

## Review Article

# Occurrence of bats in protected areas of Nepal: An update on species richness and distribution records

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## Abstract

Bat surveys in 20 Protected Areas (PAs) of Nepal are sporadic and/or had targeted purposively a few localities, therefore, bat diversity from the PAs is yet to be explored. Bat species richness in PAs from two reviews until 2011 are inconsistent. In total, seven surveys have been undertaken in six PAs since 2011. Hence, an update and revision on chiropteran account from the PAs of Nepal is warranted. We reviewed available literatures and museum collection records, and further collated and plotted bat occurrence coordinates into the country and mapped them. In total, 44 of 53 bat species in Nepal have been recorded from 12 PAs. Annapurna Conservation Area (ACA) reports highest species richness (22) followed by Shivapuri Nagarjun National Park and Buffer Zone (SNNP & BZ) (15), Makalu Barun National Park and Buffer Zone (MBNP & BZ) (14) and Chitwan National Park and Buffer Zone (CNP & BZ) (13). In contrast, survey localities are more in CNP & BZ (12), ACA and SNNP & BZ (equally 11) and MBNP & BZ (10). Species richness increased proportionately with higher survey efforts and including more habitat types in respective PAs. Three species: *Rhinolophus ferrumequinum*, *Rh. pearsonii* and *Rh. sinicus* are recorded from six out of 12 PAs. *Pipistrellus javanicus* (12), *Hipposideros armiger* (10), *Cynopterus sphinx* (9) and *Rh. sinicus* (9) are recorded from maximum number of surveyed localities in the PAs. All the PAs have limited occurrence records. Therefore, intensive surveys are recommended for understanding actual chiropteran diversity to the PAs of Nepal.

**Keywords:** Chiroptera, Diversity, Locality records, Protected areas, Species richness

## 1 | Introduction

In Nepal, 53 bat species (Thapa 2014; Sharma et al. 2019; Ruedi et al. 2021) are distributed from the

Tarai (plains) to Trans-Himalayas. Makut (probably Mukot in Dolpa District) at an elevation of 4154 m above sea level (a.s.l.) (Bates & Harrison

**Table 1.** Brief Description of PAs in Nepal

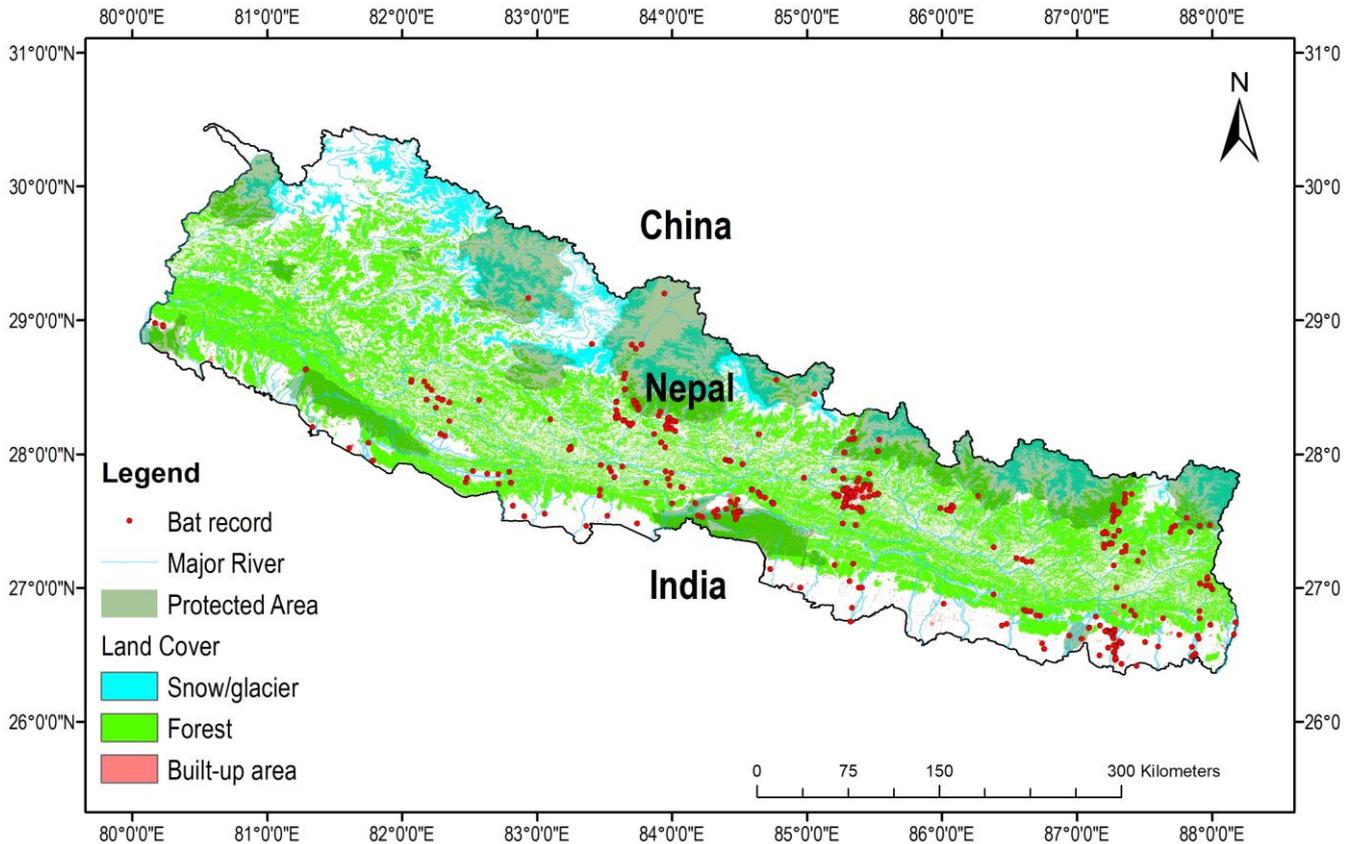
S. N.	PAs	N	E	Physio-geographic region	Dominant vegetation
1	KTWR & BZ	26° 40'	87° 0'	Tarai	Grassland, deciduous mixed riverine forest with patches of <i>Acacia-Sisso</i>
2	PNP & BZ	27° 20'	84° 50'	Tarai, Chure range	Sal, tropical mixed hardwood and broad-leaved forest, grassland
3	CNP & BZ	27° 30'	84° 30'	Chure range, Inner Tarai	Sal, tropical mixed hardwood and broad-leaved forest, grassland, deciduous mixed riverine forest
4	KCA	27° 40'	88° 0'	High mountains, High Himalayas	Temperate mixed broadleaved and needle leaved evergreen forests, alpine scrubs and meadows
5	MBNP & BZ	27° 40'	87° 10'	High mountains, High Himalayas	Sub-tropical mixed broadleaved forest, temperate mixed broadleaved and needle leaved evergreen forests, alpine scrubs and meadows
6	SNNP & BZ	27° 45'	85° 25'	Middle mountains	Sub-tropical mixed broadleaved forest, temperate mixed broadleaved and needle leaved evergreen forests
7	SNP & BZ	27° 50'	86° 50'	High Himalayas	Sub-tropical evergreen needle-leaved forest, temperate mixed needle leaved evergreen forests, alpine scrubs and meadows
8	GCA	28° 0'	86° 10'	High mountains, High Himalayas	Sub-tropical mixed broadleaved forest, temperate mixed broadleaved and needle leaved evergreen forests, alpine scrubs and meadows
9	BaNP & BZ	28° 10'	82° 0'	Chure range, Tarai	Sal, tropical mixed hardwood and broad-leaved forest, grassland, deciduous mixed riverine forest
10	LNP & BZ	28° 10'	85° 40'	High mountains, High Himalayas	Sub-tropical mixed broadleaved forest, temperate mixed broadleaved and needle leaved evergreen forests, alpine scrubs and meadows
11	KrCA	28° 15'	81° 20'	Tarai	Grassland
12	BNP & BZ	28° 30'	81° 20'	Tarai, Chure range	Sal, tropical mixed hardwood and broad-leaved forest, grassland, deciduous mixed riverine forest
13	MCA	28° 30'	84° 50'	High Himalayas	Sub-tropical evergreen needle-leaved forest, temperate mixed needle leaved evergreen forests, alpine scrubs and meadows
14	DHR	28° 40'	83° 0'	High mountains, High Himalayas	Temperate mixed broadleaved and needle leaved evergreen forests, alpine scrubs and meadows
15	ShNP & BZ	28° 50'	81° 10'	Tarai, Chure range	Sal, Grassland, tropical mixed hardwood and broad-leaved forest, deciduous mixed riverine forest
16	ACA	28° 50'	84° 0'	High mountains, High Himalayas, Trans-Himalayas	Sub-tropical mixed broadleaved forest, temperate mixed broadleaved and needle leaved evergreen forests, alpine scrubs and meadows, <i>Caragana</i> and <i>Salix</i> scrub
17	SPNP & BZ	29° 20'	82° 50'	High Himalayas, Trans-Himalayas	Temperate mixed broadleaved and needle leaved evergreen forests, alpine scrubs and meadows, <i>Caragana</i> and <i>Salix</i> scrub
18	KNP	29° 25'	82° 05'	Middle mountains	Sub-tropical mixed broadleaved forest, temperate mixed broadleaved and needle leaved evergreen forests, scrubs and meadows
19	RNP	29° 30'	82° 15'	High mountains	Temperate mixed broadleaved and needle leaved evergreen forests, alpine scrubs and meadows
20	ANCA	30° 0'	80° 50'	High mountains, High Himalayas	Sub-tropical mixed broadleaved forest, temperate mixed broadleaved and needle leaved evergreen forests, alpine scrubs and meadows

