Pteropus giganteus* (Brünnich, 1782) from the Pokhara valley. Pokhrel & Budha (2014) studied food habit of insectivore species from Mahendra cave. Sharma (2016) conducted diet analysis of *Pteropus giganteus* from Chinnedanda and later Sharma et al. (2018b) reported colony shift to new location, Shantiban Batika. Recently, two bat species—*Eonycteris spelaea* (Dobson, 1871) and *Rhinolophus luctus* Temminck, 1834—were recorded for the first time in western Nepal from the Banpale forest (Sharma et al. 2018a; Baniya et al. 2019). Further, colony monitoring and effects of visitor disturbances on *Hipposideros armiger* (Hodgson, 1835) have been studied in a bat cave, Pokhara (Baniya 2018; Sharma 2019). Although research and conservation attempts were made for bats of the Pokhara valley, actual species richness is still unknown and requires enumeration.

As Banpale forest lies within the boundary of the Institute of Forestry, Pokhara, it has been a hub for wildlife research and training programs. A few camera trapping, butterfly, and bird surveys have been conducted in the forest (Lama et al. 2013; Panthee et al. 2018, 2019); however, extensive research predominantly focusing on chiropterans is limited. Few occasional trapping and acoustic surveys were conducted in the forest (e.g., Daniel 2007a,b; Adhikari 2008; Giri 2009; Lama et al. 2013; Bhattarai 2019). These studies documented a few bat species: *Cynopterus sphinx* (Vahl, 1797), *Pteropus giganteus*, *Rhinolophus affinis* Horsfield, 1823, *Rhinolophus subbadius*, *Kerivoula picta* (Pallas, 1767), *Pipistrellus pipistrellus* (Schreber, 1774), *Pipistrellus coromandra* (Gray, 1838), *Miniopterus pussilus* (Dobson, 1876). This study was carried out to assess bat species diversity and update the valid bat checklist in the Banpale forest.

MATERIALS AND METHODS

Study area

The study was conducted in Banpale forest, Institute of Forestry, Pokhara, Tribhuvan University (28.18°N, 83.99°E), south-west of Pokhara metropolitan city-15. The institution covers 15ha of campus premises and 31.85ha of forest patches. The study site ranges from 750–915 m (Figure 1). Banpale forest is pristine subtropical mixed forest dominated by *Schima wallichii* and *Castanopsis indica*. Other species include, *Madhuca*

indica, *Diospyrus melabaricum, Dalbergia sisso*, *Michelia champaca*, *Bambusa* sp., and *Albizia* sp. A total of 112 florae species have been reported from the area (Bhatta 2011). It is surrounded by the agricultural and grazing lands, shrubs & human settlements in the north, south & east, and gorges, crevices, rocky slopes, river & landslide areas in the west. Average daily temperature in the valley ranges 25–33 °C in summer and -2–15 °C in winter (Kansakar et al. 2004) and receives mean annual precipitation of <3,000mm (Khanal 1995).

Methods

Trapping survey

The forest was divided into four different trapping sites; site A (28.188^{0}N, 83.988^{0}E), site B (28.186^{0}N, 83.990^{0}E), site C (28.186^{0}N, 83.989^{0}E), and site D (28.192^{0}N, 83.984^{0}E), and surveyed randomly once in 15 days from 15 March to 15 May 2018. In each site, two sizes of mist-nets (height 2.6m, length 4m and 6m, and 38mm mesh) were deployed >30cm from the ground level. Mist-nets were left open from 18.00 to 22.00 h with continuous inspection at 10-minute intervals to avoid serious entanglement of captured bats.

Morphometric measurement of bats

Vernier calipers (0.01mm accuracy) were used to record external morphometric measurements. The measurements taken include the head and body length (HBL), forearm length (FA), ear length (EL), tail length (TL), hind foot length (HF), and tibia length (TIB) (Bates & Harrison 1997). The body weight (BW) was measured using a pesola spring balance (1g accuracy). Bats were released after identifying their sex and age (Kunz & Parsons 2009) and capturing a few close up photographs with minimal disturbance. Aggressive and difficult to handle bats were released as soon as possible after identification. No voucher specimens were collected and no genetic analysis was performed during the study.

