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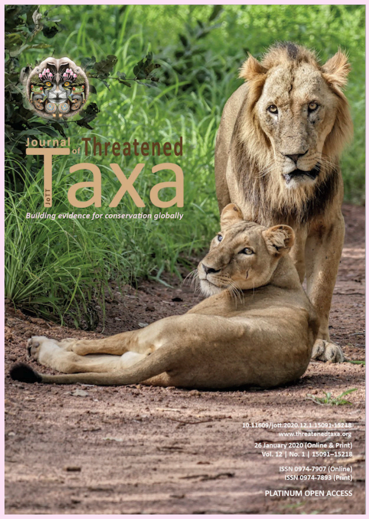

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COMMUNICATION

Bat (Mammalia: Chiroptera) diversity, dominance, and richness in the southwestern region of Bhutan with three new records for the country

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Abstract: Bats are ecologically crucial as they are good pollinators and pest controllers, but are less known in Bhutan. We investigated bat diversity and richness in broadleaved forests of southwestern Bhutan. Fieldwork was carried out from July 2016 to April 2017 using mist nets and hoop nets. The main objective of the study was to document bat diversity and species richness. We captured 157 bats of 10 species belonging to four families. Two species (*Myotis siligorensis* Horsfield, 1855 and *Rhinolophus affinis* Horsfield, 1823) accounted for almost 52% of the total captures. Species richness of bats differed depending upon habitat types. *Myotis siligorensis* was captured more often from broadleaved forests whereas *Rhinolophus macrotis* Blyth, 1844 and *Rhinolophus affinis* were common around human settlements. The present study contributed three new records for Bhutan which increased the bat diversity from 65 to 68 species. We conclude that the southwestern region, especially Chukha District, could be one of the bat diversity hotspots in Bhutan.

Keywords: Chiroptera, Chukha, Dagana, *Myotis*, *Rhinolophus*, Samtse, species richness.

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Competing interests: The authors declare no competing interests.

Author submission: Hoop nets were used with precaution and extra care not to injure/harm bats during the study. No accidental death occurred during the whole study period. We now understand that the use of hoop nets is unethical. We will not repeat this in future bat studies.

Author Details: Sangay Tshewang's research interests are in bat conservation and environment science. Dr. Dhan Bahadur Gurung's research interests are in the areas of ecotourism and taxonomy with special focus on orchids, reptiles, and fishes. Karma Sherub's research interest includes studies of mammals and birds and he is pursuing a study on bird diversity and behaviour. Dr. Sumit Dookia's current research includes habitat use by bats in urban environments with special reference to metropolitan areas of Delhi as well as the bat fauna of northern India, Rajasthan, Haryana, and Delhi. Kuenzang Dorji is a wildlife biologist with special interest in small mammals. Dr. Pema Choephyel is interested in environment conservation and ecology.

Author Contribution: ST developed the concept, collected data and wrote the draft. DBG improved the draft and finalized the paper. KS, SD, KD and PC provided valuable comments in improving the documents and assisted in species identification.

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INTRODUCTION

Chiroptera are unique and true flying mammals consisting of more than 1,300 species worldwide (Fenton & Simmons 2014). They are divided into 18 families in two unequal suborders–Yinpterochiroptera and Yangochiroptera. The Yinpterochiroptera or Pteropodiformes is a suborder of Chiroptera which includes six families: one family of fruit bats Pteropodidae, formerly known as Megachiroptera and five families comprising of Rhinopomatidae, Rhinolophidae, Hipposideridae, Craseonycteridae, and Megadermatidae. The Yangochiroptera or Vespertilioniformes is a proposed suborder of Chiroptera that includes 12 families, most of which were previously classified as Microchiroptera (Srinivasulu et al. 2010).

Bats constitute the second most diverse order of mammals (Korad et al. 2007). They represent about one-fifth of the 5,418 known mammal species (Lumsden 2004; Rajchal 2007). Bhutan has recorded 65 species which constitutes 33% of all mammal taxa of which nine species are fruit bats and 56 species are insectivorous belonging to five families (Marimuthu 2009). The most common group of bats in Bhutan is the evening bats (Vespertilionidae) with 34 species (Wangchuk et al. 2004; Choden 2009).

Species richness, diversity and distribution of bats have been well studied in many parts of the Indian subcontinent such as in the Western Ghats, Uttarakhand, and parts of Marathwada region of Maharashtra (Korad et al. 2007; Korad 2014; Sayyed 2016; Chakravarty 2017), in Kathmandu Valley of Nepal (Thapa et al. 2012) as well as in Malaysia (Shafie et al. 2011; Hanif et al. 2015). These studies added detailed information about species. In Bhutan, such studies are lacking and absence of baseline data has further impeded our understanding of bat species richness, diversity and ecological benefits. Conservation of small mammals such as bats has gained focus worldwide as they have their own ecological roles to play as pollinators, seed dispersers, and pest controllers.

The surveys by Salvo et al. (2009), Korad et al. (2007) and Raghuram et al. (2014) have added wide information about bat habitat preferences, species richness, and disturbances. Threats to bats have also been studied by Rajchal (2007) and Acharya & Adhikari (2010). In the context of Chukha District, such information is lacking despite the area having undergone rapid socio-economic development due to peoples' choice of modern development projects over biodiversity conservation. The lack of baseline information calls for an urgent need to generate data on bat species richness and diversity.

MATERIALS AND METHODS

Study area

The study area covers the southwestern districts of Samtse and Dagana including Chukha covering an area of about 1,802km^2. The area is predominantly covered by mixed broadleaved forest. It is situated between 27.117^{0}N and 89.783^{0}E (Figure 1) with elevations ranging 200–3,500 m. The landscape comprises of complex geomorphologic features with caves, rocky outgrowths and also man-made tunnels which are ideal roosting habitats for bats.