1997) is the highest elevation record. The protected area system (PAS) of Nepal currently covers more than 23.39% (34419.75 km<sup>2</sup>) of the total area of the country. The PAS comprises of 20 protected areas (PAs): 12 national parks, a wildlife reserve and a hunting reserve (Amin et al. 2018), six conservation areas and 13 buffer zones (MoFSC 2016; DNPWC 2018). These PAs are located along different latitudes and longitudes comprising different physio-geographic ranges and vegetation types (Table 1).

Biodiversity surveys had been conducted long before and after the establishment of the PAs. Large mammals have been substantially documented from all the PAs. However, there are less studies or surveys focusing on small

mammals (Jnawali et al. 2011) such as bats and its documentation is mainly opportunistic. Although bats constitute more than a quarter of total mammalian fauna in Nepal, it has been neglected in conservation policies. The taxa are also underrepresented in the management plans of the PAs.

Bats had been reported from the localities, nearly 50-150 years before the establishment of PAs. For example, *Rhinolophus pusillus* specimens was collected during September, 1876 from Soondarijal (=Sundarijal) (now Shivapuri Nagarjun National Park and Buffer Zone, SNNP & BZ) (Sinha 1973). There had been some surveys in the localities such as Sipuri (Probably Shivapuri, now SNNP & BZ) and Parchung (probably Parchyang,



**Figure 1.** Map of Nepal showing bat locality records inside and outside the PAs

now Langtang National Park and Buffer Zone, LNP & BZ) (Hinton & Fry 1923; Fry 1925). During 20-21 December, 1948 Howard Weaver and Richard Mack, collected four specimens of *Cynopterus sphinx* from Chisapani (now western border of Bardia National Park and Buffer Zone, BNP & BZ) (Johnson et al. 1980; Orell 2021). A specimen of *Plecotus homochrous* was secured by Dr. R. L. Fleming from Jomsom, Mustang District (now Annapurna Conservation Area, ACA) on 6 December 1949 (Sanborn 1950).

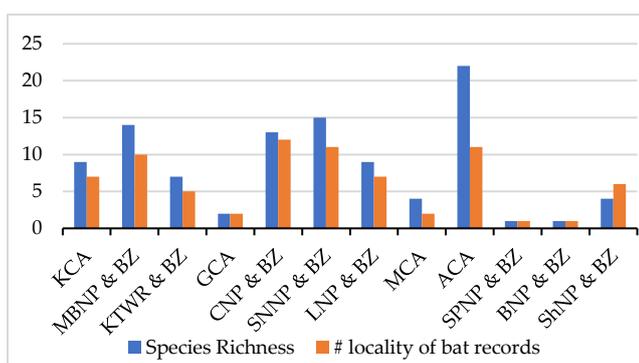
There had been several foreign expeditions in Nepal to collect bat specimens from different localities in the country, which were included in the PAs later. Japanese expedition during 1968 collected *Pipistrellus javanicus* from Birathanti (Birethanti), which is a part of ACA now (Abe 1971). Richard Merle Mitchell collected bat specimens during Nepal Health Survey (1965–66) and Nepal Ecto-parasite Program (1967–70) from the localities that are now in LNP & BZ and SNNP & BZ (Mitchell & Punzo 1977; Mitchell 1978, 1980; Peach 2011; Millen & Lim 2018). Jochen Martens

in 1970 collected bat specimens from Ringmo, Dolpa District, which is now the part of Shey-Phoksundo National Park and Buffer Zone (SPNP & BZ). In 1973, he also collected bats near Mt. Chordung and Those of Ramechhap District, which is now in the vicinity of Gaurishankar Conservation Area (GCA) and Dike Pako Cave at Balaju of Kathmandu District, which is now the part of SNNP & BZ (Kock 1987, 1996). McNeely and Lay collected specimens of nine species during Arun Valley Wildlife Expedition (AVWE) in 1973 from the localities later included in Makalu Barun National Park and Buffer Zone (MBNP & BZ) (Peach 2011; Grant et al. 2020). Zoologists from the Hungarian Natural History Museum (HNHM) and the Zoological Museum of Moscow State University (ZMMU) organized series of expeditions to Nepal for the purposes of collecting voucher specimens of bats during June, 1993 to September, 1998. The expeditions collected specimens from Nagarjun, the part of SNNP & BZ, Island Jungle Resort of Nawalparasi Purba District in the vicinity of Chitwan National Park and Buffer Zone (CNP & BZ), Mamankhe and

Tawa of Taplejung District (the vicinity of Kanchanjunga Conservation Area, KCA) and in the vicinity of Sudame, Tikhedhunga, Banthanti Ghorepani and near Tatopani of ACA (Csorba et al. 1999). Myers and Smith collected 143 specimens of 14 species during a field survey in CNP & BZ during March 1990 (Myers et al. 2000).

Management plans of protected areas included bats in the list of mammals later on. For example, KCA Management Plan 2061-2066 BS (2004-2009 AD) listed 12 bat species (Sherpa 1994). However, bat species were excluded in the most of management plans, for example, SNNP Management Plan 2074/75-2078/79 BS (2017/18-2021/22 AD). Suwal and Verheugt (1995) compiled on probable occurrence of 23 bat species from six protected areas following Corbet and Hill (1992).

Since 1998 Nepali University students conducted bat surveys in prior surveyed and thus far not surveyed PAs such as, Nagarjun Cave (Now SNNP & BZ) (Malla 2000), Koshi Tappu Wildlife Reserve and Buffer Zone (KTWR & BZ) (Thapa et al. 2012b), Manaslu Conservation Area (MCA) (Gurung 2019). Local researchers continued bat surveys in some of the PAs: KTWR & BZ (Thapa 2008, 2009b), SNNP & BZ (Thapa et al. 2009, 2012, 2017), MBNP & BZ and KCA (Acharya 2010) and CNP & BZ (Dahal et al. 2011; Thapa et al. 2015). Baral et al. (2019) included a list of 30 species of bats in ACA. Poudyal et al. (2019) included four species of bats from the Shuklaphanta National Park and Buffer Zone (ShNP& BZ). Recently, bat monitoring surveys were conducted in ACA (SMCRF 2020; Thapa 2020).