Identification of bats

Captured individuals were observed for key morphological characteristics. Identification was based on the morphological measurements (Table 1) and comparing photographs using available reference guides

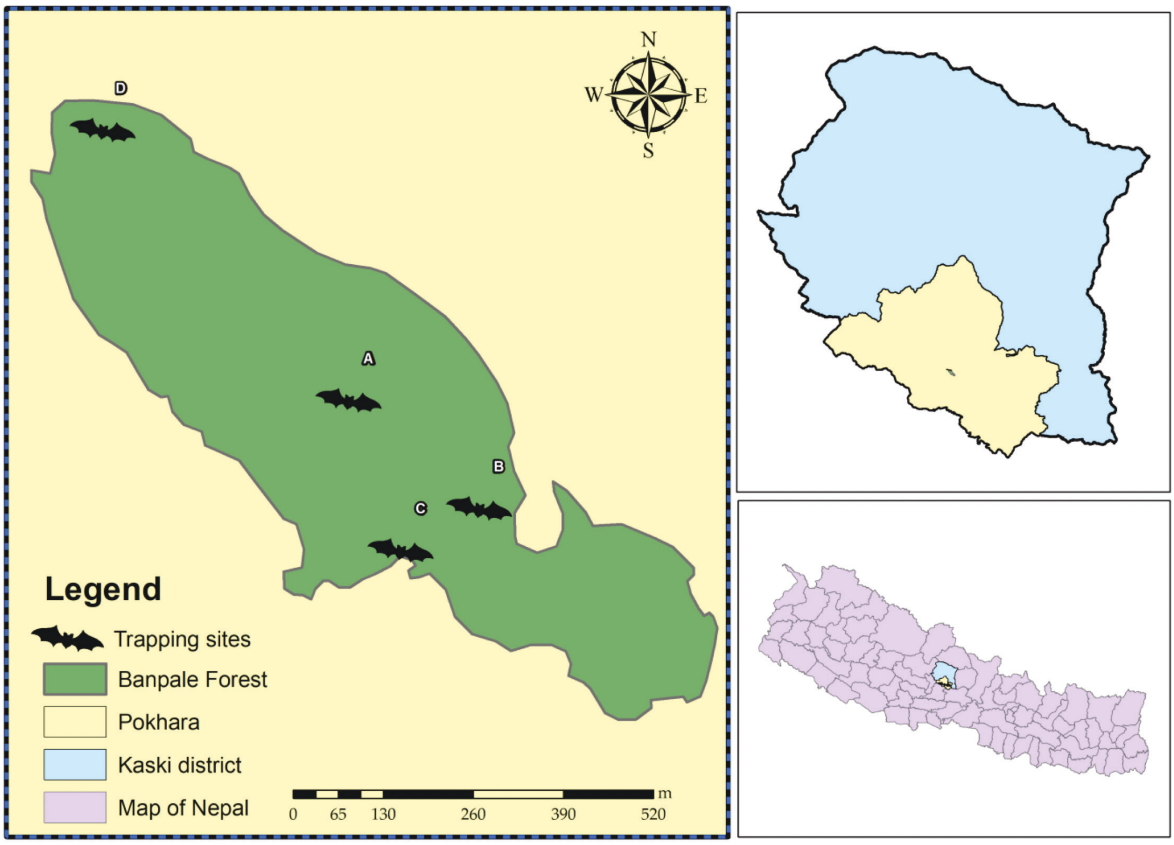

Figure 1. Map of study area showing four different sites at Banpale forest, Pokhara, Nepal. Note: A, B, C, D indicates different trapping sites inside Banpale forest where "A" is near the water resource in the middle of the forest; "B" is forest trail near the edge between forest, college quarter, and nursery; "C" is edge between forest and human settlements and "D" is near a landslide area.

and morphological keys (Bates & Harrison 1997; Acharya et al. 2010; Srinivasulu et al. 2010; Menon 2014).

Secondary data collection

Several published and unpublished reports, journal articles, newsletters, student thesis, and websites were reviewed to update the valid bat checklist in the Banpale forest.