It was reported that the study area is home to a number of bat species such as Eastern Bent-winged Bat *Miniopterus fuliginosus* Hodgson, 1835, Intermediate Horseshoe Bat *Rhinolophus affinis* Horsfield, 1823, and Blandford's Fruit Bat *Sphaerias blanfordi* Thomas, 1891(Chakraborty 1975; Bates et al. 2008; Chiozza 2008; Hutson et al. 2008; Walston et al. 2008).

Chukha District has undergone rapid land use changes due to peoples' choice of modern development activities resulting in increased threats and disturbances to the bat populations and their habitats. Despite the area having high economic value to the country, it has also major conservation issues and challenges due to ongoing hydropower projects, industries, mining, and other development activities. These projects have huge environmental impacts in terms of habitat disturbance, fragmentation, and environmental pollution.

Field sampling

We divided the region into five major habitat types (forest, cave, settlement, stream, and abandoned house). Further, it was divided into four elevation categories (<1,500, 1,500–2,500m, 2,500–3,000m and >3,000m) to study the presence or absence of bats in different elevation zones. Thirty-four sites were sampled with elevations ranging from 200–3,500 m. The sites were visited twice in each season, i.e., monsoon and winter as it is important to sample same sites in different seasons to assess the bat density and diversity of the region more appropriately.

Species richness and diversity of bats

Mist netting was carried out in sampling sites at various habitat types (forest, streams/water bodies, settlement) to investigate species diversity and habitat use. To avoid injury to bats, mist nets were monitored

Figure 1. Study area.

by the field assistant all the time. Two to three mist nets of 6m and 9m length with 2.5m height of three to five shelves were erected as nets were found more successful in capturing bats in dense forest. Mist nettings began before dusk with the use of bamboo and tree poles. Since bats use vertical stratification and forage at various heights to reduce food competition, finding the right spot for erecting the mist nets was crucial for successful capture.

In general, capture success was enhanced when nets were put at natural flyways such as across forest trails. Since the study area had dense forest cover, there are chances that certain species may not have been captured at all.

Bat trappings were carried out mostly for five hours after dusk depending on capture success and weather conditions. The study was carried out from July 2016 to April 2017 in an effort of 147 trapping nights (768 mistnet hours). Four to five field assistants were involved every night to monitor the mist nets. In addition, a hoop net was used to capture species in habitats such as abandoned houses and caves. To determine bat species richness, dominance and diversity, the following indices were assessed: (1) Shannon-Wiener diversity index (H') (Shannon & Wiener, 1949), (2) Simpson's index (D), (3) Pielou's evenness (J) and (4) Margalef's index for species richness (R) (Margalef 1958).

Shannon index $(H') = -\Sigma Pi \ln Pi$
Where $Pi = S/N$
S = Number of individual of one species
N = Total number of all individuals in the sample
ln = Logarithm to base e

$$\text{Simpson's index } D = \frac{\Sigma ni(ni-1)}{N(N-1)}$$

Where N = Total number of all organisms
n_i = Number of individuals of each individual species.

Pielou's evenness (J) compares the actual diversity value (such as the Shannon-Wiener index, H') to the maximum possible diversity value (when all species are equally common, Hmax=lnS where S is the total number of species). For Shannon-Wiener index, the Pielou's evenness (J) was used:

$$J = H'/H_{max} \text{ or } H'/\ln S$$

Where H' = Shannon Wiener index value

Hmax = Maximum possible diversity value

S = Total number of species

$$\text{Margalef's index } (R) = S - 1 / \ln(N)$$

Where S = Total number of species in the sample

ln = Logarithm to base e

N = Total number of all individuals in the sample

Morphometric measurement of bats

The live-trapped bats were carefully removed from mist nets and kept in cloth bags for morphometric measurements and identification. Using a Pesola spring balance (100g), weights of each individual were measured. The sex and age group of bats were recorded by classifying into juvenile or adult (Kunz & Parsons 2009; Kangoyé et al. 2015). Measurements were taken to the nearest 0.1mm accuracy using SPI dial calipers (Bates & Harrison 1997; Ith et al. 2015; Chakravarty 2017). Morphometric measurements included: HBL (head body length) following Soisook et al.(2016), Ear length (EL) from lower margin to tip of ear, FA (length of forearm including carpals), Tibia (TIB), and HF (hind foot including claws) as per Kangoyé et al. (2015). The length of metacarpals was taken excluding carpals. Measurements were taken immediately after capture at the study sites to assist identification.

Identification of bats

Bats were identified based on morphological measurements (Table 1) and qualitative characters by comparing photographs taken and using available morphological keys. The majority of the bats were identified based on available reference guides and keys (Bates & Harrison 1997; Csorba et al. 1999; Acharya & Adhikari 2010; Srinivasulu et al. 2010; Menon 2014). For species which could not be identified in the field, photographs were taken for seeking identification assistance from experts.

RESULTS

Species diversity of bats

The bat fauna in southwestern Bhutan is insectivorous as no fruit bats of suborder Yinpterochiroptera belonging to the family Pteropodidae were captured. A total of 157 individuals belonging to 10 species were caught with the use of mist nets and hoopnets (Images 1 & 2). For this study, 17 individuals (10.83%) were captured in hoop nets and the rest in mist nets. The Rhinolophidae was the most diverse family contributing 59% of the bat fauna in Chukha District. The family Vespertilionidae was the second most diverse family with 32% and the least was the Miniopteridae with 0.54%. Following Wangchuk et al. (2004), species that have been reported for the first time for Bhutan are marked with double asterisks (**) and the first time record from Chukha District of the south-western region are marked with a single asterisk (*) (Table 2).