**Figure 2.** Species richness and number of locality records of total bat species in PAs

The review of bats from PAs has been attempted earlier (Thapa 2011; Pearch 2011). Since, bat species richness within PAs from these two reviews is inconsistent, an update and revision on chiropteran account from PAs of Nepal based on confirmed locality records is warranted.

## 2 | Materials and methods

### 2.1 | Data collection

Bat records from secondary literatures and additional museum collections from Global Biodiversity Information Facility (GBIF 2021) were collated. All available literatures were reviewed, primarily: Csorba et al. (1999), Myers et al. (2000), Acharya et al. (2010), Pearch (2011) and Thapa (2011). We also reviewed theses, Malla (2000) and Gurung (2019); survey reports Thapa (2008, 2009b, 2020), Thapa et al. (2009) and Acharya, 2010); and publications Thapa et al. (2012a, b, 2015, 2017), Baral et al. (2019) and Poudyal et al. (2019).

Number of locality records, species richness and habitats of the reported species within and in the vicinity of protected areas including buffer zones were verified. Those species with confirmed locality records were included and those with unknown locality records which were included in (Sherpa 1994), Suwal and Verheugt (1995), Shrestha (1997), Majupuria and Kumar [Majupuria] (2006) and Thapa (2011) were excluded.

### 2.2 | GIS mapping

All collated distribution records (geographic coordinates) were plotted in Arc GIS 10.4 and maps with distribution records of bat for Nepal and PAs were prepared separately.

### 2.3 | Habitat classification

Current state of habitats in and within the proximity of occurrence records of bats species (where bat species was captured) were classified into five classes; a. Forests: that included only forests of different types, b. cave: that included its roosting habitat as cave, c. Forest / Farmland /

Settlement: that included the bat species captured site in one of the three habitats and other remaining habitats within its surroundings (proximity), d. Farmland/Settlement: that included the bat species captured site in one of the two habitats and other remaining habitat within its surrounding, e. Arid land: The barren area in the Trans-Himalayan or rain-shadow region. Each

occurrence record was assigned one or more of these habitat types.

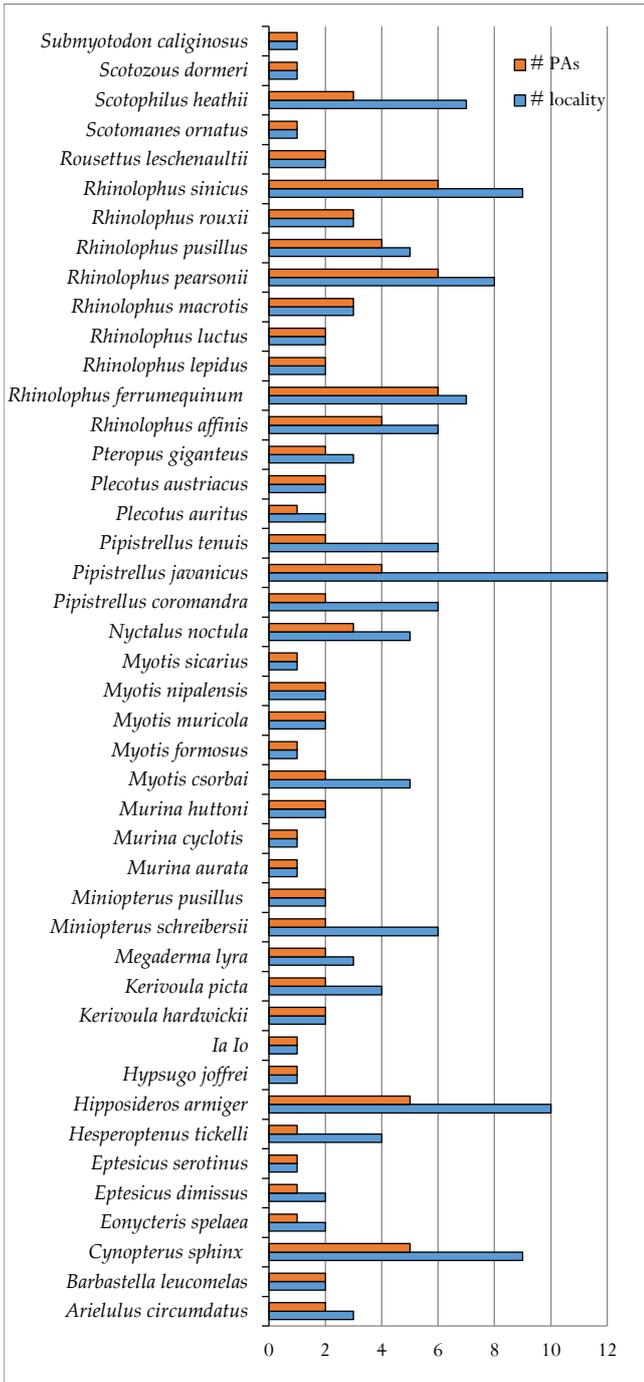
### 2.4 | Data analysis

Data on bat species richness, number of PAs, number of locality records and habitat classification were presented using bar and column diagrams.

