Journal of Animal Diversity

Online ISSN 2676-685X

Volume 4, Issue 3 (2022)

Research Article

http://dx.doi.org/10.52547/JAD.2022.4.3.6

Mammal diversity in Biological Corridor No. 03 covering the Sarpang–Tsirang District landscapes of Bhutan

Jigme Tenzin[1*], Yeshi Phuntsho[2], Phuntsho Thinley[3] and Karma Tenzin[4]

[1]*Divisional Forest Office, Sarpang, Department of Forests and Park Services, 31002, Bhutan*
[2]*Divisional Forest Office, Tsirang, Department of Forests and Park Services, 36001, Bhutan*
[3]*Ecosystem Management, University of New England, Armidale NSW 2351, Australia*
[4]*School of Ecosystem and Forest Science, University of Melbourne, Australia*
[*]*Corresponding author*: *jigmetenzin16@gmail.com*

Citation: Tenzin, J., Phuntsho, Y., Thinley, P. and Tenzin, K. (2022). Mammal diversity in Biological Corridor No. 03 covering the Sarpang–Tsirang District landscapes of Bhutan. *Journal of Animal Diversity*, 4 (3): 44–52. http://dx.doi.org/10.52547/JAD.2022.4.3.6

Received: 4 November 2021
Accepted: 15 September 2022
Published online: 30 September 2022

Abstract

In Bhutan, protected areas constitute 51.4% of the total geographical area, out of which 7.7% is designated biological corridors (BCs) that serve as connectors between protected areas. The biological corridor (BC-03) constitutes a total area of 407.7 km² and connects Phibsoo Wildlife Sanctuary in the west, Jigme Singye Wangchuck National Park and Royal Manas National Park in the north and southeast through Sarpang–Tsirang District landscapes. However, most BCs, including BC-03, lack comprehensive inventories of mammal species. We conducted joint rapid biodiversity assessment (RBA) using camera trap surveys from November 2019 to February 2020. Our findings from BC-03 include records of 26 mammal species belonging to 11 families in five orders. Nearly half of these species are listed as Endangered, Vulnerable, or Near Threatened. Overall, the BC-03 landscape was found to support 77.8% of the mammal species of Sarpang District and 21.7% of Bhutan (as per Biodiversity Statistics of Bhutan, 2017). Therefore, BC-03 is of conservation interest. Comprehensive conservation plans, periodic monitoring of keystone species, and restrictions on the expansion of cardamom plantations in BCs are suggested for securing wildlife habitats and ensuring long-term persistence of keystone species, including within BC-03 in southcentral Bhutan.

Key words: Biological corridor, camera trap, mammal species, Sarpang–Tsirang landscapes, threatened species

Introduction

Bhutan has a total geographical area of 38,343 km² and is located between the Indo-Malayan region in the south and the Palearctic region in the north (Wangchuk et al., 2004; Tenzin et al., 2019; Tenzin et al., 2021a). Nature conservation in Bhutan has always received the highest priority in national development programs and both constitution and forest policies of the country have mandated to maintain a minimum of 60.0% forest cover (RGoB, 2008). Further, the Royal Government of Bhutan has already designated 51.4% of the total geographical area as protected areas (PAs), including eight biological corridors (BCs). Bhutan supports close to 200 species of mammals (Wangchuk et al., 2004; NEC, 2011), but recent by-camera traps have captured only 129 mammal species (NBC, 2017; Tenzin et al., 2021). Bhutan presents conservation importance as part of the Himalaya Biodiversity Hotspot (Mittermeier et al., 2004; Tempa et al., 2019) and the Global 200 ecoregions (Olsen and Dinerstein, 2002). Ecologically, mammals play an important role in ecosystems and provide numerous essential ecosystem services such as seed dispersal, pollination, and regulating insect populations and

reducing disease transmissions (Keesing et al., 2010; Kunz et al., 2011). While some species may also act as indicators of ecosystem health (Jones et al., 2009). However, rapid declines in mammalian biodiversity (Schipper, 2008; Penjor et al., 2021) were induced due to monopolization of ecosystems and natural resources by anthropogenic activities (Mace et al., 2005; Butchart et al., 2011; Penjor et al., 2021). Further, several studies have also predicted that by 2070, the impact of land-use change will globally endanger ~1700 species of amphibians, birds, and mammals, including species of high conservation value and functional importance, due to habitat contraction (Barlow et al., 2016; Powers and Jetz, 2019; Penjor et al., 2021).

