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Diversity and distribution of chiropteran fauna in Bundelkhand region of Uttar Pradesh

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Abstract
Biodiversity assessment plays vital role in biodiversity conservation. This study describes the diversity and distribution of bat fauna in arid region of Uttar Pradesh. The study was carried out in seven districts of Bundelkhand from 2019 to 2021. A total of six insectivorous bats (*R. hardwickii*, *R. microphyllum*, *T. nudiventris*, *T. perforatus*, *S. heathii*, *M. lyra*) and two frugivorous bats (*R. leschenaultii*, *P. medius*) found. The distribution of *T. perforatus* was first time reported from Uttar Pradesh. The most abundant species was *R. microphyllum*, followed by *R. leschenaultii*, *R. hardwickii*, *P. medius*, *T. perforatus*, *T. nudiventris*, *M. lyra* and *S. heathii*. The most populous species was *R. hardwickii* and least populous species was *M. lyra* and *S. heathii*. Shannon diversity index of Bundelkhand regions was 1.11351 and Evenness index was 0.533549. Jaccard index of protected roost was 0.97 and unprotected roost was 1.0. The roosts of all insectivorous and *R. leschenaultii* found in attic and crevices of cave, rocks crevices, monuments and abandoned buildings. Bats prefer roosting in permanent structure which possesses single entrance with zero light intensity. Temperature of roost was more than 20° C and almost stable. The population of bat in protected area was higher than unprotected.

Keywords: bundelkhand, diversity, distribution, frugivorous, insectivorous, roost

Introduction
In evolutionary and zoogeographic point of view chiropterans are a marvelous group of mammalian orders [1]. It is one of the orders which consist of most distributed species worldwide [2], with over 1300 living species [3]. It constitutes over 20% of all mammalian species and second largest group after rodent in term of species richness [4]. Earlier chiropterans were divided in to two suborders: Megachiroptera (Fruit Bats) and Microchiroptera (laryngeally echolocating bats) but on the basis of molecular and phylogenetic methodologies chiropteran fauna were classified in two suborders, Yinpterochiroptera which include megabat (family Pteropodidae) and microbat (families Rhinolophidae, Rhinopomatidae and Megadermatidae) while Yangochiroptera includes rest of the microbat families [5-6].
Apart from taxonomic diversity, bats also exhibit great difference in size, the smallest one (*Craseonycteris thonglongyai*) weighing about 2g and a wingspan of 12 – 13cm, while the largest one (*Pteropus*) weighing up to 1.5kg and wing span over 2m [7]. They found everywhere except Arctic, Antarctic and certain oceanic islands [4, 8]. Due to difference of morphology and ecology of bats are suited for different habitats such as the spatially complex forest interior or the open areas above the canopy [9-12]. Some bats are solitary while many are colonial and colony consists of few to millions of individuals [13].
Bats are only mammals which easily cross different types of vegetation and landscapes that are physical barriers for other mammal species [14-20]. Distribution is mainly affected by the presence and absence of food resource, temperature in particular region, apart from this wind velocity and humidity also affected distribution [21].
Although bats are most adaptive animals in various kinds of climatic condition but due to various causes roosting site and foraging areas are degraded so bat population declining day by day [22]. In tropical countries population of bat decreased more rapidly than other [23] and it will be up to 40% in coming decades and causes for declining of population of bats are mainly degradation of habitat and related threats [24]. For the conservation planning of a species, it is essential to understand the patterns of biodiversity within a landscape [25-26]. Therefore, it is necessary to collect more and more information on diversity and region wised distribution.
Few studies were carried out on diversity and distribution of chiropteran fauna of Uttar Pradesh [27-28], but no systematics studies were carried out in Bundelkhand region of Uttar Pradesh. Therefore, we make an attempt to understand the diversity and distribution of chiropteran fauna of Bundelkhand region of Uttar Pradesh.

Materials and methods
Study Area
The Bundelkhand region comes under the state Uttar Pradesh and Madhya Pradesh, out of which only areas of Uttar Pradesh were selected for the study. Bundelkhand region lies between the Indo-Gangetic plain to North and

the Vindhya range to South, it is gently sloping upland, distinguished by barren hilly terrain with sparse vegetation, although it was historically forested and it contain many historical monuments and caves. The Bundelkhand region of Uttar Pradesh region consist seven districts as: Chitrakoot, Banda, Mahoba, Hamirpur, Jalaun, Jhansi and Lalitpur that hold 29000 km^2. It is a largest arid zone of Uttar Pradesh. The study area shows extreme variation in temperature, which goes up to 2°C in Winter while 49°C in Summer. The average rainfall is 898.94 mm which occur mainly in monsoon season. Out of total area of Bundelkhand 8% land comes under forest, 8.2% is non-agriculture land, 3.8% barren land, 0.2% grazing land, 3.9% cultivable wasteland and 5.9% waste land.

Periodical surveys were carried out from February 2019 to August 2021 at residential and non-residential areas in all districts along with forest, hill, agriculture land or terrain by visual observation to assess the distribution of bats. Bat detector also used for acoustic identification of bats as well as to locate their day roosts sites which include abandoned buildings, temples, caves, crevices, and monuments. The location of roost was taken with the help of mobile GPS (google earth). Maps of roosting sites were prepared using Arc GIS. Photographs of each roost site were taken using Nikon D53 (18–55 mm Nikkor lens). For the species confirmation, bats were captured using mist nets as well as hoop nets. Morphological measurements were taken and the bats were released at the site of capture, and identified on the basis of the key of Bates and Harrison [29]. The Guideline of American Society of Mammalogy was followed for capturing of bats [30].