Data analysis

Shannon diversity index (*H*) (Shannon & Wiener 1949) was calculated to understand species diversity in different trapping sites.

Shannon index (*H*) $= -\sum p_i lnp_i$

Where $p_i = \frac{S}{N}$

S = Number of individuals of one species
N = Total number of individuals captured
In = Logarithm to base e

Pielou's evenness (*J*) was calculated to compare the actual diversity value (the Shannon index, *H*) to the maximum possible diversity value (when all species are equally common, $H_{max} = InS$).

$$J = \frac{H}{H_{max}} \text{ Or } \frac{H}{InS}$$

Where *H* = Shannon index value
H_{max} = Maximum possible diversity value
S = Total number of species

RESULTS

Altogether 55 individuals were captured from four family and eight genera. Among them, eight bat species were identified while 10 individuals of *Pipistrellus* sp. remained unidentified to species level (Table 1, 2). Most of the captured species belonged to family Pteropodidae (3) and Vespertilionidae (3), followed by Rhinolophidae (2); only one species of Hipposideridae was recorded (Table 1). *Cynopterus sphinx* was the most captured (42%) followed by *Pipistrellus* sp. (18%), *Rousettus leschenaultii* (13%), *Hipposideros armiger* (9%), *Rhinolophus affinis* (9%), and *Nyctalus noctula* (3.6%); *Eonycteris spelaea*, *Rhinolophus luctus*, and *Myotis sicarius* were each captured once (Table 2). Although *Pteropus giganteus* was uncaptured, it was observed travelling to fruiting sites through the edge of Banpale forest around 18.45h hours during the study period.

Most of the bats were captured from site A (49%) followed by site B (36%), whereas only 9% of bats were captured from site C, and lowest 5.5% from site D (Table 2). Although site B was the second most captured site, bat diversity and evenness were highest among other sites (*H*= 0.37, J= 0.17) followed by site A (*H*= 0.35, J= 0.16), site C (*H*= 0.22, J= 0.10), and lowest in site D (*H*= 0.16, J= 0.07) (Table 2). The overall bat diversity of the forest was 1.1 and evenness was 0.5 (Table 2).

Based on the survey and literature review, the study confirmed and updated checklist of 10 bat species from the Banpale forest (Table 3). Out of these, four species are Pteropodidae belonging to four genera (*Cynopterus*, *Eonycteris*, *Pteropus* and *Rousettus*), three are Vespertilionidae with three genera (*Pipistrellus*, *Myotis* and *Nyctalus*), two are Rhinolophidae with genera *Rhinolophus*, and one Hipposideridae with genera Hipposideros (Table 3).

DISCUSSIONS

Of 10 bat species identified in this study, all (4) fruit bat species of Nepal were documented from the Banpale forest. At least one fruit bat was captured from each trapping site, reflecting their high activity in the forest. *Cynopterus sphinx* was captured the most, whereas *Eonycteris spelaea* was captured only once. Apart from forest vegetation, Banpale is also surrounded by several varieties of fruits inside the Institute of Forestry premises, e.g., *Diploknema butyracea, Diospyros malabarica, Psidium guajava, Magnifera indica, Bombax ceiba, Elaeocarpus sphaericus, Litchi chinensis, Musa* sp., *Oroxylum indicum* and *Neolamarckia cadamba.* These fruit plants are the most preferable diet for fruit bats in Nepal (Sharma 2016), whereas species like *Musa* sp., and *Schima wallichii*, abundant in the forest, are preferred roosts for the tent making bat, *Cynopterus sphinx* (Acharya et al. 2010). As *Pteropus giganteus*, whose nearby colony is 3.1km away, was observed travelling through the edge of the forest for foraging, perhaps cave dwelling bat species; *Rousettus leschenaultii* and *Eonycteris spelaea* also use Banpale forest as foraging route, as there is no cave in the forest (Sharma et al. 2018a). Similarly, the foliage roosting bat *Cynopterus sphinx* may use the forest as roosting site, since it has smaller foraging range (Marimuthu 1998; Nair et al. 1999) and was previously recorded roosting in *Schima wallichii* in the forest (Giri 2009). The forest vegetation is likely to host suitable roosting sites for this species. Hence, the varieties of food resources around

Table 1. Morphometric measurements of captured bats from the Banpale forest, Pokhara, Nepal. Range value (r), mean value (m) and standard deviation (sd) value of each morphometric measurements (in mm); forearm length (FA), head-body length (HBL), hindfoot length (HF), ear length (EL), tail length (TL), tibia length (TIB), and body weight (BW) (in gm) of each species is provided in brief. "n" indicates total number of individuals measured and remarks includes key identifying feature of the species.