Table 1. Morphological measurement (in range) of bats.

Species	TSS	Measurements (mm)								
		FA	HBL	HF	EL	TIB	3mt	4mt	5mt	BW
Hipposideros armiger	12	88–93.50	90.51–92.31	12.52–16.45	21.34–23.58	42.34–45.78	67–70.24	67.52–68.59	67.54–68.93	48–57.57
Myotis siligorensis	43	34–36.45	38.31–40.12	6.08–7.34	11.05–11.95	14.78–15.50	30.6–31.54	30–30.93	29.5–30.51	4.86–5.94
Myotis longipes	8	35.01–36.74	39.50–41.68	6.81–7.58	10.51–11.47	14–15.46	30–31.24	31–31.50	31.90–40.12	5.23–6.05
Rhinolophus affinis	38	53–55.51	47–49	6–70.81	17–18	24–25.5	36.50–37.83	39–40.54	40–41.71	16.20–17
Rhinolophus luctus	9	68–70.32	81–82.45	11.50–12.65	32–36	37–38.56	50–51	52.50–53.8	55–56.80	31.85–34
Rhinolophus pusillus	7	35–37.83	31–32.70	6–70.32	15.50–16.8	15–16	25–26.40	26.50–27.3	27.50–28	5–6.42
Rhinolophus lepidus	5	40.05–41	32–33.50	6.20–7.08	16–17	16.30–16.9	30.8–31.50	31–31.50	31.40–31.70	5–6.81
Rhinolophus sinicus	13	45–46.52	50.20–52.40	6–7.31	17–17.80	16.80–17.50	36.80–37.90	36–37	35.90–36.40	10.30–11.21
Rhinolophus macrotis	21	41.56–54	50–55.67	10–11.55	17.50–18.50	24–26.34	40–42.35	41–43.90	42.02–43.57	7–8.40
Miniopterus fuliginosus	1	47.85	53.54	7.52	10.32	19.67	40.15	39.51	37.64	13.94

TSS—Total specimen measured in each species |FA—forearm | HBL—head body length | HF—hind foot | EL—ear length| TIB—Tibia | 3mt—third metacarpal | 4mt—fourth metacarpal | 5mt—fifth metacarpal |BW—body weight.

Table 2. Information on the species and number of individuals caught.

Species	NI	NIP (%)	NSC	H'	J	D
*Hipposideros armiger**	12(M:3, F:9)	7.64	1	1.97	0.86	0.17
*Myotis siligorensis**	43(M:17, F:26)	27.39	11			
*Myotis longipes***	8(M:8)	5.10	2			
Rhinolophus affinis	38(M:25, F:13)	24.20	9			
*Rhinolophus luctus**	9(M:6, F:3)	5.73	2			
*Rhinolophus pusillus**	7(M:2, F:5)	4.46	1			
*Rhinolophus lepidus**	5(M:4, Ju:1)	3.18	2			
*Rhinolophus sinicus***	13(M:9, F:4)	8.28	2			
*Rhinolophus macrotis**	21(M:8, F:12, Ju:1)	13.38	5			
*Miniopterus fuliginosus***	1(M:1)	0.64	1			

M—male | F—female |Ju—juvenile| NI—number of individuals | NIP—number of individuals in % | H'—species diversity | J—Pielou's evenness | D—Simpson's index |NSC—number of sites caught.

Myotis siligorensis had the highest overall bat count (NI=43, NIP=27.39%), followed by *Rhinolophus affinis* (NI=38, NIP=24.20%), and lowest for *Miniopterus fuliginosus* (NI=1, NIP=0.64%) (Table 2). Shannon-Wiener diversity index (H') and Pielou's evenness (J) were 1.97 and 0.86 respectively. The capture rate of *M. siligorensis* ranged from two to six individuals per trapping night followed by *R.affinis* with one to five individuals. The family Rhinolophidae contained the maximum number of individuals captured (N=93, NIP=59.24%). The diversity index (H') and Pielou's evenness (J) were 0.90 and 0.78 for the families captured (Table 3).

Occurrence of bats at different elevations

The species richness was comparatively higher between the elevations 1,500–2,500 m and there after it decreased significantly with increasing elevation (Table 4). The majority of species (63%) were captured within the elevation range of <1,000–2,500 m. *Rhinolophus affinis* and *Myotis siligorensis* were the most common species in an elevation range of <1,500–2,500 m. The average species capture rate and richness were highest between elevations of 1,500–2,500 m (μ=6.10, R=1.78, SD=4.53) followed by <1,500m (μ=6.10, R=1.38, SD=6.52) and lowest in >3,000m (μ=0.90, R=0.59, SD=1.28). The maximum total number of individuals captured was highest at elevation <1,500m and 1,500–2,500 m (TNI=61) and lowest at >3,000m (TNI=9).

Table 3. Summary of bat diversity in different family category.

Family diversity	Total no. of individuals (N)	%	H′	J
Hipposideridae	12	7.64	0.90	0.78
Vespertilionidae	51	32.48		
Rhinolophidae	93	59.24		
Miniopteridae	1	0.64		

Table 4. Summary of bat occurrence in different elevation range.