Data analysis

The roost sites were divided into two categories: protected roost (Caves, Forts, monuments which comes under Archaeological survey of India (ASI), temples) and unprotected roost (Tree, abandoned buildings, private buildings). Population of bats was studied by visual observation at the time of emergence by following Easterla and Watkins [31], Humphrey and Cope [32], and Swift [33]. The population of roost was accessed by photographic count [34]. The Shannon Diversity Index was calculated by following Shannon [35] equation. Jaccard diversity Index was calculated using following formula (J) [36]:

$$J=\sum(AXB)/\sum\{(A^2+B^2)+(AXB)\}.$$

Where A is the population of bats species in permanent roost, B is the population of bats species in temporary roost.

The species evenness index (J`) was calculated using following formula [37]:

$$J`=H`/\log S$$

Where H` is Shannon diversity index, S is species richness (or total number of species in particular area)

Results

The two years field survey carried out in seven districts of Bundelkhand region of Uttar Pradesh explored 40 roost sites. Out of which 35 roosts were occupied by eight species of bats (Figure 1), out of which six species, *Rhinopoma hardwickii, R. microphyllum, Taphozous nudiventris, T. perforatus, Scotophilus heathii* and *Megaderma lyra* were insectivorous (Figure 2-7) and *Rousettus leschenaultii* (Figure 8) and *Pteropus medius* were frugivorous bats. A total of 133 individuals of seven species were captured and their morphological measurements were given in Table 1, *P. medius* measurement was not taken. The highest number of roosts was of *R. hardwickii* (15) and minimum of *S. heathii, T. perforatus* and *M. lyra* (single) observed in the study area (Table 2).

The most abundant species in Bundelkhand region was *R. microphyllum* (62.73%), followed by *R. leschenaultii* (10.69%), *R. hardwickii* (8.00%), *P. medius* (7.25%), *T. perforatus* (6.90%), *T. nudiventris* (3.50%), *M. lyra* (0.53%) and *S. heathii* (0.372%). The most abundant species was *R. hardwickii* and least abundant species was *M. lyra* and *S. heathii* (Table 2). The roost characteristic such as temperature, humidity, light intensity, roost area and number of entrances of all 35 roost were given in Table 3. Shannon diversity index of Bundelkhand regions was 1.113 and Evenness index was 0.533. Jaccard index of protected roost was 0.97 and unprotected roost was 1.0.

Table 1: Morphological measurements of bats *T. nudiventris*, *T. perforatus*, *R. hardwickii*, *R. microphyllum*, *S. heathii*, *M. lyra* and *R. leschenaultii*. Values are given in mean ± SD.

Species/ Parameter	***T. nudiventris* (n=29) (♂=27, ♀=2)**	***T. perforatus* (n=7) (♂=4, ♀=3)**	***R. hardwickii* (n=28) (♂=20, ♀=8)**	***R. microphyllum* (n=39) (♂=30, ♀=9)**	***S. heathii* (n=15) (♂=10, ♀=5)**	***M. lyra* (n=9) (♂=3, ♀=6)**	***R. leschenaultii* (n=6) (♂=3, ♀=3)**
Body mass (gm)	50.78±9.78	31.07±8.06	20.34±6.22	30.31±3.77	32.00±6.71	52.11±5.28	84.98±6.59
BH length	93.37±18.16	83.36±7.80	70.56±3.32	77.31±4.31	75.03±8.28	71.89±7.93	101.16±9.24
Head length	31.17±1.95	27.96±2.04	19.85±4.01	27.10±2.75	21.34±3.40	27.31±5.06	31.73±1.27
Tail length	20.45±2.49	17.81±2.48	57.92±5.57	53.00±4.10	46.86±6.61	-	12.44±1.48
Ear length	15.86±3.30	16.58±2.45	13.01±1.56	13.86±1.85	12.58±2.06	31.96±4.38	18.86±2.02
Tragus	5.30±0.45	5.86±1.08	5.54±0.83	5.36±0.61	7.15±1.01	14.25±1.90	-
Forearm	69.22±3.00	67.03±4.04	58.13±2.89	68.67±3.23	58.84±2.50	64.06±0.92	79.05±3.26
5th Metacarpal	42.89±3.05	39.10±2.60	42.25±2.50	45.27±2.95	50.27±4.32	55.43±3.22	51.72±2.33
First phalanx	14.42±1.87	14.63±1.22	10.66±0.72	11.37±1.42	10.17±1.27	19.35±0.74	25.56±1.82
Second phalanx	8.88±0.73	8.54±0.61	9.22±0.93	10.07±1.03	8.75±1.59	19.25±1.28	27.59±1.43
4th Metacarpal	51.90±2.75	49.10±2.89	37.11±2.19	37.90±2.20	52.99±4.54	51.27±1.95	52.72±3.09
First phalanx	15.77±1.61	14.10±0.85	12.66±0.92	15.15±1.27	15.04±1.48	16.48±0.92	28.15±1.17
Second phalanx	8.72±0.89	8.38±0.91	10.28±1.49	10.71±1.01	11.83±1.27	22.15±1.66	29.23±2.37
3rd Metacarpal	61.92±11.46	60.78±3.16	42.54±2.85	47.05±1.64	54.73±3.68	42.65±14.29	54.46±3.31
First phalanx	26.68±2.08	21.62±1.16	8.86±0.83	9.90±1.28	19.09±1.34	27.80±1.24	33.38±2.39
Second phalanx	27.50±2.42	23.63±1.32	16.98±1.90	13.61±3.41	16.40±4.96	48.76±3.25	38.31±2.79
2nd Metacarpal	58.62±2.81	57.12±3.65	41.87±3.96	47.05±1.84	53.29±3.57	57.65±2.79	34.12±0.97
Wing span (cm)	42.41±3.49	41.96±3.22	31.19±2.29	33.36±1.57	36.05±3.50	40.13±2.36	41.24±2.75
Hind arm	29.78±2.32	25.67±1.12	29.87±1.62	26.75±2.48	25.92±5.85	53.00±30.60	26.30±3.55
Thumb length	8.21±0.73	6.03±0.47	7.24±0.51	7.36±0.49	11.82±16.14	12.20±4.21	13.34±1.76
Foot	11.81±3.48	6.43±0.91	9.71±3.74	12.57±1.32	6.38±1.93	11.65±2.19	19.22±1.83

No morphometry of *P. medius* was given as they were not captured.