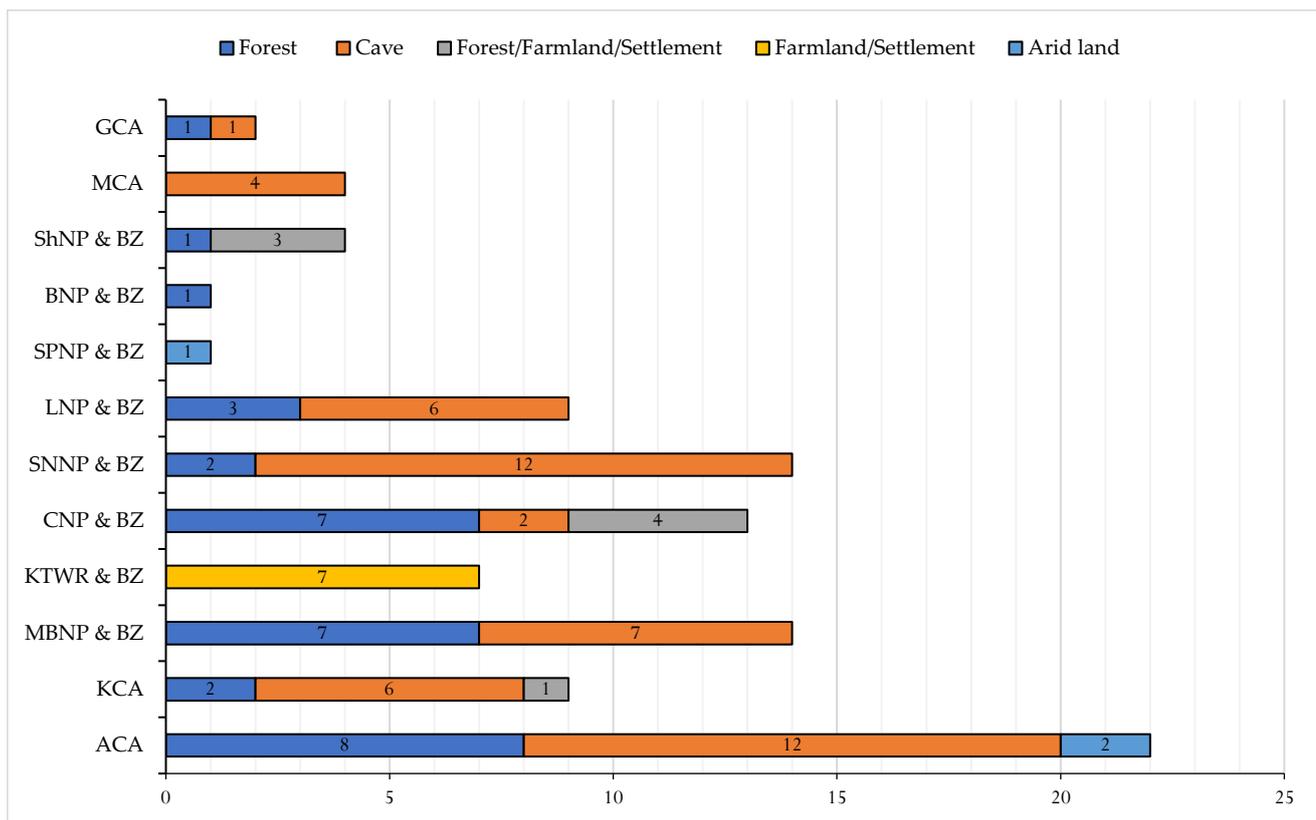
## 3 | Results

Total of 621 unique occurrence coordinates of bats within Nepal include 75 localities within and in the vicinity of 12 PAs (Fig. 1). Bats' distribution in PAs was found within an elevation range from 70m a.s.l. (KTWR & BZ) to 3938 m a.s.l. (ACA). Among 12 PAs, the ACA harbors highest species richness (22 species), followed by SNNP & BZ (15 species), MBNP & BZ (14 species) and CNP & BZ (13 species). Other eight PAs accounts for less than 10 species with BNP & BZ and SPNP & BZ constituting single species each (Fig. 2, Annex I).

Three species: *Rh. sinicus*, *Rh. pearsonii* and *Rh. ferrumequinum* each are confirmed from six PAs while *Cy. sphinx* and *Hi. armiger* each are recorded from five PAs. Occurrences of *Rh. sinicus* and *Rh. pearsonii* overlapped in all six PAs: ACA, KCA, LNP & BZ, MBNP & BZ, SNNP & BZ and MCA while occurrence of *Rh. ferrumequinum* overlapped in five PAs. In addition, the species is reported from GCA and yet to be reported from KCA. Similarly, occurrence of *Hi. armiger* overlapped at five PAs and yet to be reported from MCA. Occurrence of *Cy. sphinx* overlapped with all four species at KCA and reported in addition from CNP, KTWR, BNP and ShNP, whereas, 15 bat species are only recorded from single PA, 11 out of which have single locality (occurrence) record (Fig. 2). Four species are recorded from two to four different localities within the same PAs (Annex I). *Submyotodon caliginosus*, *Scotozous dormeri* and *Eptesicus dimissus* are recorded once in the country thus far (Myers et al. 2000; Thapa et al. 2012b; Ruedi et al. 2021). Other eight species are,



**Figure 3.** Number of PAs and number of locality records for 44 bat species



**Figure 4.** Species richness of bats in different current classified habitats in PAs

however, reported from other localities outside PAs. Four species, *Pi. javanicus* (12), followed by *Hi. armiger* (10), *Cy. sphinx* and *Rh. sinicus* (9 each) are reported from maximum locality records in PAs (Fig. 3). Eight species (*Ep. dimissus*, *Kerivoula hardwickii*, *Ke. picta*, *Murina cyclotis*, *Pl. wardi*, *Pl. homochrous*, *Sc. dormeri* and *Su. caliginosus*) have been recorded only from PAs, while nine (*Hypsugo affinis*, *Hi. cineraceus*, *Hi. fulvous*, *Hi. genitilis*, *Mu. leucogaster*, *Mu. blythii*, *Nyctalus montanus*, *Scotophilus kuhlii* and *Taphozous longimanus*) species are yet to be reported from PAs.

Each occurrence record from PAs was assigned to five habitat types. Highest species richness was found in Forest (43%, 19 species), followed by Cave (37%, 16 species). Forest/Farmland/Settlement (11%, 5 species), Arid land (5%, 2 species), Cave/Settlement and Settlement (2% each, 1 species each) include few species richness. Habitat types with species richness in 12 PAs is given in Fig. 4. Altogether, 17 species were first time recorded in Nepal from PAs (Table 2).

Sporadic and seasonal bat surveys and opportunistic recordings have been conducted in 12 PAs with the most in SNNP & BZ (Table 3). However, CNP & BZ shares highest number of locality records (12) followed by ACA and SNNP & BZ (equally 11) and MBNP & BZ (10). Maps of 12 PAs plotted with confirmed recorded localities are presented in Annex II.

## 4 | Discussion

More than 83% (44 species) of the bat species recorded from the country (53) (Jnawali et al. 2011) are recorded from 12 (60 %) out of 20 PAs. PAs include only 12% (75) of the national bat localities records (652) (Fig. 1). As the PAs cover more than 23.39% of Nepal (DNPWC 2018), bat inventory in all the PAs would be national representative.

Earlier, Pearch (2011) reported only 28 species from five PAs; ACA, CNP & BZ, LNP & BZ, SPNP & BZ and SNNP & BZ, while Thapa (2011) collated 32 locality records for 41 species from 10 PAs. A few surveys in not surveyed (KTWR & BZ and MCA) and prior surveyed PAs (SNNP & BZ,

CNP & BZ and ACA) have been conducted since 2011. Pearch (2011) and Thapa (2011) reported highest elevation of bat occurrence at 3600m (SPNP & BZ) within the PAs. Thapa et al. (2014) recorded *Pl. homochrous* from an elevation of 3938m (ACA), which is the highest elevation record of bat species within PAs. However, the highest elevation record of bat species (*Mu. aurata*) for the country is from Mukot, Dolpa District, outside the PAs at 4154 m (Bates & Harrison 1997). The lowest elevation record (70 m) of bat species from PAs is consistent with Thapa et al. (2012b).

Maximum species richness was found in ACA (23) amongst 10 PAs followed by CNP & BZ (15) (Thapa 2011). However, Thapa (2011) included species records from unknown localities within PAs, which is excluded in the current review. Pearch (2011) reported highest species richness from CNP & BZ (13) followed by ACA (12). In the current review, amongst 12 PAs, ACA harbors highest species richness (22) followed by SNNP & BZ (15), MBNP & BZ (14) and CNP & BZ (13) (Fig. 2). The PAs in higher elevations (Middle Mountains and High Mountains) such as ACA, SNNP & BZ and MBNP & BZ are found to be more diverse than the PAs in lower elevations (Tarai, Churia range, Inner-Tarai) such as CNP & BZ, KTWR & BZ, BNP & BZ and ShNP& BZ. This is because of larger areas, varying elevations and more localities surveyed and more survey efforts in PAs from mountainous region compared to Tarai, Chure and Inner-Tarai regions (Table 3).

The current review includes six additional species *Ia io*, *Rh. lepidus*, *Rh. pearsonii*, *Rh. rouxii*, *Sc. heathii* and *Su. caliginosus* to Thapa (2011), but excludes three species *Hi. cinearceus*, *Myotis siligorensis* and *Ny. montanus* from Thapa (2011) in lack of confirmed localities.

In the current review, rhinolophid bats (such as *Rh. sinicus*, *Rh. pearsonii* and *Rh. ferrumequinum*) which have larger distribution range are confirmed from several PAs (six each). Similarly, other species with larger distribution range *Cy. sphinx* and *Hi. armiger* (Thapa et al. 2021) are also confirmed from five PAs each (Annex I). However, Thapa (2011) and Pearch (2011)

reported *Rh. sinicus* from three and two PAs and *R. ferrumequinum* from four PAs and single PA (ACA), respectively. Though *Rh. pearsonii* had been recorded from localities long before the establishment of PAs (Hinton & Fry 1923), the species was not included earlier from PAs (Pearch 2011; Thapa 2011). Thapa (2011) and Pearch (2011) reported *Cy. sphinx* from seven PAs and single PA (CNP & BZ) and *Hi. armiger* from four PAs and single PA (SNNP & BZ), respectively. The current review corrects occurrence of least known species reported in Thapa (2011). Occurrence of *Barbastella leucomelas* previously in four PAs is now confirmed from two PAs which is in accordance to Pearch (2011). Occurrence of *My. muricola* in two PAs (Pearch 2011; Thapa 2011) is similar in current review, however, *Myotis* sp. (provisional identification as *My. muricola* by Csorba et al. (1999) from LNP is currently identified as *Su. caliginosus* (Ruedi et al. 2021) is added to the list of bats in PAs.