Species	Elevation (in m)			
	<1,500	1,500–2,500	2,500–3,000	>3,000
Rhinolophus luctus	4	5	0	0
Rhinolophus affinis	16	13	6	3
Rhinolophus pusillus	3	3	1	0
Rhinolophus lepidus	2	2	0	1
Rhinolophus sinicus	6	4	3	0
Rhinolophus macrotis	8	6	5	2
Myotis siligorensis	19	12	9	3
Myotis longipes	3	3	2	0
Miniopterus fuliginosus	0	1	0	0
Hipposideros armiger	0	12	0	0
No. of species	8	10	6	4
Average no. of species captured (μ)	6.10	6.10	2.60	0.90
Max (Min)	19(0)	13(1)	9(0)	3(0)
Margalef's index(R)	1.38	1.78	0.99	0.59
SD	6.52	4.53	3.13	1.28
Total no. of individuals (TNI)	61	61	26	9

Diversity of bats by habitat type

From the total of 157 bats captured, 87 (55.41%) were captured from forests followed in order by settlements (N=36, 22.93%), streams (N=19, 12.10%) and abandoned houses (N=3, 1.91%) (Table 5). The Shannon-Wiener diversity index (H'), however, showed that diversity among the different habitats was 1.19 and the overall Pielou's evenness (J) was 1.03.

Bat species richness in relation to habitat types

Margalef's index showed that forest habitat had the highest species richness (R=1.34) followed by settlements (R=1.12) and the least in caves and abandoned houses

Image 1. Bat species recorded in the study area: A—*Rhinolophus luctus* | B—*Myotis longipes* | C—*Miniopterus fuliginosus* | D—*Hipposideros armiger* | E—*Rhinolophus macrotis* | F—*Rhinolophus affinis.*

(R=0) (Table 5). The total number of individuals caught was high for Rhinolophidae family (N=93) followed by other families in decreasing order: Vespertilionidae (N=51), Hipposideridae (N=12), and Miniopteridae (N=1) (Table 3). The capture rate was comparatively higher for Rhinolophidae and Vespertilionidae families.

DISCUSSION

Species diversity of bats

Studies on bats in the landlocked Himalayan country of Bhutan is almost non-existent though it has been well studied in neighboring countries such as Nepal and India (Korad et al. 2007; Thapa et al. 2012; Korad 2014; Sayyed 2016; Chakravarty 2017). This study is the first to assess the bat diversity in southwestern region of Bhutan (Chukha District) in which a total of 10 bat species were documented. All the species captured during the

Image 2. Bat species recorded in the study area: G—*Rhinolophus lepidus* | H—*Rhinolophus sinicus* | I—*Rhinolophus pusillus* | J—*Myotis siligorensis*.

current survey were insectivorous bats.

Considering the reports of bats from Bhutan (Chakraborty 1975; Bates et al. 2008; Chiozza 2008; Walston et al. 2008), all species except *Rhinolophus affinis* and *Miniopterus fuliginosus* are new records for the country and nine species except *Rhinolophus affinis* are recorded for the first time from Chukha District. Following the studies conducted by Wangchuk et al. (2004), however, only three of the 10 species are new to Bhutan. These are *Myotis longipes*, *Rhinolophus sinicus*, and *Miniopterus fuliginosus*. This indicates that the subsequent studies (Bates et al. 2008; Chiozza 2008; Walston et al. 2008) might have over looked the study of Wangchuk et al. (2004).

Occurrence of bats at different elevations

Bat species richness was highest between the elevations 1,500–2,500 m and thereafter decreased with increasing elevation. This finding is in contrast with the report from Kathmandu valley by Thapa et al. (2012) where it is mentioned that bat assemblage was rich at altitudinal range of 1,300–1,500 m. The difference in findings could be due to geographical variation, habitat types and availability of roosting sites besides food availability (moths and insects). However, the similar findings on the difference in distribution of bat species and their richness at different elevations were reported by Thapa et al. (2012) and Raghuram et al. (2014).

In terms of the average number of species captured,

Table 5. Information on bat diversity by habitat type.

Habitat	Family	Species	Total (N)	%	H'	R
Forests	Rhinolophidae	*Rhinolophus pusillus*	87	55.41	0.33	1.34
		Rhinolophus lepidus				
		Rhinolophus sinicus				
		Rhinolophus macrotis				
	Vespertilionidae	*Myotis siligorensis*				
		Myotis longipes				
	Hipposideridae	*Hipposideros armiger*				
Caves	Hipposideridae	*Hipposideros armiger*	12	7.64	0.20	0
Settlements	Miniopteridae	*Miniopterus fuliginosus*	36	22.93	0.34	1.12
	Rhinolophidae	*Rhinolophus affinis*				
		Rhinolophus macrotis				
		Rhinolophus lepidus				
	Vespertilionidae	*Myotis longipes*				
Streams	Vespertilionidae	*Myotis siligorensis*	19	12.10	0.26	0.34
	Rhinolophidae	*Rhinolophus lepidus*				
Abandoned houses	Rhinolophidae	*Rhinolophus luctus*	3	1.91	0.08	0

%—percentage | H'—species diversity | R—species richness.

bat assemblage was highest between 1,500–2,500 m and lowest for >3,000m. This finding is consistent with the report of Choden (2009) mentioning bat distribution range 500–3,000 m. A decrease in species density at higher elevation was reported by Martins et al. (2015). Similar findings on different number of individuals confining to different elevation zones such as low or high elevations, some across the elevation gradient was also reported by Raghuram et al. (2014). The difference in capture rate in different elevation zones could be due to variations in habitats as well as climatic influence and disturbance in different elevation gradients.