Table 2: Population of six insectivorous and two frugivorous bat species in different roost sites of Bundelkhand region of Uttar Pradesh.

Roost location	**Bat species**							
	R. hardwickii	***R. microphyllum***	***T. nudiventris***	***T. perforatus***	***M. lyra***	***S. heathii***	***R. leschenaultii***	***P. medius***
Baradari, Majhgawan, Hamirpur	45	-	-	-	-	-	-	-
Cave, Belatal, Mahoba	21	-	-	-	-	-	-	-
Boundary of Badal mahal, Belatal, Mahoba	11	-	-	-	-	-	-	-
Badal mahal, Belatal, Mahoba	20	-	-	-	-	-	-	-
Mahal, Sarila, Hamirpur	-	-	-	-	93	-	-	-
Surya Mandir, Mahoba	12	-	-	-	-	-	-	-
Dark cave, Mahoba	27	-	-	-	-	-	-	-

Senapat Mahal, Kulpahar, Mahoba	22	-	-	-	-	-	-	-
Chakravarti fort, Kulpahar, Mahoba	-	-		1205	-	-	832	-
Barua Sagar Fort, Jhansi	35	-	110				320	-
Jhansi Fort, Jhansi Site- 1	185	-			-	-		-
Jhansi Fort, Jhansi Site- 2	-		104	-	-	-	-	-
Jhansi Fort, Jhansi Site- 3	323	-	-	-	-	-	-	-
Jhansi Fort, Jhansi Site- 4	-	5075	-	-	-	-	-	-
Jhansi Fort, Jhansi Site- 5	540	-	-	-	-	-	-	-
Jhansi Fort, Jhansi Site- 6	-	1140	-	-	-	-	-	-
Jaggamanpur Fort, Jalaun	-	1260	-	-	-	-	-	-
Bhuragarh, Fort, Banda	-	3480	-	-	-	-	-	-
Kalinjar Fort, Banda	83	-	15	-	-	-	-	-
Gupt Godavari Cave, Chitrakoot	6	-	-	-	-	-	-	-
Chaurasi Gumband, Kalpi, Jalaun	-	-	-	-	-	65	-	-
Joran Fort, Mahoba	-	-	310	-	-	-	-	-
Supa Cave, Mahoba	-	-	40	-	-	-	-	-
Fort (Talbehat) Lalitpur	35	-	17	-	-	-	-	-
Jarai Ka Math, Barua Sagar, Jhansi	-	-	16	-	-	-	-	-
Terminalia arjuna, Belatal, Mahoba	-	-	-	-	-	-	-	300
Eucalypteus obliqua, Belatal, Mahoba	-	-	-	-	-	-	-	276
Azadirachta indica, Rath, Hamirpur	-	-	-	-	-	-	-	460
Ficus benghalensis, Mahoba	-	-	-	-	-	-	-	230
Garhi, Malehta, Hamirpur	33	-	-	-	-	-	715	-

Table 3: Roost location and characteristic of six insectivorous (*R. hardwickii*, *R. microphyllum*, *T. nudiventris*, *T. perforatus*, *S. heathii* and *M. lyra*) and two frugivorous bats (*R. leschenaultii* and *P. medius*). Table 3. Roost location and characteristic of six insectivorous (*R. hardwickii*, *R. microphyllum*, *T. nudiventris*, *T. perforatus*, *S. heathii* and *M. lyra*) and two frugivorous bats (*R. leschenaultii* and *P. medius*).

Roost location	Roost area (square Feet)	Temp (ºC) (Mean ± SD)	Humidity (%) (Mean ± SD)	Roost height above the ground (Feet)	Light intensity (Lux)	No. of entrance	Entrance height (Feet)	Entrance width (Feet)	Threats
Baradari, Majhgawan, Hamirpur	36	30.86±5.60	61.20±20.03	9	0	1	5	2	Renovation and bat hunting
Cave, Belatal, Mahoba	18	24.27±6.18	59.25±24.90	18	0	2	12	1	Bat hunting
Boundary of Badal mahal, Belatal, Mahoba	12	25.50±6.24	63.00±21.60	8	0	1	4	2	Treasure hunt and bat hunting
Badal mahal, Belatal, Mahoba	54	31.17±11.30	59.75±23.47	18	8	3	8	3	Ruined building and bat hunting