Biological corridor is one of the landscape-based management regimes primarily established to facilitate gene flow through uninterrupted movements and habitats succession of wildlife species (Tshering and Wangchuk, 2003). Initially, there were 12 BCs in Bhutan constituting a total area of 3,640 km² (NCD, 2004; Sherpa et al., 2004). However, the number of BCs was later reduced to eight after the establishment of Wangchuck Centennial National Park in 2008 (DoFPS, 2020; WWF Bhutan, 2021). The revised protected area system (PAS) indicated that the overall percentages of protected areas remained the same (51.4%), however, there is slight increase in the area of national parks (from 30.6% to 33.8%) and wildlife sanctuaries (9.1% to 9.7%), readjusted through the reduction of BC areas (9.0% to 7.7%) (DoFPS, 2020). Thus, currently BCs comprise a total area of 2,966.5 km² connecting 10 PAs of Bhutan. However, none of the BCs had a scientific management plan until 2019, although most of the rapid biodiversity assessment (RBA) had been completed by 2012. According to an anecdote report, Phrumsengla National Park (PNP) was the first park under the Department of Forests and Park Services (DoFPS) to conduct RBA inside BC-04, which connects the Jigme Singye Wangchuck National Park (JSWNP) and PNP in 2012 (Per. Com. U. Namgyal, 2021). Later in 2019, the Bumthang Forest Division led the survey of BC-08, which connects JSWNP with the Jigme Dorji National Park (JDNP) and Wangchuck Centennial National Park (WCNP) in the central part of Bhutan (Per. Com. U. Namgyal, 2021). Likewise, in the western region, the Paro Forest Division (PFD) led the study of BC-01, which connects the JDNP, Jigme Kheser Strict Nature Reserve (JKSNR), and PFD in 2016 in collaboration with the JKSNR and JDNP (PFD, 2020). Simultaneously, Wangdue Forest Division (WFD) led the study of BC-02 in 2016, which connects WFD, Thimphu Forest Division (TFD) and JDNP in collaboration with TFD and JDNP (Per. Com. K. Dorji, 2021). In the eastern region, the Mongar Forest Division (MFD) led the survey of BC-07 towards the end of 2018 in collaboration with the WCNP and Bumdeling Wildlife Sanctuary (BWS) (Per. Com. Norbu Wangchuk, 2021). After that in 2020, the Trashigang Forest Division (TGFD) surveyed BC-06, which connects the TGFD and Jomotsangkha Wildlife Sanctuary (JWS) (Per. Com. U. Dechen, 2021). In the southern region in mid-2018, Pemagatshel Forest Division (PGFD) led RBA of BC-05, which connects JWS and RMNP (Tshewang and Wangchuk, 2019). Likewise, in 2019 the Sarpang Forest Division (SFD) led the survey of BC-03, which connects Phibsoo Wildlife Sanctuary (PWS) with JSWNP–RMNP in the southcentral part of Bhutan, in collaboration with Tsirang Forest Division (TFD).

Although RBA inside BCs was started since 2012, the management plans of only two BCs (BC-01 and BC-05) were approved as of 2021. BC-05 was the first BC in Bhutan to get an approved scientific management plan in 2019 under the initiative of the Pemagatshel Forest Division, followed by BC-01 in 2020 by the Paro Forest Division. In the case of BC-03, the Nature Conservation Division (NCD) had already carried out RBA in 2012 in collaboration with Royal Manas National Park (RMNP); however, the survey lacks structured reports that describe the flora and fauna (SFD, 2016). On other hand, DoFPS (2015) carried out the first nationwide tiger survey (2014–2015), covering the entire BC-03 area. Tenzin and Dhendup (2017) also inventoried Liebig's paa frog *Nanorana leibigii* (Gunther, 1860) inside the same BC area. Furthermore, Tenzin and Wangyal (2019) recorded a new toad (*Leptrobrachium bompu* Sondhi and Ohler, 2011) from BC-03 in the same year. Later, a second RBA was recarried out in 2019–2020 using camera traps survey methods. However, BC-03 still lacks comprehensive baseline species inventories needed in light of the rapid-changing ecosystem of Bhutan (Dhendup and Dorji, 2018; Penjor et al., 2018; Dhendup et al., 2019). Here we use camera traps to document the diversity and relative abundance of mammals in BC-03 of the Sarpang–Tsirang District landscape in Bhutan and to provide baseline information to facilitate the preservation of such sites for the conservation of globally threatened species in the area.