Sherpa (1994) and Suwal and Verheugt (1995) do not include confirmed locality records of species occurrences from the PAs. The former includes species reported from Sikkim but not recorded yet from KCA and the latter followed Corbet and Hill (1992).

However, list of mammals of KCA published in management plan 2077/78-2081/82 B.S. (2019/20-2023/24 A.D.) followed Jnawali et al. (2011) and includes six species of bats. A list of altogether 30 species of bats occurring in ACA has been recently compiled (Baral et al. 2019). The list includes five families and number of species is given in parentheses; Pteropodidae (3); Rhinolophidae (7), Hipposideridae (3), Vespertilionidae (16) and Miniopteridae (1). However, species included in the list such as *Rh. subbadius*, *My. mystacinus*, *My. siligorensis* and *Ke. picta* needs further clarification. In absence of holotype of *Rh. subbadius*, the species is excluded from the Checklist of Mammals of Nepal. Also, *My. mystacinus* is a European species, and *My. siligorensis*, reported from Siliguri, India has yet to be reported from Nepal (Thapa 2014). Thus far *Ke. picta* is known occurring only from CNP & BZ and ShNP & BZ (Myers et al. 2000; Poudyal et al. 2019) in Nepal. Baral et al. (2019)

**Table 2.** List of confirmed bat species and its first record from PAs

S.N.	Species	PAs first record	Reference	Remarks
1	<i>Arielulus circumdatus</i>	MBNP	Pearch (2011), Grant et al. (2020)	First record to Nepal
2	<i>Barbastella leucomelas</i>	LNP	Pearch (2011), Millen & Lim (2018)	Collected by R.M. Mitchell on 8/12/1968
3	<i>Cynopterus sphinx</i>	BNP	Johnson et al. (1980)	Four specimens collected during 20-21 December, 1948 by Howard Weaver and Richard Mack
4	<i>Eonycteris spelaea</i>	CNP	Myers et al. (2000)	First record to Nepal
5	<i>Eptesicus dimissus</i>	CNP	Myers et al. (2000)	First and only record to Nepal
6	<i>Eptesicus serotinus</i>	MBNP	Pearch (2011), Grant et al. (2020)	
7	<i>Hesperoptenus tickelli</i>	CNP	Myers et al. (2000)	
8	<i>Hipposideros armiger</i>	SNNP	Pearch (2011), Millen & Lim (2018)	Collected by R.M. Mitchell on 7 September 1969
9	<i>Hypsugo joffrei</i>	MBNP	Pearch (2011), Grant et al. (2020)	First record to Nepal
10	<i>Ia io</i>	ACA	Thapa (2020)	
11	<i>Kerivoula hardwickii</i>	KCA	Csorba et al. (1999)	First record to Nepal
12	<i>Kerivoula picta</i>	CNP	Myers et al. (2000)	First confirmed locality record
13	<i>Megaderma lyra</i>	SNNP	Csorba et al. (1999)	
14	<i>Miniopterus pusillus</i>	CNP	Myers et al. (2000)	
15	<i>Miniopterus schreibersii</i>	ACA	Csorba et al. (1999)	
16	<i>Murina aurata</i>	SNNP	Maeda (1980)	First record to Nepal
17	<i>Murina cyclotis</i>	CNP	Csorba et al. (1999)	First record to Nepal
18	<i>Murina huttoni</i>	MBNP, KCA	Acharya (2010)	
19	<i>Myotis csorbai</i>	ACA	Csorba et al. (1999)	
20	<i>Myotis formosus</i>	ACA	Csorba et al. (1999)	
21	<i>Myotis muricola</i>	GCA	Kock (1996)	First record to Nepal
22	<i>Myotis nipalensis</i>	MBNP	Pearch (2011), Grant et al. (2020)	FMNH 114250 as <i>M. mystacinus</i> collected by AVWE on 27 May 1973
23	<i>Myotis sicarius</i>	ACA	Csorba et al. (1999)	
24	<i>Nyctalus noctula</i>	MBNP	Pearch (2011), Grant et al. (2020)	
25	<i>Pipistrellus coromandra</i>	CNP	Myers et al. (2000)	
26	<i>Pipistrellus javanicus</i>	SNNP	Fry (1925)	
27	<i>Pipistrellus tenuis</i>	CNP	Myers et al. (2000)	
28	<i>Plecotus wardi</i>	SPNP	Kock (1996)	First record to Nepal
29	<i>Plecotus homochrous</i>	ACA	Sanborn (1950)	First record to Nepal
30	<i>Pteropus giganteus</i>	KTWR	Thapa (2008)	First confirmed locality record from PAs
31	<i>Rhinolophus affinis</i>	SNNP	Kock (1996); Pearch (2011)	SMF 58415—SMF 58417 collected by Jochen Martens 1 May 1973
32	<i>Rhinolophus ferrumequinum</i>	SNNP	Pearch (2011), Millen & Lim (2018)	Collected by R.M. Mitchell on 30 August and 7 November 1969
33	<i>Rhinolophus lepidus</i>	LNP	Mitchell 1980	First record to Nepal
34	<i>Rhinolophus luctus</i>	MBNP	Bates and Harrison (1997), Pearch (2011), Grant et al. (2020)	FMNH
35	<i>Rhinolophus macrotis</i>	MBNP	Bates and Harrison (1997), Pearch (2011), Grant et al. (2020)	FMNH
36	<i>Rhinolophus pearsonii</i>	LNP	Hinton and Fry (1923)	First record to Nepal
37	<i>Rhinolophus pusillus</i>	SNNP	Sinha (1973)	Specimens collected during September 1876 from Soondarijal (=Sundarijal) (now SNNP), at Zoological Survey of India, Kolkata
38	<i>Rhinolophus rouxii</i>	SNNP	Fry (1925)	First record to Nepal
39	<i>Rhinolophus sinicus</i>	LNP	Hinton and Fry (1923)	First record to Nepal
40	<i>Rousettus leschenaultii</i>	ACA	Csorba et al. (1999)	
41	<i>Scotomanes ornatus</i>	ACA	Csorba et al. (1999)	
42	<i>Scotophilus heathii</i>	CNP	Myers et al. (2000)	
43	<i>Scotozous dormerii</i>	KTWR	Thapa et al. (2012a)	First and only record to Nepal
44	<i>Submyotodon caliginosus</i>	LNP	Ruedi et al. 2021	First and only record to Nepal

speculated possibly occurring bats in ACA that has been reported earlier from Pokhara valley such as *Cy. sphinx*, *Hi. cineraceus*, *Hi. pomona*, *Miniopterus. pusillus*, *Pi. coromandra*, *Pteropus giganteus*, *Rh. affinis* and *Rh. macrotis*. Thapa (2020) added a few species to the list of bats from ACA: *Ia io*, *Pl. wardi*, *Rh. affinis* and *Rh. rouxii*.

Due to the sporadic and seasonal bat surveys in PAs of Nepal (Table 3), and mostly opportunistic surveys targeted in limited localities or areas within the PAs, it will be early to conclude its correlation with location (latitude/longitude), physio-geography and climate and vegetation type of PAs. However, PAs with more habitat types (forest and cave) consist of higher species richness. Though, bat surveys have been mostly conducted in the vicinity of settlements in PAs and purposively targeted in caves besides CNP & BZ. Bat species richness and assemblage in a few PAs such as ACA, SNNP & BZ, MBNP & BZ and CNP & BZ are found to be high. However, more

localities were surveyed in CNP & BZ (12) followed by ACA and SNNP & BZ (equally 11) and MBNP & BZ (10).