Mahal, Sarila, Hamirpur	324	29.25±2.21	61.25±23.76	14	0	1	6	2	Renovation
Rahila Sagar Sun Temple, Mahoba	25	27.00±6.98	62.00±22.94	18	0	1	5	3	Tourism
Dark cave, Mahoba	36	29.25±6.39	64.75±19.60	21	0	1	18	3	Bat hunting
Senapati Mahal, Kulpahar, Mahoba	189	29.50±8.34	62.50±24.63	18	5	2	6	3	Treasure hunt, bat hunting and Tourism
Chakravarty Samrat fort, Kulpahar, Mahoba (*T. Perforatus*)	254	27.00±3.82	74.25±19.18	20	0	1	5	3	Renovation and bat hunting
Chakravarty Samrat fort, Kulpahar, Mahoba (*R. leschenaultii*)	108	27.24±3.46	74.25±18.96	20	0	1	5	3	Renovation and bat hunting
Barua Sagar fort, Jhansi (*T. Nudiventris*, *R. leschenaultii*)	162	27.85±4.96	64.75±24.30	24	2	2	7	3	Tourism
Barua Sagar fort, Jhansi (*R. hardwickii*)	72	27.00±3.00	69.00±23.25	9	0	1	3	2	Tourism
Jhansi fort, Jhansi Site- 1	201	28.62±1.51	66.2±24.99	24	0	1	6	2	Tourism and development work
Jhansi fort, Jhansi Site- 2	201	28.62±1.51	66.2±24.99	24	0	1	6	2	″
Jhansi fort, Jhansi Site- 3	201	28.62±1.51	66.2±24.99	24	0	1	6	2	″
Jhansi fort, Jhansi Site- 4	160	28.62±1.51	66.2±24.99	18	0	1	6	2	″
Jhansi fort, Jhansi Site- 5	201	28.62±1.51	66.2±24.99	24	0	1	6	2	″
Jhansi fort, Jhansi Site- 6	574	28.62±1.51	66.2±24.99	12	0		4	2	″
Jaggamanpur fort, Jalaun	216	25.85±7.63	68±19.20	24	0	1	7	3	Tourism
Bhuragarh, fort, Banda	48	29.42±7.76	69.00±19.65	8	0	1	4	2	Treasure hunt, bat hunting and Tourism
Kalinjar fort, Banda (*R. hardwickii*)	150	27.88±6.21	64.40±19.96	18	0	1	8	3	Tourism
Kalinjar fort, Banda (*T. nudiventris*)	20	27.95±7.91	64.75±18.60	16	2	2	10	3	Tourism
Gupt Godavari cave, Chitrakoot	-	27.30±0.60	80.66±13.05	-	-	-	-	-	Tourism
Chaurasi Gumband, Kalpi, Jalaun	56	24.10±6.87	57.25±14.22	24	0		16	8	Tourism
Garhi Joran, Mahoba	144	28.12±3.06	70±16.02	21	0	1	5	2	Treasure hunt and Tourism
Supa cave, Mahoba	-	26.00±2.58	62±17.79		0	-	-	-	Hunting of bat
Fort (Talbehat) Lalitpur (*R. hardwickii*)	25	27.02±3.88	71.50±20.72	25	0	1	5	2	Treasure hunt and Tourism
Fort (Talbehat)Lalitpur (*T. nudiventris*)	130	27.66±3.78	68.33±24.02	24	2	1	7	3	Treasure hunt and Tourism
Jarai Ka Math, Barua Sagar, Jhansi	64	28.37±3.68	67.73±23.23	18	2	1	8	3	Tourism and development work
Terminalia arjuna, Belatal, Mahoba	-	29.65±8.59	61.23±24.86	-	-	-	-	-	Local people
Eucalypteus obliqua, Belatal, Mahoba	-	29.65±8.59	61.23±24.86						Local people
Azadirachta indica, Rath, Hamirpur	-	30.00±8.20	60.75±24.85						Local people

Ficus benghalensis, Mahoba	-	32.50±8.73	59.75±23.51						Local people
Garhi, Malehta, Hamirpur (*R. hardwickii*)	63	29.38±7.3	66.25±21.23	12	0	1	6	2	Renovation and hunting
Garhi, Malehta, Hamirpur (*R. leschenaultii*)	168	30.25±7.41	62±21.21	12	2	1	6	2	Renovation and hunting

Jhansi Fort: Site 1: In front of Kadak Bijli Toap *R. hardwickii* roost, Site 2 and 3: Adjacent to Kadak Bijali Toap *T. nudiventris* and *R. microphyllum* roost, Site 4: Below the Gulam Gauskhan cemetery, *R hardwickii* roost, Site 5: In front of Panch Mahal, *R. hardwickii* roost, Site 6: In Panch Mahal, *R. hardwickii* roost.