Material and Methods

BC-03 initially had a total area of 376.60 km² (NCD, 2004; Sherpa et al., 2004), however, it was revised to 407.6 km² on 3 August 2020 by the Nature Conservation Division, DoFPS (DoFPS, 2020). This corridor runs between the Phibsoo Wildlife Sanctuary in the southwest and JSWNP–RMNP in the southeast in Sarpang District (Fig. 1). About 84.5% of the total BC-03 area falls inside the jurisdiction of Sarpang Forest Division and 15.5% inside the Tsirang Forest Division (DFO-Sarpang and Tsirang, 2022). Eleven geogs (blocks administrations) fall inside BC-03, of which nine (Jigmecholing, Chudzom, Dekiling, Gakidling, Samtenling, Gelephu, Chuzagang, Serzhong and

Sengye) are in Sarpang and two blocks (Dunglagang and Patsaling) are in Tsirang District. The elevation ranges from 329–2,647 m. a.s.l. whereby the area experiences sub-tropical to temperate climatic conditions with a wet summer and dry winter. BC-03 also serves as a main habitat for globally threatened species such as the Royal Bengal tiger *Panthera tigris tigris* (Linnaeus, 1758), Clouded leopard *Neofelis nebulosa* (Griffith, 1821), Himalayan black bear *Ursus thibetanus laniger* Cuvier, 1823, Golden langur *Trachypithecus geei* (Khajuria, 1956), Asiatic elephant *Elephas maximus* Linnaeus, 1756, and Gaur *Bos gaurus* (Smith, 1827) in the southern central region. However, the recent gewog center road (GCR) connection of Chudzom, Gonsekha–Jigmecholing, and Jigmecholing–Chudzom in 2021 not only fragmented the BC-03 landscapes, but also intersected the migratory corridors of the tigers from the eastern and central part of the BC-03 landscapes.

There are 32 National Forestry Inventory (NFI) grids that fall inside BC-03 (407.7 km²). Of the total NFI grids, 65% (21 NFI grids) were randomly selected using ArcGIS (version 10.3.1) for camera trap surveys. A total of 21 camera traps were stationed with one camera trap per grid for period of 90 days (November 2019–February 2020) as suggested by Thinley et al. (2015) for special cases (limited budget and camera traps). Meanwhile, rechargeable batteries (Tenergy premium 1000 mAh Ni-MH Rechargeable) were used for all camera traps (Reconyx, U-way and Cuddleback). Camera traps were set to 24-hour time with a capture rate of 3 images/capture within the interval of 3–5 second. Additionally, a few camera traps were kept in video mode to capture the activity pattern of the keystone species. Camera traps were kept 45–50 cm above the ground and no bait/lures were used. Captured mammal species were identified using guides to the mammals of Bhutan (Wangchuk et al., 2004) and the Indian subcontinent (Menon, 2013). After identification, species were check-listed, and relative abundance index (RAI) and naïve occupancy were calculated using Renamer software (Sanderson and Harris, 2013) and the conservation status of each species was accordingly updated as per the IUCN Red List of Threatened Species, CITES, and Forest and Nature Conservation Act of Bhutan (1995), respectively.