	Pteropodidae			Rhinolophidae		Hipposideridae	Vespertilionidae		
Species **Measurements**	*Cynopterus sphinx* (n= 23)	*Eonycteris Spelaea* (n= 1)	*Rousettus leschenaultii* (n= 7)	*Rhinolophus affinis* (n= 5)	*Rhinolophus luctus* (n= 1)	*Hipposideros armiger* (n= 5)	*Nyctalus noctula* (n= 2)	*Myotis sicarius* (n= 1)	*Pipistrellus* sp. (n= 10)
FA	r= 59.3–69.3 m= 64.9 sd= 3.6	71.3	r= 75.1–84.2 m= 79.1 sd= 4.0	r= 52.3–53.8 m= 52.9 sd= 0.7	70.5	r= 83.7–86.5 m= 84.8 sd= 1.3	r= 53.5–55.3 m= 54.4 sd=1.3	46.4	r=2 7.8–28.8 m= 28.3 sd= 0.4
HBL	r= 83.1–99.6 m= 91.7 sd= 5.4	99.5	r= 95.5–114.2 m= 104.4 sd= 8.1	r= 60.7–62.9 m= 61.6 sd= 1.0	81.7	r= 91.5–94.6 m= 92.5 sd= 1.4	r= 72.5–73.2 m= 72.9 sd= 0.5	57.0	r= 40.2–44.9 m= 42.9 sd= 2.0
HF	r= 10.5–14.1 m= 11.9 sd= 1.2	17.9	r= 15.1–17.3 m= 16.1 sd= 0.8	r= 7.9–9.3 m= 8.4 sd= 0.8	16.3	r= 13.1–15.1 m= 13.9 sd= 0.9	r= 10.1–10.5 m= 10.3 sd= 0.3	15.8	r= 5.1–5.8 m= 5.4 sd= 0.3
EL	r= 18.3–24.1 m= 21.3 sd= 2.1	19.9	r= 14.5–18.8 m= 17.1 sd= 1.6	r= 13.9–15.5 m= 14.6 sd= 0.8	34.2	r= 24.1–29.7 m= 26.3 sd= 2.5	r= 14.1–14.8 m= 14.5 sd= 0.5	15.0	r= 8.1–9.5 m= 8.8 sd= 0.6
TL	r= 7.7–18.1 m= 12.0 sd= 3.4	10.6	r= 9.8–14.3 m= 12.5 sd= 1.9	r= 22.1–24.5 m= 23.1 sd= 1.1	40.2	r= 52.8–56.8 m= 54.2 sd= 1.8	r= 42.9–45.1 m= 44.0 sd= 1.6	56.5	r= 27.5–30.1 m= 28.7 sd= 1.0
TIB	r= 25.1–28.5 m= 27.3 sd= 1.2	29.5	r= 35.1–41.6 m= 38.7 sd= 2.5	r= 22.8–24.1 m= 23.3 sd= 0.6	36.8	r= 36.6–40.8 m= 38.3 sd= 2.0	r= 19.3–19.7 m= 19.5 sd= 0.3	17.4	r= 10.6–11.5 m= 11.0 sd= 0.4
BW	r= 38.3–78.1 m= 61.7 sd= 13.1	68.0	r= 85.5–98.1 m= 90.9 sd= 4.4	r= 15.4–16.3 m= 15.8 sd= 0.4	31.4	r= 52.5–55.6 m= 53.9 sd= 1.4	r= 23.5-24.3 m= 23.9 sd= 0.6	11.2	r= 9.6–11.6 m= 10.4 sd= 0.8
Remarks	presence of white ear margin on both sides of ear.	presence of anal glands; absence of claw on second digit.	presence of claw on second digit; pinnae margins less marked than *C sphinx.*	ear is short, horseshoe is broad.	presence of circular basal lappets; long, dark and woolly pelage.	presence of four supplementary leaflets in noseleaf with outer leaflet distinctively smaller.	larger than other species of *Nyctalus*, ear is short and tragus is club shape.	hair tips at the belly are ginger in colour.	naked muzzle, ear is short and broad, antitragus is obsolete.