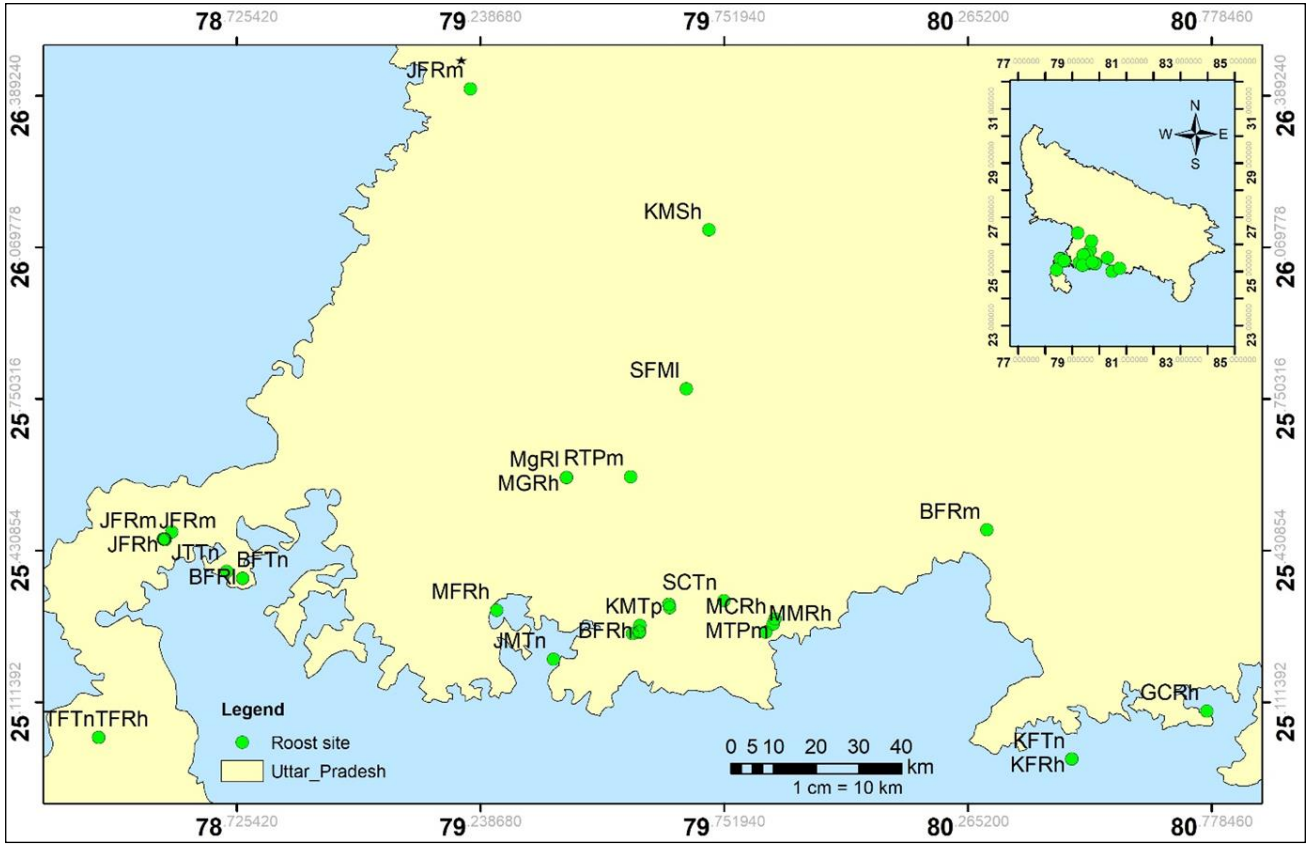

Fig 1: Distribution of six insectivorous and two frugivorous species of bats in Bundelkhand region of Uttar Pradesh, India.

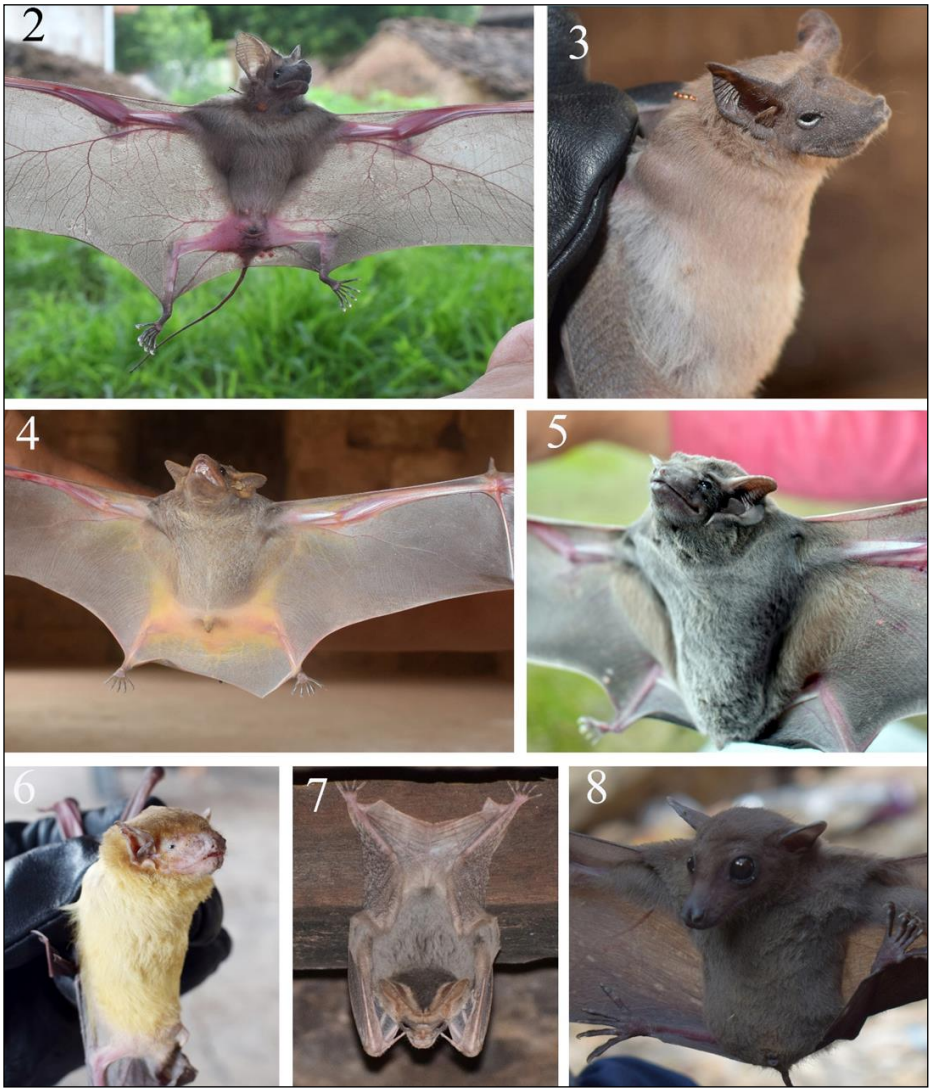

Fig 2-8: Six individuals of insectivorous bats 2, *R. hardwickii*; 3, *R. microphyllum*; 4, *T. nudiventris*; 5, *T. perforatus*; 6, *S. heathii*; 7, *M. lyra*; and one frugivorous bat 8, *R. leschenaultii* were recorded from Bundelkhand region of Uttar Pradesh.