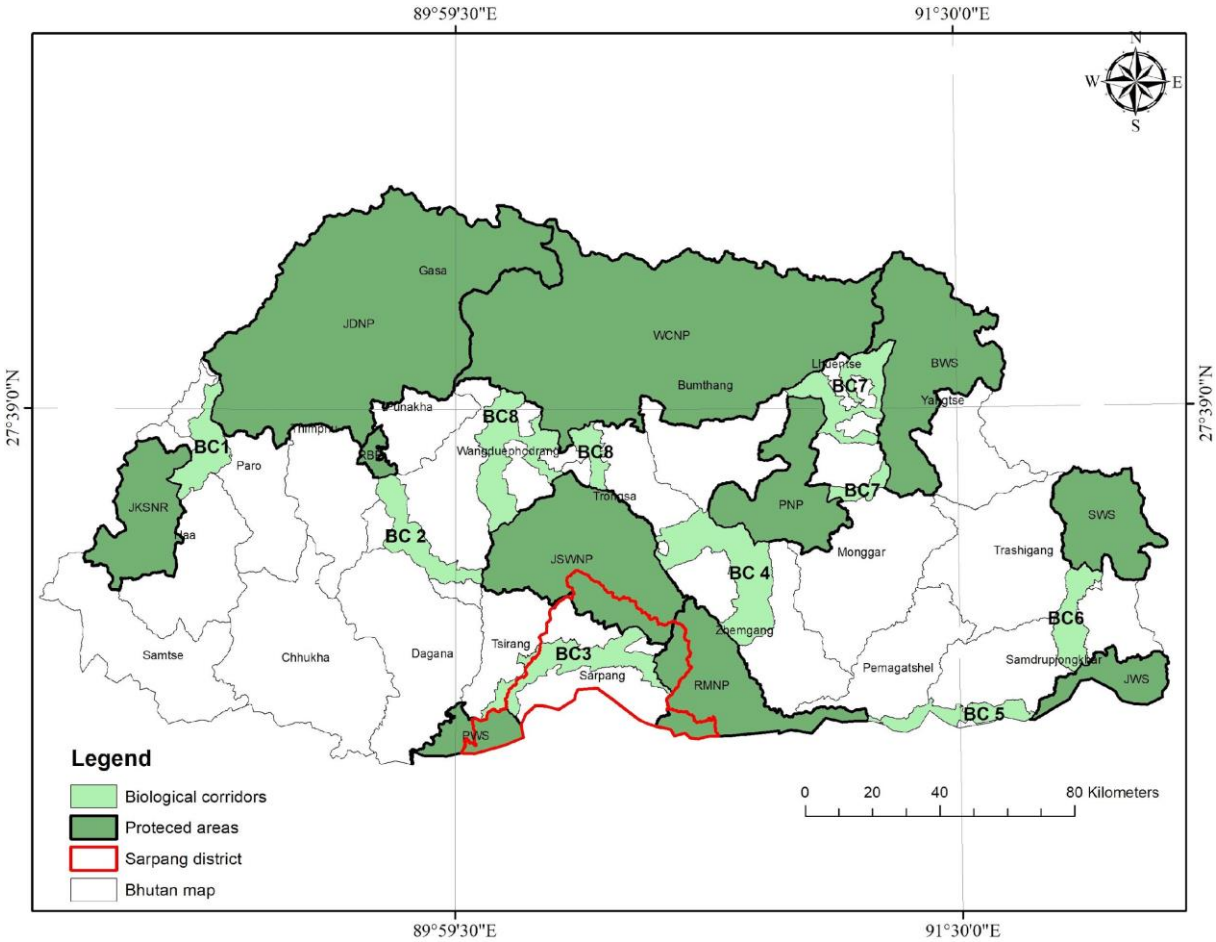

Figure 1: Bhutan map showing the location of BC-03 within Tsirang–Sarpang District and the three surrounding protected areas joined by BC-03. Map generated using ArcGIS (version 10.3.1)

Results and Discussion

Within a three-month period (November 2019–February 2020), 21 camera traps captured a total of 6,477 images. The trap night total was 1,687 with 2,159 images/month captured. From the total 6,477 images, 26 mammal species were recorded belonging to 11 families in five orders (Table 1). The species detected were: Tiger *Panthera tigris* (Linnaeus, 1758); Asiatic golden cat *Catopuma temminckii* (Vigors and Horsfield, 1827); Marbled cat *Pardofelis marmorata* (Martin, 1836); Leopard cat *Prionailurus bengalensis* (Kerr, 1792); Leopard *Panthera pardus* (Linnaeus, 1758); Clouded leopard *Neofelis nebulosa* (Griffith, 1821); Asiatic wild dog *Cuon alpinus* (Pallas, 1811); Himalayan serow *Capricornis sumatraensis thar* Hodgson, 1831; Gaur *Bos gaurus* (Smith, 1827); Himalayan goral *Naemorhedus goral* (Hardwicke, 1825); Barking deer *Muntiacus muntjak* (Zimmermann, 1780); Sambar *Rusa unicolor* (Kerr, 1792); Wild boar *Sus scrofa* Linnaeus, 1758; Asian elephant *Elephas maximus* Linnaeus, 1756; Yellow-throated marten *Martes flavigula* Bodaert, 1785; Asiatic black bear *Ursus thibetanus* Cuvier, 1823; Himalayan crestless porcupine *Hystrix brachyura* Linnaeus, 1758; Asiatic brush-tailed porcupine *Atherurus macrourus* (Linnaeus, 1758); Golden langur *Trachypithecus geei* (Khajuria, 1956); Assamese macaque *Macaca assamensis* McClelland, 1840; and Rhesus macaque *Macaca mulatta* (Zimmermann, 1780). Additional taxa that were not captured by camera trap but were sighted within BC-03 during the RBA included: Malayan giant squirrel *Ratufa bicolor* (Sparrman, 1778); Hoary-bellied Himalayan squirrel *Callosciurus pygerythrus* (Geoffroy Saint-Hilaire, 1831); Orange-bellied Himalayan squirrel *Dremomys lokriah* (Hodgson, 1836); Pallas's squirrel *Callosciurus erythraeus* (Pallas, 1779); and Masked palm civet *Paguma larvata* (Smith, 1827).