Table 2. Comparison of species abundances and bat diversity in four different trapping sites at Banpale forest; A, B, C and D. "m" represents total number of male captured, "f" as female captured and "j" as juvenile. "0" indicates no capture.

Sites **Species**	**A**	**B**	**C**	**D**	**Total**	**Relative abundance (%)**
Cynopterus sphinx	11	8	2	2	23 (m= 8, f= 12, j= 3)	41.81
Eonycteris spelaea	0	1	0	0	1 (m= 1)	1.82
Rousettus leschenaultii	4	2	1	0	7 (m= 3, f= 3, j= 1)	12.73
Rhinolophus affinis	2	2	0	1	5 (m= 3, f=2)	9.09
Rhinolophus luctus	1	0	0	0	1 (m= 1)	1.82
Hipposideros armiger	3	2	0	0	5 (m= 3, f= 2)	9.09
Nyctalus noctula	1	1	0	0	2 (f= 2)	3.64
Myotis sicarius	0	1	0	0	1 (f= 1)	1.82
Pipistrellus sp.	5	3	2	0	10 (m= 4, f= 5, j= 1)	18.18
Total	27	20	5	3	55	100
Capture percent (%)	49.09	36.36	9.09	5.45		
Diversity (*H*)	0.35	0.37	0.22	0.16		
Evenness (*J*)	0.16	0.17	0.10	0.07		

Table 3. Updated bat checklist of Banpale forest, Institute of Forestry, Pokhara, Nepal. "LC" indicate least concern, "DD" as data deficient, and "VU" as vulnerable.

	Species name	Common name	Nepali name	Family	IUCN status	National status	Sources
1	*Cynopterus sphinx*	Greater Short-nosed Fruit Bat	नेप्टे चमेरो	Pteropodidae	LC	LC	this study; Giri 2009; Bhattarai 2019
2	*Eonycteris spelaea*	Dawn Bat	मिर्मिरे चमेरो	Pteropodidae	LC	DD	this study; Sharma et al. 2018a
3	*Pteropus giganteus*	Indian Flying Fox	वदुरा, राज चमेरो	Pteropodidae	LC	LC	this study
4	*Rousettus leschenaultii*	Leschenault's Rousette	सानो वदुरा	Pteropodidae	LC	LC	this study
5	*Rhinolophus affinis*	Intermediate Horse-shoe Bat	मझौला घोड्नाले चमेरो	Rhinolophidae	LC	LC	this study; Giri 2009
6	*Rhinolophus luctus*	Great Woolly Horse-shoe Bat	मखमली घोड्नाले चमेरो	Rhinolophidae	LC	LC	this study; Baniya et al. 2019
7	*Hipposideros armiger*	Great Himalayan Leaf-nosed Bat	ठुलो गोलोपत्रे चमेरो	Hipposideridae	LC	LC	this study; Adhikari 2008
8	*Nyctalus noctula*	Common Noctule	गन्धे चमेरो	Vespertilionidae	LC	DD	this study
9	*Myotis sicarius*	Mandelli's Mouse-eared Bat	मंडेलिको मुसाकाने चमेरो	Vespertilionidae	VU	VU	this study
10	*Pipistrellus coromandra*	Coromandel Pipistrelle	बुच्चे चमेरो	Vespertilionidae	LC	LC	Daniel 2007a,b

Banpale could be the key reason for high species capture from family Pteropodidae and availability of roosting vegetation for most capture of *Cynopterus sphinx.* The only record of *Eonycteris spelaea* could be due to rarity; it is 'Data Deficient' in the National Red List (Jnawali et al. 2011) and occasionally reported from Nepal (Sharma et al. 2018a).