Description of Roost Sites

Majhgawan

A monument known as Baradari situated in center of Majhgawan village of Hamirpur district and the property is belong to a king's family (Manvendar Singh). The monument is well maintained and protected. *Rhinopoma hardwickii* found roosting in this monument. There are ten rooms, out of which only one room was occupied by bats. Room is square in shape with only one entrance and the height of roost was 9 feet from the ground. The bats were occupied the woody attic of roof.

Garhi, Malehta

Grahi is situated in Malehta village of Hamirpur district. There were three buildings in Garhi, out of which one building was used for residential purpose and one building was ruined and third one was small temple. *Rhinopoma hardwickii* and *R. leschenaultii* were found roosting in attic of building which was used for residential purpose and in temple. There was open field in front of roost and behind the building small bushy area available. The shape of roost was rectangle and roof is made of wooden with single entrance. The height of roost was 12 feet from the ground and height and width of entrance was six feet and two feet respectively.

Belatal

A total of four roosts of *R. hardwickii* and *P. medius* were found in Belatal village of Mahoba districts. *Rhinopoma hardwickii* were found roosting in Badal Mahal fort and cave while *P. medius* roosting in tree of *Termina arjuna* and *Eucalyptus* sp.

Fort is situated outside of village and there is a big pond attached to boundary of fort. Roosts in Badal Mahal fort square in shape, most part of fort were ruined and most of the rooms were without roof. Only 4-5 individuals of *R. hardwickii* were found roosting on roof of the fort and there was direct sun light penetration in the roost due to

damage of roost roof. Whereas cave was situated in center of village and surrounded by human colony and two entrances in cave roost. *R. hardwickii* found roosting in upper side crevices of cave.
Pteropus medius roosting near to human colony and below the tree, land uses to make cow dung cake by local villagers. Bats prefer only dense canopy and long height tree. One side of roost a local road is passed and another side agriculture field occurs.

Sarila
Sarila mahal belongs to queen Sarila, which is located in center of tehsil Sarila of Hamirpur district. In mahal there was a large hall with many pillars. In the roof of hall there were horizontal wooden pillar, in which *M. lyra* roosting. Roost was rectangle in shape and there was only one entrance in roost and height and width of entrance was 6 and 2 feet respectively. The bats are roosting in many groups on the wooden pillars of roof. There was a water filled large pit behind the mahal.

Rath: Rath is a tehsil of Hamirpur district, which is center of Bundelkhand. There was orchard of neem, eucalyptus and banyan tree in PWD office. *Pteropus medius* were found roosting in neem tree. Three big cement tank presents below of the roost that's used from storing and melting of road making material (dammar). An open field is present on one side of roost and other side a small agriculture land. In front of the roost a road present.

Mahoba
Two permanent roost, Dark cave and Rahila Sagar Sun Temple and one tree roosts were found in Mahoba district. *Rhinopoma hardwickii* were found roosting in Dark cave and Rahila Sagar Sun Temple, while *P. medius* were roosting in Banyan tree.
The height of roost from ground was 21 feet, only one entrance was in the roost and height and width of entrance was 18 and 3 feet respectively. *Rhinopoma hardwickkii* were roosting on top of the cave. The height of roost from ground was18 feet, only one entrance also here and height, width of roost was 5 and 3 feet respectively.

Kulpahar
Kulpahar is a town area of Mahoba district. In Kulpahar two sites were found where three species of bat were roosting. Senapati Mahal situated at center of Kulpahar, it is a three-story building. The height of roost is 18 feet from ground. There were two entrances in the roost and every entrance size was 6 feet in height and 3 feet in width. *Rhinopoma hardwickii* were found roosting here. Bird also nesting everywhere in fort roof. Human activity is also common inside the fort.
Chakravarty Samrat fort is located on boundary of town and adjacent the boundary of fort, there was a big pond. A total of eight rooms were in the fort, out of which four rooms used for residential purpose by a human family. Two rooms were occupied by *R. leschenaultii* while *T. perforatus* roosting in only one room. There was a store room of cow fodder below the roost. The roost is circle in shape and height of roost from ground was 20 feet. The shape of roost where *T. perforatus* roosting is tomb shaped and many crevices are present on roof of roost which used by bats for roosting. The shape of *R. leschenaultii* roost was tunnel shaped, bat occupied the attic of roof and height of the roost above the ground was 20 feet. There was a single entrance in every roost, height and width of every entrance was 5 and 3 feet respectively.

Barua Sagar
Barua Sagar fort is situated in Barua Sagar town area of Jhansi district. The fort is six story building which is protected by ASI. There were three rooms in the ground floor, all rooms connected to each other. Two rooms were large and rectangle in shape, in which one room occupied, was by *T. nudiventris* and *R. leschenaultii* where light penetration was zero. There was a tunnel connected to small room at the entrance of the roost, where *R. hardwickii* were roosting. There were two entrances in the roost, and the height of front and backside entrances were thee and seven feet respectively.

Jarai Ka Math
A temple is situated on Jhansi Road, which is known as Jarai Ka Math and it comes under ASI. The roost was square in shape and there was only one entrance in the roost. The height and width of entrance was eight and three feet respectively. *Taphozous nudiventris* were occupied the attic of temple.