Among the 26 recorded mammal species, four are listed as Endangered (Tiger, Wild dog, Asian Elephant and Golden langur), six Vulnerable (Gaur, Himalayan serow, Sambar, Clouded leopard, Leopard and Himalayan black bear), five Near Threatened (Himalayan goral, Asiatic golden cat, Marbled cat, Assamese macaque and Malayan giant squirrel), and the remaining 11 were listed as Least Concern in the IUCN Red List of Threatened Species. Although Red panda *Ailurus fulgens* (F. Cuvier, 1825) was recorded from BC-03 during the first RBA in 2012, this species was not detected in the recent RBA. This requires a species-specific survey protocol to validate the presence in the future.

Meanwhile, the relative abundance index (RAI) and naïve occupancy were calculated for 21 species that were captured in the recent camera trap survey (Table 2). Among the 21 species for which these values were calculated, Barking deer had the highest RAI (26.50) and naïve occupancy (0.95), followed by Himalayan serow (RAI, 6.34; naïve occupancy, 0.55), while, Asiatic brush-tailed porcupine and Leopard were equally lowest in terms of RAI (0.12) with naïve occupancy of 0.10 and 0.05, respectively. In the case of Felidae, Asiatic golden cat had the highest RAI (0.83) and naïve occupancy (0.30), followed by Leopard cat (RAI, 30; naïve occupancy, 0.15) and Leopard was the lowest (RAI, 0.12; naïve occupancy, 0.05). Meanwhile, human activities were reported from seven of the total 21 camera stations, indicating a prominent level of human presence in the study site.

Overall, from BC-03 were recorded 77.77% (N= 26 species) of the known mammal species of Sarpang District (N= 36 species) (Tenzin et al., 2021b) and 21.70% of those known from Bhutan (NBC, 2017). The rich assemblage of mammals, including globally threatened species such as the Tiger, Wild dog, Asian elephant, and Golden langur suggests that BC-03 is a primary habitat for most of the keystone species and hence, requires stringent protection and conservation. The landscape of BC-03 is connected with three biodiversity-rich protected areas: Jigme Singye Wangchuck National Park in the north, Royal Manas National Park towards the southeast, and Phibsoo Wildlife Sanctuary towards the connecting Buxa Tiger Reserve in West Bengal, India. Given the rich diversity of mammal species, including six felid species (Tenzin et al., 2019), BC also facilitates uninterrupted movement of wide-ranging predators, including tigers, from Black Mountain in the Jigme Singye Wangchuck National Park in the north to the Phibsoo Wildlife Sanctuary in the extreme southern Indo–Bhutan border during winter, through Chitriray–Darachu migratory routes in BC-03. Thus, the functionality of BC-03 is clearly indicated.

However, these areas are currently used for selective logging, grazing, and other resource allocations for peripheral communities of BC-03. In addition, extensive cardamom plantations of the vicinity communities across the northcentral part of BC-03 intrude on the seasonal migration routes of the wide-ranging tigers. This may affect the movement of the species both outside and inside protected areas. Therefore, the area warrants immediate adaptation of a biological corridor management plan, periodic monitoring of keystone species, and restrictions on mass cardamom plantation or relocation of the cardamom planted areas outside BC-03 are suggested for long-term conservation of the globally threatened keystone species in BC-03 in the southcentral part of Bhutan.