Diversity of bats by habitat type

The highest bat diversity was from the forest with seven species (*Rhinolophus pusillus*, *R. lepidus, R. sinicus, R. macrotis, Myotis siligorensis, M. longipes*, and *Hipposideros armiger*). A similar finding on abundant bat species composition in the forest was reported from Bolivia (Loayza & Loiselle 2009), Malaysia (Shafie et al. 2011) and southern Western Ghats of India (Deshpande 2012). Korad et al. (2007) and Korad (2014) also reported that bat diversity and distribution is governed by forest types. The reason for the presence of a high diversity of bats in the forest and around human settlement might be due to the availability of more food such as moths and insects. It might also be due to the presence of high number of roosting sites and foraging opportunities in forests compared to other sampling sites. Other preferred habitats are caves, abandoned houses and human settlements (Mickleburgh et al. 2002; Korad et al. 2007; Raghuram et al. 2014). In current study, caves and abandoned houses are seen to prefer as day roosting sites.

In this study, use of acoustic recorders to record the echolocation call of bats was felt important due to the presence of dense forest cover. Acoustic recorder, however, was not available during the field work which is one of the limitations of this study. Further, bats use vertical stratification and forage at various heights to reduce competition for food as well as to detect prey (Plank 2011; Carvalho 2013; Marques 2015). Therefore, there are high chances that certain species may not have been captured at all during the survey.

Hipposideros armiger was observed roosting in caves with large openings. Species such as *Rhinolophus luctus* roosted in abandoned houses near cowsheds while other species such as *Myotis siligorensis* and *Rhinolophus lepidus* were captured near streams. Some species such as *Rhinolophus affinis* and *R.macrotis* were found in disturbed areas as well as in agricultural areas and around human settlements. In Malaysia, Shafie et al. (2011) found that plantations and agricultural areas provide suitable habitats for bat species. In India and Nepal (Deshpande 2012; Swamidoss et al. 2012; Thapa et al. 2012; Korad 2014) have mentioned that water bodies, farm land, human settlement, hillock, abandoned houses, tree hollows, unused railway tunnels, canal tunnels, caves and forests are some of the most preferred habitats of microchiropteran bats.

Bat species richness in relation to habitat types

In a world where conversion of forest to farmland and pastures is occurring at an accelerating rate (Loayza & Loiselle 2009), a study documenting bat species richness in forest is a critical step for bat conservation. In the current study, bat species richness was highest in forest and least in caves and abandoned houses. The reason for the high bat species richness in forest might be due to the presence of forest clearings, trails and open areas which provide diverse refuge and foraging habitats for bats. The weather condition and forest structure also influenced the capture success within the study areas. Heavy rain affects capture rate as the bats delay their emergence (Hanif et al. 2015). In the current study, the capture rate was higher in the monsoon season and this could be due to more food (insects) availability compared to winter season or we might have captured more migratory bats.

CONCLUSION

With the use of mist nets and hoop nets, a bat survey was conducted in southwestern region, Chukha District of Bhutan. The present study added three new records to the already existing 65 species of bats in Bhutan. The rich diversity of bats from Chukha District in southwestern Bhutan highlights the presence of diverse habitat types. Since bats provide many ecosystem services, it is required to protect their habitats to conserve them. In addition, it is important to expand similar studies to other parts of the country as Bhutan seems to harbor a diverse bat fauna.

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Appendix 1. Individual morphological measurements for all specimens of *Rhinolophus affinis*.

Species	TNS (38)	Measurements (mm)								
		FA	HBL	HF	EL	TIB	3mt	4mt	5mt	BW
	1	54.31	48	6.21	17	25.11	36.9	39.8	41	16.3
	2	53	47.34	6.83	17.5	24.6	37	40	40.4	16.5
	3	55	48.42	7	18	25	37.4	39.8	40.35	17
	4	54.2	47.9	6.61	17.21	24.33	36.67	39	40	16.75
	5	53	47.11	6.54	17	24.05	36.6	39	40.5	16.25
	6	55	48.54	7.32	17.87	24.98	37	40.03	41	16.85
	7	53.33	47	6.04	17.51	24.66	36.77	39.22	40.56	16.43
	8	53	47	6	17.06	24	36.61	39	40.01	16.4
	9	54	48	7.55	17.4	24.76	36.99	40	40.5	16.77
	10	54	48.03	7.6	17.8	24.91	37	40.3	40.55	17
	11	55	48	7.6	17.5	25	37.22	40.4	40.7	16.2
	12	53.5	47.3	6.8	17	24	36.7	39	40	16.5
	13	55.43	48.6	7.35	17.78	25.04	37	40	41	17
	14	55	49	7.71	18	25	37.76	40.44	41.31	16.2
	15	55.51	49	7.8	17.92	25.44	37.83	40.5	41.65	17
	16	53	47.21	6.33	17	24.03	36.5	39.04	40.12	16.32
	17	54	47.5	6.5	17.5	24.5	36.8	39.5	40.75	16.55
	18	54.06	47	6.66	17.2	24.71	37	40	41	17
Rhinolophus affinis	19	54.21	47.91	7	17	24.96	36.99	39.62	40.84	16.45
	20	54	47.5	6.65	17.43	24.61	37	40	41	17
	21	53	47	6.3	17.32	24	36	39	40	17
	22	55	48.76	7.54	18	25	37.67	40	41	16.5
	23	54.2	47.9	6.61	17.21	24.33	36.67	39.12	40	16.75
	24	54	48	7.55	17.4	24.76	36.99	40	40.5	16.77
	25	55.43	48.6	7.35	17.92	25.44	37.83	40.5	41.65	17
	26	54.31	48	6.21	17	25.11	36.9	39.8	41	16.3
	27	53.5	47.3	6.8	17	24	36.7	39	40	16.5
	28	55	48.42	7	18	25	37.4	39.8	40.35	17
	29	54	47.66	7.55	17.45	24.89	37	40	41	17
	30	53.55	48	6.98	17.67	24.81	36.86	39.34	40.56	16.71
	31	55.51	48.91	7.81	18	25.5	37.76	40.54	41	16.85
	32	54	48	7	17.45	25.5	37.83	40	41.34	17
	33	53.33	47	6.04	17.51	24	36.61	39	40.01	16.4
	34	55	48.54	7.32	18	25	37.67	40	41	17
	35	54.2	47.9	7.55	17.4	24.89	37	39	40	16.5
	36	53.5	47.3	6.3	17.32	24.05	36.5	39.04	40.12	16.32
	37	55.51	49	7.78	17.89	25.53	37.83	40.54	41.71	16.92
	38	53	47	6.05	17.45	24	37	39.18	40.05	16.45