Of the six insectivorous bat species, three belong to the Vespertilionidae family, two to Rhinolophidae, and one to Hipposideridae. Although *Pipistrellus* sp. has remained unidentified, we can extrapolate the unidentified species to be *Pipistrellus coromandra*, previously recorded in the forest by Daniel (2007a,b); however, its morphological measurements, distribution ranges, and echolocation parameters overlap with *Pipistrellus javanicus* (Srinivasulu et al. 2017). Further genetic analysis or cranio-dental characteristics is required for confirmation. It is also the most captured insectivore. High capture from the forest could be due to its diverse roosting and feeding habits; as it is found to roost in a wide variety of roost sites such as tree cavities, buildings, rock cervices, cracks in walls, beneath slates, and within cavity walls (Avery 1991; Jenkins et al. 1998), which are prominent in and around the forest and provide varied habitats (Russo & Jones 2003). Other two vesper bat species were *Nyctalus noctula* and *Myotis sicarius. Nyctalus noctula* is a high elevation bat (Acharya et al. 2010) and little is known about its distribution, hence it is considered 'Data Deficient' in the National Red List (Jnawali et al 2011). Seasonal migration is common to some high elevation bats, especially to the female population to escape from seasonally harsh weather conditions, scarcity of foods, and to find suitable roosts in milder climate (Fleming & Eby 2003). Female *Nyctalus noctula* also undergo seasonal migration in the lower elevational regions during winter (Furmankiewicz & Kucharska 2009). Here both captured females during March suggest they could be migratory individuals. Likewise, *Myotis sicarius* is 'Vulnerable' globally (Srinivasulu & Srinivasulu 2019) as well as nationally (Jnawali et al. 2011) and endemic to southern Asia (Bates & Harrison 1997). It is generally found in hilly forests and faces massive threats due to habitat alterations and deforestation, and hence is only known to be present in protected areas and forests (Molur et al. 2002). Low capture of these two species could be due to their rarity. Even though *Hipposideros armiger* and *Rhinolophus affinis* are mainly cave dwellers, a few individuals were captured from the forest. Both of these species are widespread throughout Nepal, roost on a wide variety of sites (caves, tunnels, old houses, and temples; Acharya et al. 2010), and feed on a diverse array of insects (Zubaid 1988). As there is no cave in the forest, they might use tree cavity or rock cervices as a roosting site or use the forest as a foraging ground. Only one individual of *Rhinolophus luctus* was captured throughout our study period. It is solitary and roosts in several roost types; old houses, tree cavities, tunnel, mines, holes, and caves (Csorba et al. 2003; Baniya et al. 2019). Perhaps due to its lone roosting behavior and variety of preferred habitats, it was captured only once from the forest. Further, the availability of roost sites

and high insect abundance (Racey & Swift 1985; De Jong & Ahle´n 1991; Jenkins 1998) could be the main reason for the presence of these insectivorous bats in the forest.

Bat species diversity and richness were unevenly distributed within the Banpale forest. Site B was the most diverse with eight species recorded, followed by Site A with seven, while sites C and D had three and two species, respectively. Site B is located in the forest trail near the edge between forest, college quarter, and nursery site, and is relatively less disturbed compared to sites C and D. Likewise, site A was near the water resource in the middle of the forest, which may account for high bat density. Anthropogenic disturbances such as illegal logging were prominent in site C (edge between forest and human settlements), and site D was located near a landslide area which may account for low bat diversity. In consonance with these findings, bat diversity was also found to decrease due to logging activities (Danielsen & Heegaard 1995; Brosset et al. 1996; Clarke et al. 2005; Meyer et al. 2016; Sharma et al. 2018b), and landslides (Vanlalnghaka 2013). Bat species diversity and composition in forests have been studied from different parts of the world (Korad et al. 2007; Loayza & Loiselle 2009; Shafie et al. 2011; Thapa et al. 2012b; Deshpande 2012; Korad 2014, 2018; Tshering et al. 2020).