Table 1: Checklists of mammal species showing distribution, order, family, and conservation status based on IUCN, CITES, and Forest and Nature Conservation Act (1995 and 2022).

Sl.	Scientific name	Species authority	Common name	Distribution inside BC-03	Order	Family	IUCN	CITES	FNCAB (1995)
1	*Muntiacus muntjak*	(Zimmermann, 1780)	Barking deer	Lampokhari, Ranidunga, Bakutidrangra, Labarbotrey, Charadey, Melidara, Jandeydara, Tsishingpong	Artiodactyla	Cervidae	LC	Not listed	Not listed
2	*Bos gaurus*	(Smith, 1827)	Guar	Rateykhar, Bakutidrangra	Artiodactyla	Cervidae	VU	Appendix I	Schedule I
3	*Naemorhedus goral*	(Hardwicke, 1825)	Himalayan goral	Ranibagantop, Tormey,Charadey, Dhaptop, Melidara	Artiodactyla	Cervidae	NT	Appendix I	Not listed
4	*Capricornis sumatraensis thar*	Hodgson, 1831	Himalayan serow	Ranibagantop, Tormey,Charadey, Dhaptop, Melidara	Artiodactyla	Cervidae	VU	Appendix I	Schedule I
5	*Cervus unicolor*	(Kerr, 1792)	Sambar	Jandadara, Labarbotrey, Dawnidhap, Charadey based, Melidara, Rateykhar	Artiodactyla	Cervidae	VU	Not listed	Not listed
6	*Sus scrofa*	Linnaeus, 1758	Wild pig	Jandaydara, Charadey, Lampokhari, Nilpokhari	Artiodactyla	Suidae	LC	Not listed	Not listed
7	*Catopuma temminckii*	(Vigors and Horsfield, 1827)	Asiatic golden cat	Lompokharey, Tseshingpong	Carnivora	Felidae	NT	Appendix I	Not listed
8	*Neofelis nebulosa*	(Griffith, 1821)	Clouded leopard	Galechu, Jorphokhari, Samtenling top, Dawralidara	Carnivora	Felidae	VU	Appendix I	Schedule I
9	*Panthera pardus*	(Linnaeus, 1758)	Leopard	Kutikeydara	Carnivora	Felidae	VU	Not listed	Schedule I
10	*Prionailurus bengalensis*	(Kerr, 1792)	Leopard cat	Labarbotrey, Lampokhoarey, Nilpokhari	Carnivora	Felidae	LC	Appendix II	Schedule I
11	*Pardofelis marmorata*	(Martin, 1836)	Marbled cat	Tsishingpong, Dhapdara, Malidara, Jandaydara	Carnivora	Felidae	NT	Not listed	Not listed
12	*Panthera tigris tigris*	(Linnaeus, 1758)	Tiger	Gopidara, Jandedara, Dawnidhap, Labarbotrey, Chitridara	Carnivora	Felidae	EN	Appendix I	Schedule I
13	*Cuon alpinus*	(Pallas, 1811)	Wild dog	Jandeydara, Lampokhari, Ranidunga, Charadey, Paspaley, Rateykhar	Carnivora	Canidae	EN	Appendix II	Not listed
14	*Ursus thibetanus laniger*	Cuvier, 1823	Himalayan black bear	Jandeydara, Lampokhari	Carnivora	Ursidae	VU	Appendix I	Schedule I
15	*Martes flavigula*	Bodaert, 1785	Yellow-throated marten	Tseshingpong, Dhapdara	Carnivora	Mustelidae	LC	Not listed	Not listed
16	*Paguma larvata*	(Smith, 1827)	Masked palm civet	Gophidara, Jandeydara,	Carnivora	Viverridae	LC	Not listed	Not listed
17	*Elephas maximus*	Linnaeus, 1756	Asian elephant	Lampokhari, Labarbotrey	Proboscidea	Elephantidae	EN	Appendix I	Schedule I
18	*Macaca assamensis*	McClelland, 1840	Assamese macaque	Rateykhar, Ranidunga, Loringtop, Labarbotrey	Primates	Cercopithecidae	NT	Appendix II	Not listed
19	*Macaca mulatta*	(Zimmermann, 1780)	Rhesus macaque	Labarbotrey, Laringtop, Rateykhar	Primates	Cercopithecidae	LC	Appendix II	Not listed
20	*Trachypithecus geei*	(Khajuria, 1956)	Golden langur	Nilpokhari, Charadey, Melidara, Galechu	Primates	Cercopithecidae	EN	Appendix I	Schedule I
21	*Ratufa bicolor*	(Sparrman, 1778)	Malayan giant squirrel	Tsishingpong, Tormaphu	Rodentia	Sciuridae	NT	Appendix II	Not listed
22	*Dremomys lokriah*	(Hodgson, 1836)	Orange-bellied Himalayan squirrel	Nilpokhari, Above Saundaley	Rodentia	Sciuridae	LC	Not listed	Not listed
23	*Callosciurus pygerythrus*	(Geoffroy Saint-Hilaire, 1831)	Hoary-bellied Himalayan squirrel	Dewnidhap, Nilpokhari	Rodentia	Sciuridae	LC	Appendix II	Not listed
24	*Callosciurus erythraeus*	(Pallas, 1779)	Pallas's squirrel	Nilpokhari, Charedey	Rodentia	Sciuridae	LC	Not listed	Not listed
25	*Atherurus macrourus*	(Linnaeus, 1758)	Asiatic brush-tailed porcupine	Ranibagantop, Tormey, Lampokharey	Rodentia	Hystricidae	LC	Not listed	Not listed
26	*Hystrix brachyura*	Linnaeus, 1758	Himalayan crestless porcupine	Jandadara, Labarbotrey	Rodentia	Hystricidae	LC	Appendix I	Not listed