TSN—Total number of specimen of *Rhinolophus luctus* |FA—forearm | HBL—head body length | HF—hind foot | EL—ear length| TIB—Tibia | 3mt—third metacarpal | 4mt—fourth metacarpal | 5mt—fifth metacarpal |BW—body weight.

Appendix 2. Individual morphological measurements for all specimens of *Rhinolophus luctus*.

Species	TNS (9)	Measurements (mm)								
		FA	HBL	HF	EL	TIB	3mt	4mt	5mt	BW
Rhinolophus luctus	1	69	81.56	11.6	34	37.58	50.51	52.86	55.5	32.62
	2	70.32	82	12.45	36	38.52	51	53	56.80	33
	3	68.59	81.78	12	33.85	37.42	50	52.04	55.42	31.85
	4	68	81.09	11.76	32	37	50	53.15	55	32
	5	70	82.45	12.65	36	38.56	50.98	53.8	56.57	34
	6	70.06	82	12.79	35.73	38	50.06	53.47	56.09	32.85
	7	69.57	81	11.95	33.65	37.98	50.75	52.86	55.76	33.62
	8	68.34	81.05	11.50	32.09	37.54	50.12	52.5	55.62	31.91
	9	70.22	82	12.64	35.52	38	50.96	53	55.69	31.98

TSN—Total number of specimen of *Rhinolophus luctus* |FA—forearm | HBL—head body length | HF—hind foot | EL—ear length| TIB—Tibia | 3mt—third metacarpal | 4mt—fourth metacarpal | 5mt—fifth metacarpal |BW—body weight.

Appendix 3. Individual morphological measurements for all specimens of *Rhinolophus pusillus*.

Species	TNS (7)	Measurements (mm)								
		FA	HBL	HF	EL	TIB	3mt	4mt	5mt	BW
Rhinolophus pusillus	1	36.76	31.81	6.5	16	15.34	25.56	26.89	27.52	5.43
	2	35	31	6.23	15.5	15	25	26.59	27.5	5.98
	3	37.83	32.5	7.32	16.8	16	26.34	27.3	28	6.32
	4	36	31	6.23	15.95	15.81	25.54	26.5	27.59	5.87
	5	35	31.11	6	15.56	15.32	25.21	26.51	27.5	5.45
	6	37	32.7	7.30	16.56	15.98	26.4	27.12	27.97	6.42
	7	35.06	31.21	6.09	15.9	15.11	25.54	26.5	27.32	5

TSN—Total number of specimen of *Rhinolophus pusillus* |FA—forearm | HBL—head body length | HF—hind foot | EL—ear length| TIB—Tibia | 3mt—third metacarpal | 4mt—fourth metacarpal | 5mt—fifth metacarpal |BW—body weight.

Appendix 4. Individual morphological measurements for all specimens of *Rhinolophus lepidus*

Species	TNS (5)	Measurements (mm)								
		FA	HBL	HF	EL	TIB	3mt	4mt	5mt	BW
Rhinolophus lepidus	1	40.54	32.41	6.4	16.43	16.5	30.95	31.05	31.40	5.52
	2	41	33.23	7	16.98	16.9	31.45	31.34	31.52	6
	3	40.05	32	6.2	16.34	16.3	30.8	31	31.45	5
	4	40.98	33.50	7.08	17	16.78	31.5	31.5	31.7	6.81
	5	40.76	32.94	7.03	16.85	16.65	31	31.23	31.54	6.41

TSN—Total number of specimen of *Rhinolophus lepidus* |FA—forearm | HBL—head body length | HF—hind foot | EL—ear length| TIB—Tibia | 3mt—third metacarpal | 4mt—fourth metacarpal | 5mt—fifth metacarpal |BW—body weight.

Appendix 5. Individual morphological measurements for all specimens of *Rhinolophus sinicus.*

Species	TNS (13)	Measurements (mm)								
		FA	HBL	HF	EL	TIB	3mt	4mt	5mt	BW
Rhinolophus sinicus	1	45.34	51	6.5	17.45	16.98	36.9	36.56	35.98	10.54
	2	45	50.2	6.23	17	16.8	36.8	36	35.91	10.3
	3	46	51.5	7	17.6	17.45	37.23	37	36	11
	4	45	50.66	6	17.09	16.95	36.87	36.54	35.9	10.55
	5	45.87	51	6.88	17.31	17.11	36.96	36.35	36.09	10.61
	6	46.52	52.4	7.31	17.67	17.5	37.9	37	36.4	11.21
	7	45.09	50.35	6.23	17.72	16.86	37.21	36.89	36.35	10.83
	8	45	50.23	6	17	17.09	37	36.86	36.12	11.05
	9	45.9	51	6.55	17.06	17.12	36.98	36	35.96	10.89
	10	46	52	7.03	17.8	17.45	37.7	36.85	36.38	10.57
	11	45.86	50.2	6.23	17.6	17.45	36.88	36.73	35.99	10.85
	12	46.34	52	7	17.69	17.34	37.56	36.98	36.05	10.38
	13	46	52.4	7.31	17.06	17.12	37.9	37	36	11

TSN—Total number of specimen of *Rhinolophus sinicus* |FA—forearm | HBL—head body length | HF—hind foot | EL—ear length| TIB—Tibia | 3mt—third metacarpal | 4mt—fourth metacarpal | 5mt—fifth metacarpal |BW—body weight.