Some of the species such as *Cy. sphinx*, *Hi. armiger*, *Megaderma lyra*, *Rousettus leschenaultii* and *Rh. affinis* have currently large distribution range throughout the country (Thapa et al. 2021). However, *Cy. sphinx* is only confirmed from the PAs at lower elevations such as; BNP & BZ, CNP & BZ, KTWR & BZ and ShNP & BZ and at higher elevations such as KCA. The species is likely to occur in other PAs from the Tarai to High Mountains. Similarly, *Hi. armiger* is only confirmed from KCA, MBNP & BZ, SNNP & BZ, LNP & BZ and ACA. Since, the species is recorded from Dang District (Ghimire 2015). The species is likely to occur in other PAs from Middle Mountains to High Himalayas. In the case of *Rh. affinis*, the species is confirmed from KCA, SNNP & BZ, MCA and ACA. It has also been recorded from Dang District (Ghimire 2015). The species is

**Table 3.** Bat studies/ surveys conducted in PAs of Nepal

PAs	Detailed survey	Short field survey	Opportunistic records
KCA		Csorba et al. (1999) Acharya (2010)	
MBNP & BZ	Arun Valley Wildlife Expedition	Acharya (2010)	
KTWR & BZ		Thapa et al. (2012b)	Thapa (2008, 2009b)
GCA			Kock (1987, 1996)
CNP & BZ	Myers et al. (2000)	Thapa et al. (2015)	Csorba et al. (1999) Dahal et al. (2011) SMCRF (2014)
SNNP & BZ		Mitchell & Punzo (1977), Mitchell (1978, 1980) Kock (1987, 1996) Csorba et al. (1999) Malla (2000) Thapa et al. (2009) Thapa et al. (2012a) Thapa et al. (2017)	Sinha (1973) Hinton & Fry (1923) Fry (1925)
LNP & BZ		Mitchell & Punzo (1977), Mitchell (1978, 1980),	Hinton & Fry (1923) Fry (1925) Lewis (1970) Csorba et al. (1999)
MCA		Gurung (2019)	
ACA	Csorba et al. (1999)	Thapa (2020)	Sanborn (1950) Abe (1971) SMCRF (2020)
SPNP & BZ			Kock (1987, 1996)
BNP & BZ			Johnson et al. (1980)
ShNP & BZ			Poudyal et al. (2020)

likely to occur in PAs from Middle Mountains and High Mountains. Though *Ro. leschenaultii* is confirmed from CNP & BZ and ACA, the species is likely to distribute in the PAs in the Chure range, Inner-Tarai to High Himalayas throughout Nepal. Also, *Me. lyra* is confirmed from KTWR & BZ and SNNP & BZ, however, the species is likely to distribute in PAs from the central and western Tarai.

In the current study, *Rh. ferrumequinum* is confirmed from MBNP & BZ, GCA, SNNP & BZ, LNP & BZ, MCA and ACA and *Rh. pearsonii* and *Rh. sinicus* both are confirmed from KCA, MBNP & BZ, SNNP & BZ, LNP & BZ, MCA and ACA. The three *Rhinolophus* species are likely to occur in PAs from Middle Mountains to High Himalayas. *Pi. javanicus* is confirmed from CNP & BZ, ACA, SNNP & BZ and LNP & BZ. The species is likely to distribute in the PAs from Tarai to High Mountains. Very few species are confined to lower elevations (Tarai, Churia range and Inner-Tarai) such as *Sc. heathii*. The species is confirmed from KTWR & BZ, CNP & BZ and ShNP & BZ. The species is expected to occur in the PAs from the region. Large fruit bats such as *Pt. giganteus* travel large distances for foraging and are its roosting colonies are distributed from the Tarai to Middle Mountains, but their roosting colonies are confirmed surprisingly only from two PAs; KTWR & BZ and ShNP & BZ (Annex I). There is possibility of occurrence of its roosting colony in some more PAs from the region. There are also possibilities of occurrence of species (so far recorded from single PA) in other PAs and in other localities within the same PA. There are also possibilities of occurrence of some species in PAs that has yet to be recorded.

## 5 | Conclusions

Bat surveys in PAs of Nepal are sporadic and had targeted a few localities; therefore, bat diversity from the PAs is yet to be explored. Chiropteran profile has yet to be prepared for PAs in Nepal. Surprisingly, there have not been any confirmed bat records from eight other PAs and nine species has not been reported yet from PAs which occur outside PAs. Furthermore, maps of PAs plotted

with confirmed recorded localities prepared for 12 PAs (Annex II), revealed that sampling localities are limited and uneven. This suggests targeting future surveys and monitoring in non-surveyed eight PAs (SNP & BZ, PNP & BZ, DHR, BaNP& BZ, RNP & BZ, KNP & BZ and ANCA) and PAs with few confirmed locality records such as BNP & BZ, SPNP & BZ, MCA and GCA. However, not surveyed locations within remaining other PAs should also be continued.

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## Authors' contributions

Thapa, S., Yu, W. and Yi, W. designed the concept of this study. Thapa S. wrote the first draft of the manuscript and all authors contributed with their input in data collection and figure and map preparation. All the authors contributed for verification of data and revision of the comments from reviewers. All authors read, reviewed and agreed on the final manuscript.

## Conflicts of interest

Authors declare no conflict of interest.

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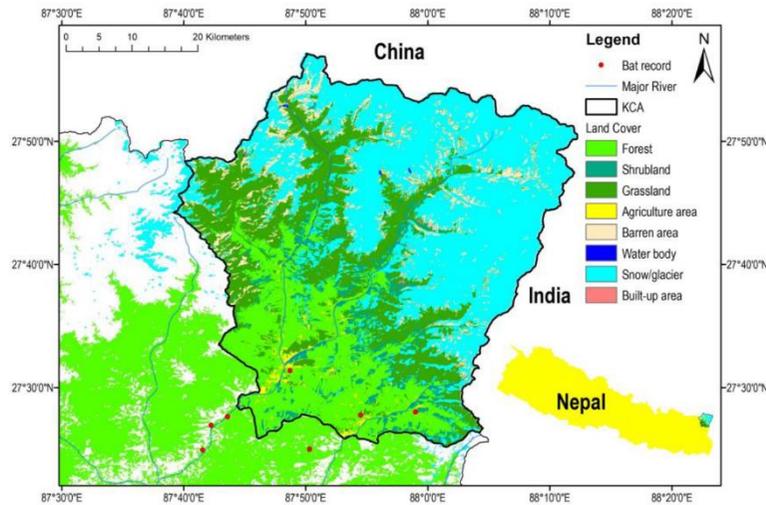
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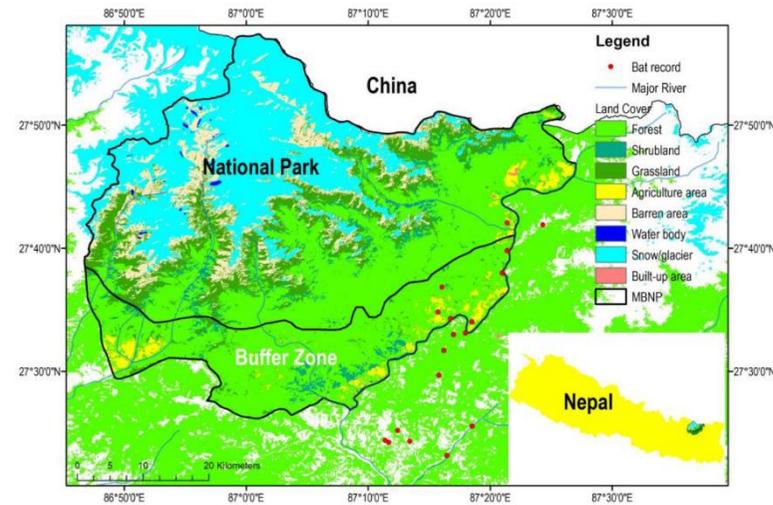