Revision of bat species from the Banpale forest

A few species have previously been reported from the Banpale forest. Daniel (2007a,b) reported *Pipistrellus coromandra,* and later Adhikari (2008) supported this finding. Giri (2009) reported *Cynopterus sphinx*, *Rhinolophus affinis*, and *Pipistrellus pipistrellus;* however, the existence of *Pipistrellus pipistrellus* has not been documented from Nepal (Acharya et al. 2010; Thapa 2014); moreover, occasionally reported from southern Asia (Hutson et al. 2008). This report lacks photographic evidence, and we suggest the species identified could have been *Pipistrellus coromandra*, reported earlier by Daniel (2007a,b). *Cynopterus sphinx* was reported earlier by Bhattarai (2019) as well as Baniya et al. (2019) and this study also supports the record of both *Cynopterus sphinx* and *Rhinolophus affinis* from the forest. Lama et al. (2013) reported *Rhinolophus subbadius*, *Kerivoula picta* and *Miniopterus pussilus* based on unpublished secondary data. An occurrence of *Rhinolophus subbadius* is doubtful from Nepal (Csorba et al. 2003; Thapa 2014). *Kerivoula picta* has been recorded only from two locations, Chitwan and Shuklaphanta national parks (Myers et al 2000; Poudyal et al. 2019), and most probably distributed in lower elevated areas of Nepal, i.e., Terai regions. *Miniopterus pussilus* is 'Data Deficient' nationally (Jnawali et al. 2011) but recorded from Pokhara valley (Bates & Harrison 1997). Due to unpublished sources, lack of photographic evidence, and taxonomic details, we also doubt the record of these species from the forest. *Pteropus giganteus* was observed flying through the edge of the forest; foraging in the forest, and an electrocuted individual was also sighted inside the campus premises. Further, *Rousettus leschenaultii* was recorded by Acharya, P.R. (as personal communication), *Eonycteris spelaea* by Sharma et al. (2018a) (part of this study), and *Rhinolophus luctus* by Baniya et al. (2019). Both *Rousettus leschenaultii* and *Rhinolophus luctus* were also recorded during our study period. Here, we represent the first record of *Eonycteris spelaea* from the Banpale forest and western Nepal as well as fourth record for the country (Sharma et al. 2018a); the first record of *Nyctalus noctula* and *Myotis sicarius* from the Banpale forest and second record from the Pokhara valley; previously recorded at Sudame by Csorba et al. (1999); the first record of *Hipposideros armiger*; second record of *Rousettus leschenaultii* and *Rhinolophus luctus* from Banpale forest. The record of these species from the forest indicates that they might have been overlooked during previous mammal researches or sparse and inconsistent bat surveys in the forest. All of these findings sum up a total of 10 bat species from the Banpale forest.

CONCLUSION

Comprehending our study and data, we can generalize the Banpale forest to be rich in bat diversity harbouring either roosting habitat or foraging grounds for both fruit dependent as well as insect dependent bats. Availability of fruits, good insect abundance, and the presence of edges, water resources, crevices, and cavities might be a vital reason for high bat diversity in the forest. Based on survey efforts and literature, we confirmed the record of 10 species of bats in the forest, indicating relatively high density in terms of its geographic extent. Bat diversity in the forest was noted to vary among sites, with maximum diversity near the forest edge, water resources and less disturbed areas, and lower diversity in the landslide and logged areas. Hence, this study recommends the campus committee adopt practices to conserve the forest from landslides and minimize illegal logging. This study did not capture bats from high tree canopies nor record echolocation calls, and was limited to only two months. Surveying of bats throughout the year with the

Image 1. *Eonycteris spelaea*

Image 2. *Rousettus leschenaultii*

Image 3. *Cynopterus sphinx*

Image 4. *Pteropus giganteus*

Image 5. *Rhinolophus luctus*

Image 6. *Rhinolophus affinis*

Image 7. *Hipposideros armiger*

Image 8. *Myotis sicarius*

Image 9. *Nyctalus noctula*

Image 10. *Pipistrellus* sp.

use of trapping as well as acoustic devices will provide a better understanding of seasonal species composition in the forest, and can lead to new information and findings to guide conservation efforts.

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