Jhansi Fort
The fort is named on the queen of Jhansi which is situated in city of Jhansi. Total six roosts were found in the fort, that occupied by three species of bat as: *T. nudiventris, R. microphyllum* and *R. hardwickii*. The fort is under the protection of ASI and tourist place. In front of Kadal Bijli Toap, two roosts, one is known as Baradari which was occupied by *R. hardwickii* and in right side one roost which was occupied by *T. nuduventris*. Third one roost was situated in right side of the Kadak Bijli Toap, that occupied by *R. microphyllum.* There was an underground room in front of Gulam Gaus Khan Cemetery, which was occupied by the *R. hardwickii*. The 5th one roost was in Panch Mahal which was occupied by *R. hardwickii*. Sixth roost was just below of jumping spot and *R. hardwickii* were roosted there.

All roosts were circle in shape and only one entrance possess except of Panch Mahal and in front of Gulam Gaus Khan Cemetery. The roof of roost was tomb in shape. There were two rooms in Panch Mahal which is rectangle in shape and roof was also rectangle. The roost in front of Gaus Khan Cemetery is tunnel shaped. There were many entrances in Panch Mahal while only one entrance was Gulam Gaus Khan roost.

Jaggamanpur Fort

Jaggamanpur Fort is a private property and situated in Jaggamanpur village of Jalaun district. In fort a school is ongoing. There were three rooms in ground floor of fort, out of which one was occupied by *R. microphyllum.* In front of fort an open ground is available and back side of fort is surrounded by forest. Roost was rectangle in shape, it possesses only single entrance, height and width of entrance was 7 and 3 feet respectively. Roost made up of brick stone with many crevices in roof. *Rhinopoma microphyllum* roosting on attic of room where light penetration was zero.

Bhuragarh Fort

It is situated at the bank of the Ken River. In Banda district under the protection of ASI. Most part of the fort is damage, only one building was in good condition that occupied by Saints and converted it in to temples. *Rhinopoma microphyllum* roosting on wall of roof, in that's building which also used by Saints. Front of the fort facing a railway track, back side of fort is surrounded by river and small forest. Roost rectangle in shape and consist of single entrance for entry. There is Hawan kund in front of roost entrance for offering prayers to God in front of fire which produces huge amounts of fumes and noise.

Kalinjar Fort

Fort is located on an isolated rocky hill at the end of the Vindhya Range in Banda district. Most of building of fort were destroyed and falling. *Rhinopoma hardwickii* roosting attic of King Aman Singh Palace, which used by ASI staff. The roost consists of single entrance, some light comes in the roost. *Taphozous nudiventris* were roosting in crevices and attic of room of Queen Palace, the palace is rectangle in shape. It possesses two entrances which were in same size and shape, height and width of entrances are 10 and 3 feet respectively. The tourist activity is frequent in this palace.

Gupt Godavari Cave

Cave is situated over 1000 feet on a mountain and located at the base of a mount at a distance of 12 Km to the south-west of Chitrakoot in Madhya Pradesh. *Rhinopoma hardwickii* roosting over a hanging rock locally called Khat-khata Chor. Another cave is present attached to the roost in which stream of water flowing below the roost and halogen light is pasted over the rocks. It is a tourist place and thousands of peoples visiting every day.

Chaurashi Gumbad, **Kalpi**

The monument is situated on Kanpur, Jhansi national highway. It is a cemetery of Lodhi Sah which situated in Kalpi town of Jalaun district. The monument is protected by ASI. Three sides of monument were surrounded by agriculture land. Monument made up of brick, rectangle in shape and open from all sides. There were deep crevices in the roof of monument in which *Scotophillus heathi* were roosting. The local peoples are coming for worshiping of Lodhi Sah. Height of roost above the ground is 24 feet.

Joran Palace

It is situated in Joran village of Mahoba district which locally called Garhi. There were 7 to 8 rooms, most of which roof were damage. There was a one room with well-maintained roof that connected with a tunnel shaped hall. *Taphozous nudiventris* were roosting in only this room. In front of palace a small water canal is flowing and a large rocky area which is protected by forest department. All other sides of palace surrounded by agriculture field and forest. The roof of room was tomb shaped while of hall was in tunnel shaped. Local people using as a store room for cow dung cake and for caging of cattle. There was single entrance for entry inside the roost.

Cave Supa

Cave is located on boundary of village Supa of Mahoba district which attached with a monument. The 90 percent of monument is damage, left over part converted in to temple. The roost of *T. nudiventris* found in between two mountains and approximately 150 feet deep and bats were roosting on surface of rock and top of cave. All other sides are surrounded by agriculture field and forest. The caves open towards agriculture field.

Talbehat Fort

The Fort has massive structures and situated on the bank of massive Mansarovar Lake in Talbehat town of Lalitpur districts. Most part of the monuments were damaged and local tourist also damaging fort in search of treasure. There was a square shape room on top of the fort, attic and wall of room occupied by *R. hardwickii*. Most of the bat roost on a rounded hole in center of roof in winter. There was also a rectangle shape room with many crevices a on the roof below the fort toward lake that occupied by *T. nudiventris*. The monuments made up of bricks, beside that's three temples also situated in the fort.

Discussion

A total of eight species of bats, six were insectivorous and two frugivorous bats were recorded in this study. The Shannon diversity index of Bundelkhand region indicates that the diversity of bats was moderate in Bundelkhand region. The survey indicates that these bat species were unevenly distributed across the Bundelkhand region (Evenness index 0.53); it may be due to degree of protection.