Appendix 6. Individual morphological measurements for all specimens of *Rhinolophus macrotis*.

Species	TNS (21)	Measurements (mm)								
		FA	HBL	HF	EL	TIB	3mt	4mt	5mt	BW
Rhinolophus macrotis	1	50.53	53	11.05	17.85	25	41.5	42.53	42.65	7.5
	2	45.65	50.53	10.87	17.5	24.86	41	41.57	41.98	7
	3	41.56	50	10	17.59	24	40.98	41.23	42.06	7.56
	4	53	54.23	11.26	18	25.45	42	43	43.51	8.40
	5	54	55.67	11.55	18.5	26	42.08	43.23	43.45	7.98
	6	47	53.34	10.67	17.89	25.53	41.98	42.56	43	8
	7	46.91	52	11	17.78	24,96	41.90	42.45	42.97	7.40
	8	53.76	54.98	11.56	17.9	25	42	43	43.43	8.40
	9	50.55	51	10.87	17.83	24.97	41	41.78	42.8	7.76
	10	41.56	50	10	17.5	24	40	41	42.02	7.56
	11	48	51.56	11.05	17.9	25.01	41.05	42.31	42.59	8
	12	54	55.67	11.55	18.5	26.34	42	43.47	43.57	8.09
	13	51.89	52.87	11.48	17.97	25.67	41.67	42	42.96	7.78
	14	45.65	50.53	11	17.78	24,96	41	41.57	41.98	8
	15	50.53	53.76	11.25	17.83	24.97	41	42.31	42.59	7.77
	16	41.56	50	10.55	17.59	24.06	41.5	42.23	42.65	8.03
	17	46	51.89	53.67	17.5	24.86	41.90	42.45	42.97	7.78
	18	53.80	54.98	11.46	18.06	25.65	42.35	43.90	43.45	8.04
	19	43.59	50.78	10.56	17.87	24,36	41.03	41.55	42	8
	20	46.11	51.43	10.98	17.58	24,26	41.62	42.15	42.58	7.01
	21	51.55	51.34	10.97	17.98	24.99	41.34	41.68	42.89	8.26

TSN—Total number of specimen of *Rhinolophus macrotis* |FA—forearm | HBL—head body length | HF—hind foot | EL—ear length| TIB—Tibia | 3mt—third metacarpal | 4mt—fourth metacarpal | 5mt—fifth metacarpal |BW—body weight.

Appendix 7. Individual morphological measurements for all specimens of *Myotis siligorensis*.

Species	TNS (43)	Measurements (mm)								
		FA	HBL	HF	EL	TIB	3mt	4mt	5mt	BW
	1	35	39.05	6.35	11.23	14.90	30.78	30.45	29.95	5.06
	2	34	38.56	6.19	11.23	14.93	30.65	30.34	29.85	4.89
	3	34.91	38.31	6.08	11.05	14.78	30.63	30.43	29.50	5.01
	4	35.67	40.04	7	11.45	15.32	31.45	30.13	30.86	5.75
	5	36.45	40.12	7.24	11.85	15.40	31.54	30.83	30.51	5.64
	6	34	38.75	6.39	11.43	14.85	30.75	30.54	29.66	5.03
	7	35.56	40.05	6.75	11.83	14.95	30.98	30.75	29.99	5.66
	8	34.12	38.31	6.08	11.09	14.59	30.60	30.06	29.5	4.86
	9	36.33	40	7.34	11.95	15.50	31.44	30.93	30.32	5.34
	10	36.42	40.08	7.26	11.87	15.43	31.49	30.76	30.42	5
	11	34	38	6.13	11.14	14.78	30.6	30.23	29.34	4.98
	12	35.45	39.45	6.35	11.44	14.81	30.95	30.75	29.88	5.93
	13	34.09	38.65	6.29	11.63	14.82	30.75	30.54	29.78	5.50
	14	36.35	40.10	7.17	11.65	15.23	31.39	30.83	30.11	4.98
	15	35.86	40.04	7	11.34	15.22	31.45	30.23	30.46	5
	16	36.44	40.11	7.24	11.88	15.50	31.35	30.90	30.50	5.45
	17	35.45	39.46	6.16	11.23	14.79	30.85	30.66	29.81	5.09
	18	34	38.45	6.41	11.43	14.91	30.75	30.44	29.85	5.56
	19	35.27	40.10	7.23	11.45	15.45	31.35	30.03	30.48	4.9
	20	35.81	40.01	6.21	11.61	14.79	30.76	30.25	29.95	4.88
	21	36.42	40.03	7.06	11.91	15.42	31.18	30.64	30.44	5.39
Myotis siligorensis	22	35.78	40.12	7.24	11.23	15.32	31.28	30.19	30.39	5
	23	34.23	38.45	6.5	11.43	14.84	30.65	30.04	29.85	4.96
	24	35	38.42	6.14	11.21	14.81	30.61	30.16	29.48	4.95
	25	36.35	40.12	7.08	11.55	15.12	31.29	30.73	30.22	5.34
	26	34.25	38.56	6.19	11.20	14.92	30.65	30.34	29.89	5
	27	35.08	39.96	7.09	11.39	15.38	31.49	30.21	30.46	5.65
	28	34	38.05	6.24	11.14	14.93	30.41	30	29.77	5.07
	29	35.77	40.12	6.40	11.61	14.79	30.76	30.33	29.87	5.85
	30	35.70	40	6.27	11.55	14.83	30.76	30.43	29.55	5.09
	31	36.32	40.10	7.14	11.87	15.43	31.49	30.76	30.42	5.34
	32	35.45	39	6.49	11.34	14.80	30.71	30.54	29.66	5.81
	33	36	39.54	7.24	11.49	15.5	31.87	30.43	30.41	5.34
	34	36.22	40.11	7.04	11.77	15.45	31.23	30.76	30.31	5
	35	35	38.85	6.98	11.87	14.92	30.84	30.24	29.68	4.92
	36	35.34	40.00	7.23	11.42	15.43	31.35	30.08	30.40	5.08
	37	35.82	39.53	7.08	11.45	15.44	31	30.13	30.32	4.96
	38	35.32	39.15	6.22	11.42	14.82	30.66	30.42	29.87	5.94
	39	34.88	38.77	6.45	11.29	14.91	30.88	30.65	29.69	4.87
	40	35.67	39	7.23	11.52	15.11	31.76	30.42	30.51	5.23
	41	34.65	38.90	6.88	11.73	14.98	30.81	30.55	29.89	4.95
	42	36.04	40.12	7.16	11.75	15.21	31.22	30.74	30.25	5.79
	43	34.90	38.68	6.39	11.47	14.79	30.97	30.45	29.86	5.42