29	<i>Plecotus austriacus</i>	1 (1)	0	0	0	0	0	0	0	0	0	0	1 (1)
30	<i>Pteropus giganteus</i>	0	0	0	0	1 (2)	0	0	0	0	1 (1)	0	0
31	<i>Rhinolophus affinis</i>	1 (2)	0	0	1 (1)	0	0	0	1 (2)	1 (1)	0	0	0
32	<i>Rhinolophus ferrumequinum</i>	1 (1)	0	1 (1)	0	0	1 (1)	1 (1)	1 (2)	1 (1)	0	0	0
33	<i>Rhinolophus lepidus</i>	0	0	0	0	0	1 (1)	0	1 (1)	0	0	0	0
34	<i>Rhinolophus luctus</i>	0	0	0	0	0	0	1 (1)	1 (1)	0	0	0	0
35	<i>Rhinolophus macrotis</i>	0	0	0	1 (1)	0	0	1 (1)	1 (1)	0	0	0	0
36	<i>Rhinolophus pearsonii</i>	1 (1)	0	0	1 (2)	0	1 (1)	1 (3)	1 (1)	1 (1)	0	0	0
37	<i>Rhinolophus pusillus</i>	1 (1)	0	0	1 (1)	0	0	1 (1)	1 (2)	0	0	0	0
38	<i>Rhinolophus rouxii</i>	1 (1)	0	0	0	0	1 (1)	0	1 (1)	0	0	0	0
39	<i>Rhinolophus sinicus</i>	1 (2)	0	0	1 (3)	0	1 (1)	1 (1)	1 (1)	1 (1)	0	0	0
40	<i>Rousettus leschenaultii</i>	1 (1)	1 (1)	0	0	0	0	0	0	0	0	0	0
41	<i>Scotomanes ornatus</i>	1 (1)	0	0	0	0	0	0	0	0	0	0	0
42	<i>Scotophilus heathii</i>	0	1 (5)	0	0	1 (1)	0	0	0	0	1 (1)	0	0
43	<i>Scotozous dormeri</i>	0	0	0	0	1 (1)	0	0	0	0	0	0	0
44	<i>Submyotodon caliginosus</i>	0	0	0	0	0	1 (1)	0	0	0	0	0	0

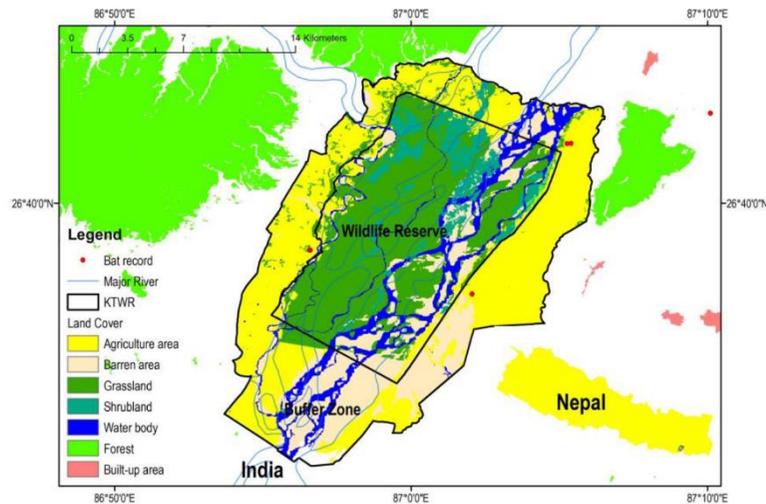
**Annex II:** Map of PAs showing confirmed bat locality records: A. KCA, B. MBNP& BZ, C. KTWR& BZ, D. GCA E. LNP& BZ, F. MCA, G. SNNP& BZ, H. CNP& BZ, I. ACA, J. SPNP & BZ, K. BNP & BZ, L. ShNP & BZ