A total of 15 roosts sites occupied by *R. hardwickii*, in fort, historical monument, old temple, house and cave. Earlier study also reported that this species preferred roosting in abounded building, cave, where light intensity was zero and humidity was high [38-39], old, ruins, abandoned and undisturbed building [40]. According to Purohit and Senacha [41], Benda *et al*. [39] they lived mostly in small colony while the results of present study indicate that they live from small colony to thousands of individuals depend upon degree of protection and area of roost. Male and female roost together and shared the roost with *T. nudiventris* and *R. microphyllum* that supported by earlier study [41]. A peculiar pattern was observed that they prefer roosting mainly where water source was available nearby the roost.

All four roost sites of *R. microphyllum* were found in historical monuments, cave and the roost sites were surrounded by mountain and forest. Although, the number of roosts was less, but the population size was very high. The striking feature of *R. microphyllum* roost is temperature, which was around 20°C and the temperature inside the roost did not much fluctuate with ambient temperature. They mostly prefer roosting at attic of the interior part of the monuments fort and cave, with zero light penetration. According to Elangovan *et al*., [42] *R. micophyllum* roosted in monument, cave and fort; and they consist of large colony size.

Two species of *Taphozous* genus were recorded from eight sites in the study area, out of which seven roosts were occupied by *T. nudiventris* and single roost by *T. perforatus*. *Taphozous nudiventris* colony consist of few individuals to hundred individuals while *T. perforatus* in thousands. The colony of both species consist of more male than female. Both species roosting in hilly region where rocky outcrops, caves and crevices found. Water source is present adjacent to roost of both species. They prefer roosting outside the human colony, and roost surround by forest and agriculture land [43]. Shehab *et al*., [44] reported *T. nudiventris* from fortress city of Halabiyyeh where they were roosting in fissure which was present between stone block, ancient building and ruins building. *T. perforatus* roosting in tunnel in which many chamber or crevices are found [38], in deep fissure [45]. Roosts of *T. perforatus* possess single entrance, and height of the roost from ground is more than 20 feet. They prefer roosting in those rooms where light intensity was zero lux but, in some roosts, it goes up to 2 lux, while temperature not less than 20°C. *Taphozous nudiventris* share roost with both insectivorous (*R. hardwickii*, *R. microphyllum*) and fruigivorous (*R. leschenaultii*) bats while *T. perforatus* with *R. leschenaultii*.

Single roost consist 65 individuals *S. heathii* found in crevices of monuments and in winter they go in deep of crevices to avoid cold. Earlier study reported that's *S. heathi* roosting in abandoned buildings, trunk and fronds of tree, and in tree holes [46].

Single roost consists 93 individuals of *M. lyra* found in abandoned and ruined building. The roof of roost was made of wooden with single entrance. Prakash [38] reported that's *M. lyra* roosts in tunnel and fort where light intensity was zero while Brosset [49] in temple, old building, and caves. The temperature of roost was also stable not goes below 20°C, Habersetzer [48] also reported that's *M. lyra* roost with stable temperature and high humidity. Water source also available near by the roost [38, 49]. There was no visibility inside the roost.

A total of three roosts of *P. medius* recorded on *Terminalia arjuna*, *Eucalypteus* sp., *Ficus benghalensis*, *Azadirachta indica* plants, which indicate that *T. medius* prefer mainly long tree with dense canopy and bushy area. Earlier study reported that *P. medius* roosts on long tree with dense canopy like *Ficus* [38, 49-51]. They roost on top of the tree in summer while in winter move down side the tree to avoid to heat of sun. According to Markus and Blackshaw [52] Black Flying Fox (*Pteropus Alecto*) exposing towards sun in top of the tree in cooler time and lower branches of tree in hotter period. We found that's they live in medium to large size colony. They hunted by local people for bush meat and extraction of oil. Dey *et al*. [50] reported from West Bengal that *P. medius* was hunted by outsider nomads for meat and traditional medicines. *Pteropus medius* mostly roosts outside of human colony where many dense trees are found and water source or food source are present nearby the roost. According to Granek [53] and Gulraiz *et al*. [54] *P. medius* roosting on wider or dense canopy tree because it is benefitted for spacious roosting area which decrease competition among the bat for space, for reproduction and sheltering.

Rousettus leschenaultii medium sized fruit eating bat, which were roosting in fort, monument which was almost abandoned and ruined. They prefer roosting where height of the roost is more than 14 feet and possess only single entrance. Earlier study on *R. leschenaultii* reported that they lived in cave, undisturbed building, wells and farm house and harbor large colony size [55-58], while our results show medium size colony. They share roost with *T. nudiventris* and *T. perforatus* and colony size of *R. leschenaultii* consist hundred to thousand individuals. *Rousettus leschenaultii* prefer roosting where water source is present nearby roost.

Conclusion

This is the first and detailed study on diversity and distribution of chiropteran faun of Bundelkhnad region of Uttar Pradesh. The *T. perforatus* first time reported from Uttar Pradesh. Eight species recorded from the study sites, out of which species of genus *Rhinopma*, and *Taphozous* were only found in Bundelkhnad region. The result of current study reveals that's the all above mention eight species except *P. medius*, roost in caves, rock, crevices and attic of monument, abandoned and ruined buildings in the day time. Most of the roost found outside

of human colony, where water source available nearby roost. Bats preferred to roost in permanent structure which possesses single entrance with zero light intensity. Bats were roosting in attic and crevices of building, monuments and cave where height of roost above the ground was more than 14 feet. Temperature of roost was more than 20° C and almost stable. Those roosts where temperature fluctuates with environment, bats vacate the roost in winter and return back when temperature becomes normal. Insectivorous bats control populations of agricultural pests and reduce the need to use pesticides while frugivorous bats serve as pollinators and seed dispersers of many plants. The population of bat decreased more rapidly due to degradation of roosting site and foraging areas due to unawareness of their role in common people. For the conservation of these bats species, it is necessary to conserve their habitats and foraging area.

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