TSN—Total number of specimen of *Myotis siligorensis* |FA—forearm | HBL—head body length | HF—hind foot | EL—ear length| TIB—Tibia | 3mt—third metacarpal | 4mt—fourth metacarpal | 5mt—fifth metacarpal |BW—body weight.

Appendix 8. Individual morphological measurements for all specimens of *Myotis longipes*.

Species	TNS (8)	Measurements (mm)								
		FA	HBL	HF	EL	TIB	3mt	4mt	5mt	BW
Myotis longipes	1	35.46	40.07	6.89	10.85	14.97	30.45	31.08	31.98	5.56
	2	36.54	41.26	7.31	11.06	15.35	31	31.24	40.10	6.01
	3	35.01	39.50	6.81	10.56	14	30.5	31	31.95	5.23
	4	35.23	39.58	6.97	10.51	14.27	30	31.34	31.90	5.98
	5	36.41	41.55	7.32	11.09	15.32	31.21	31.33	40.03	6
	6	36.74	41.68	7.58	11.32	15.36	31.24	31.50	40	6.05
	7	35.95	39.89	6.92	10.88	14.56	30.96	31.08	31.99	5.86
	8	36.65	41.59	7.52	11.47	15.46	31.09	31.45	40.12	6.04

TSN—Total number of specimen of *Myotis longipes* |FA—forearm | HBL—head body length | HF—hind foot | EL—ear length| TIB—Tibia | 3mt—third metacarpal | 4mt—fourth metacarpal | 5mt—fifth metacarpal |BW—body weight.

Appendix 9. Individual morphological measurements for all specimens of *Miniopterus fuliginosus*.

Species	TNS (1)	Measurements (mm)								
		FA	HBL	HF	EL	TIB	3mt	4mt	5mt	BW
Miniopterus fuliginosus	1	47.85	53.54	7.52	10.32	19.67	40.15	39.51	37.64	13.94

TSN—Total number of specimen of *Miniopterus fuliginosus* |FA—forearm | HBL—head body length | HF—hind foot | EL—ear length| TIB—Tibia | 3mt—third metacarpal | 4mt—fourth metacarpal | 5mt—fifth metacarpal |BW—body weight.

Appendix 10. Individual morphological measurements for all specimens of *Hipposideros armiger*.

Species	TNS (12)	Measurements (mm)								
		FA	HBL	HF	EL	TIB	3mt	4mt	5mt	BW
Hipposideros armiger	1	90.09	91.32	14.55	22.51	43.86	69.32	67.86	67.91	55.75
	2	89.45	90.85	13.21	22.13	42.94	68.06	67.93	67.58	53.74
	3	88.38	90.51	13	21.86	41.24	67.34	67.59	67.55	49.51
	4	91.76	91.84	14.76	22.69	44.01	69.53	67.91	67.95	55.82
	5	88.41	90.51	12.52	21.85	42.64	67	67.83	67.54	48
	6	92.09	91.89	15.17	23	45.05	69.56	68.55	68.78	57.42
	7	88	90.59	12.52	21.34	42.34	67.06	67.52	67.59	50.59
	8	90.56	91	14.88	22.34	44.07	69.14	68.09	68.23	56
	9	93.50	92.31	16.45	23.41	45.67	70.24	68.39	68.52	57.09
	10	93.49	92.30	16.38	23.58	45.78	70.21	68.59	68.93	57.57
	11	89.01	91.19	12.87	21.59	42.83	67.59	67.58	67.64	49.67
	12	92.54	91.98	16.32	23.09	45.12	69.95	68.81	68.90	54.71

TSN—Total number of specimen of *Hipposideros armiger* |FA—forearm | HBL—head body length | HF—hind foot | EL—ear length| TIB—Tibia | 3mt—third metacarpal | 4mt—fourth metacarpal | 5mt—fifth metacarpal |BW—body weight.

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