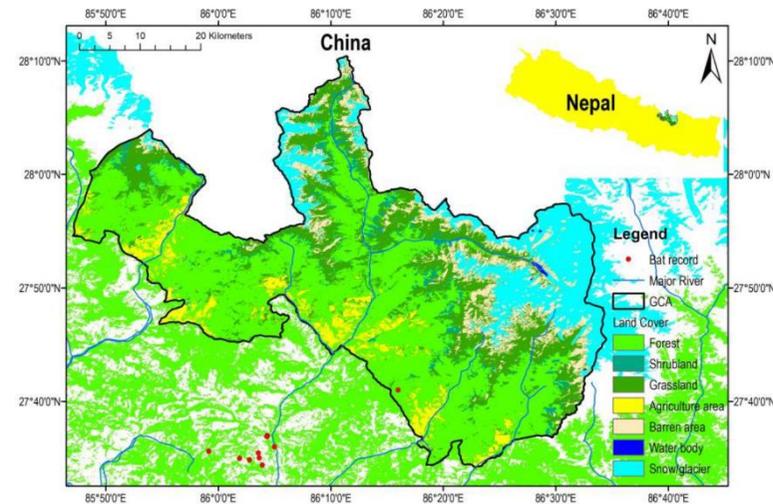
**A**



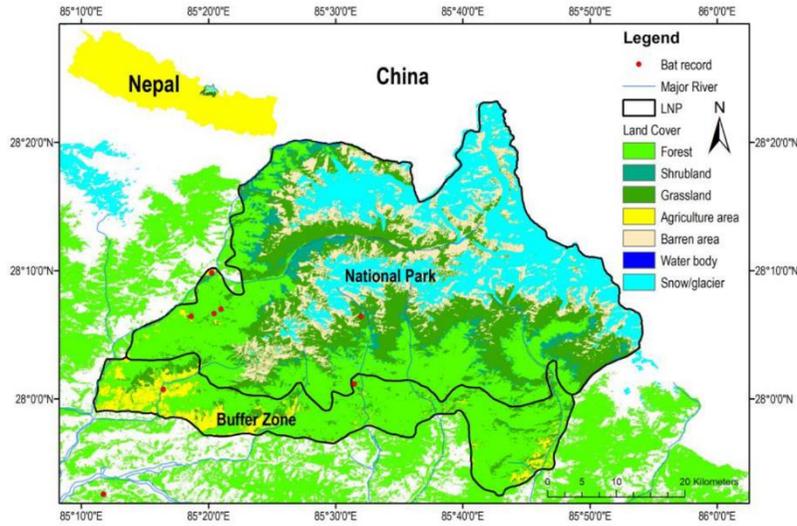
**B**



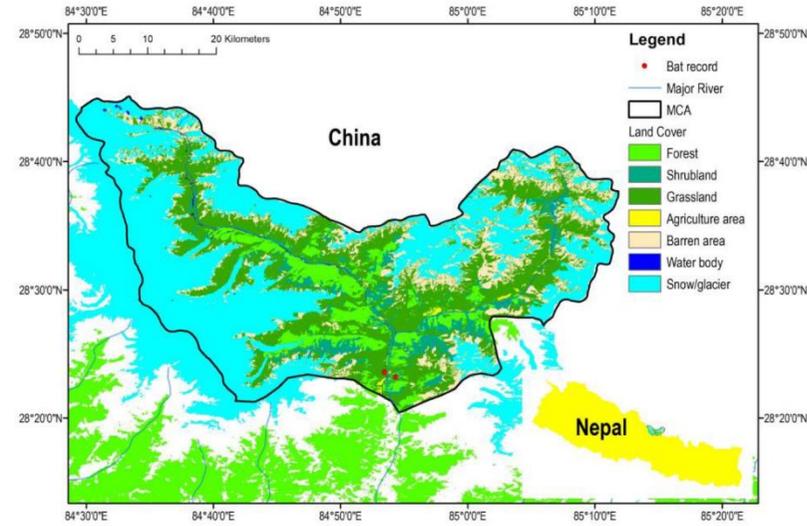
**C**



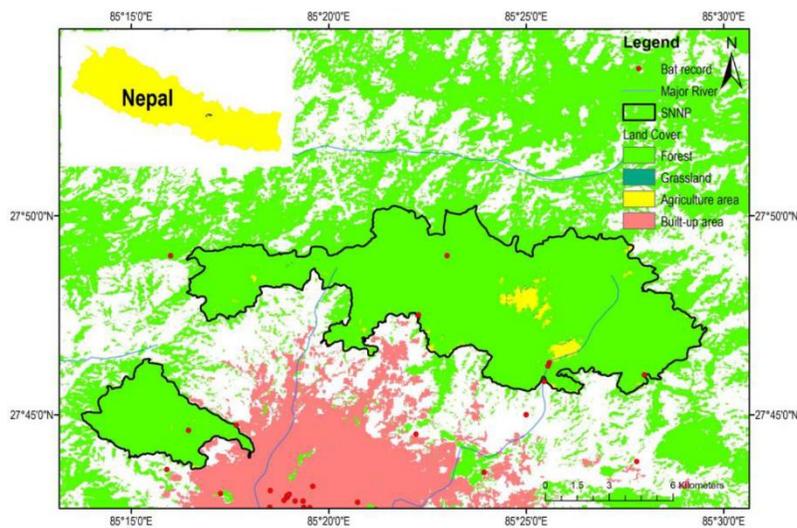
**D**



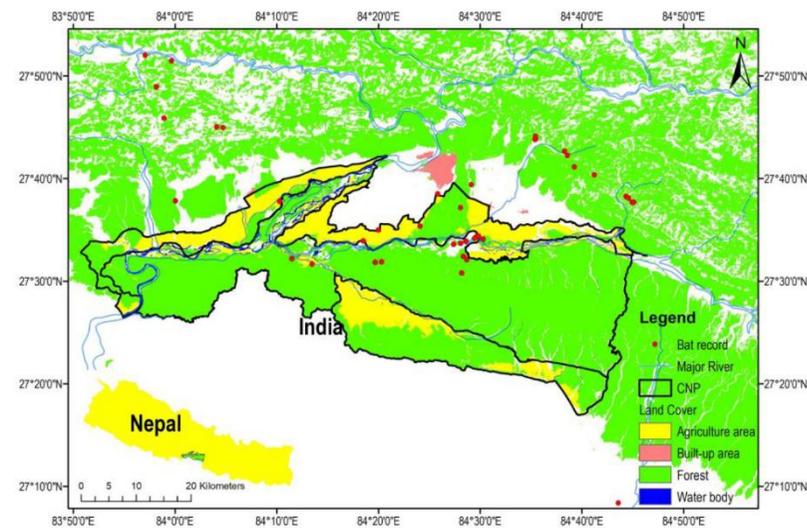
E



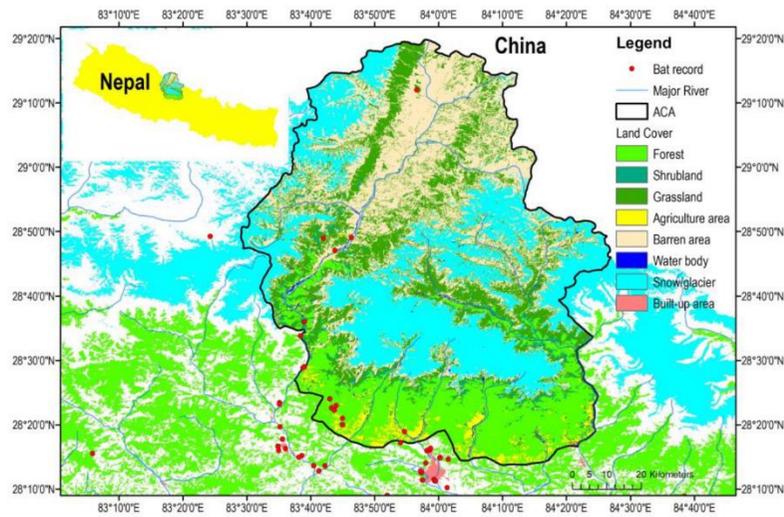
F



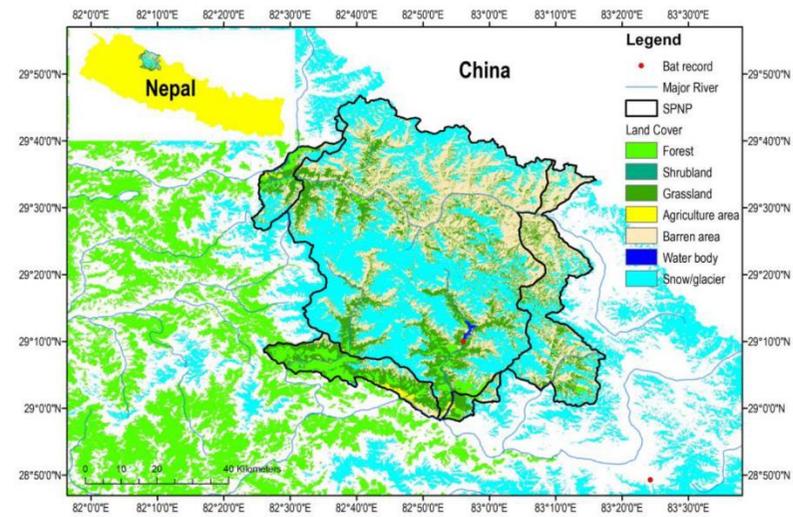
G



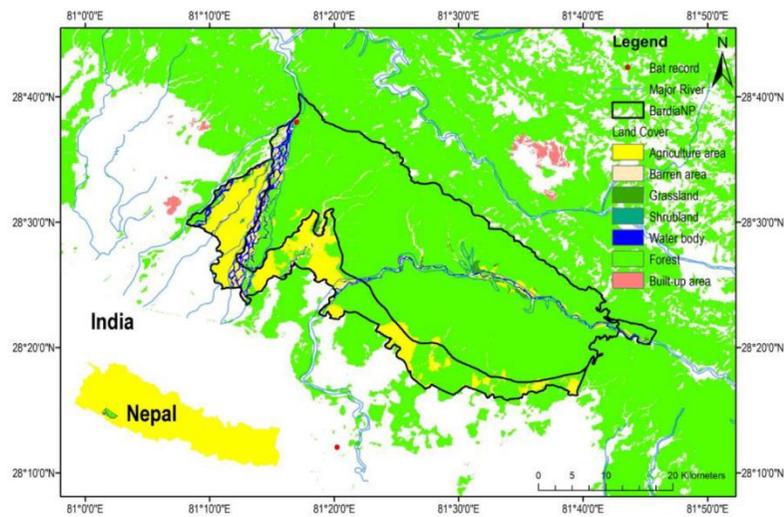
H



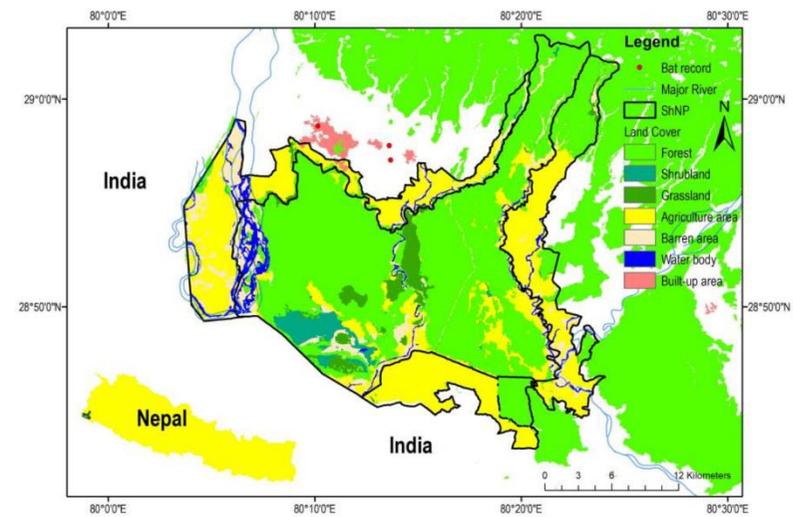
I



J



K



L