Figure 2: Mammal species photo-captured during the recent rapid biodiversity assessment of BC-03. Picture courtesy: © Divisional Forest Office, Sarpang 2019 under DoFPS, Bhutan.

Table 2: Details of mammal species recorded in BC-03, Bhutan during 2019–2020 with camera trap records, total capture events, relative abundance index (RAI), and naïve occupancy.

Common name	Scientific name	Family	Camera traps records	Total events	RAI1	Naïve occupancy2
Barking deer	*Muntiacus muntjak*	Cervidae	3963	447	26.50	0.95
Guar	*Bos gaurus*	Cervidae	260	48	2.85	0.20
Himalayan goral	*Naemorhedus goral*	Cervidae	134	31	1.84	0.45
Himalayan serow	*Capricornis sumatraensis thar*	Cervidae	486	107	6.34	0.55
Sambar	*Cervus unicolor*	Cervidae	504	76	4.51	0.55
Wild pig	*Sus scrofa*	Suidae	588	72	4.27	0.85
Asiatic golden cat	*Catopuma temminckii*	Felidae	28	14	0.83	0.30
Clouded leopard	*Neofelis nebulosa*	Felidae	5	3	0.18	0.15
Leopard	*Panthera pardus*	Felidae	7	2	0.12	0.05
Leopard cat	*Prionailurus bengalensis*	Felidae	10	5	0.30	0.15
Marbled cat	*Pardofelis marmorata*	Felidae	3	3	0.18	0.10
Tiger	*Panthera tigris tigris*	Felidae	18	4	0.24	0.20
Wild dog	*Cuon alpinus*	Canidae	40	13	0.77	0.25
Himalayan black bear	*Ursus thibetanus laniger*	Ursidae	46	15	0.89	0.20
Yellow-throated marten	*Martes flavigula*	Mustelidae	14	7	0.41	0.15
Asian elephant	*Elephas maximus*	Elephantidae	293	6	0.36	0.10
Assamese macaque	*Macaca assamensis*	Cercopithecidae	46	9	0.53	0.20
Rhesus macaque	*Macaca mulatta*	Cercopithecidae	9	6	0.36	0.05
Golden langur	*Trachypithecus geei*	Cercopithecidae	10	4	0.24	0.20
Asiatic brush-tailed porcupine	*Atherurus macrourus*	Hystricidae	4	2	0.12	0.10
Himalayan crestless porcupine	*Hystrix brachyura*	Hystricidae	9	6	0.36	0.20

[1] Relative abundance index (RAI) was calculated as the number of captures divided by the total sampling effort in days multiplied by 100 (O'Brien, 2011; Hedwig et al., 2018).

[2] Naïve occupancy was quantified as the number of camera trap locations at which each species was detected divided by the total number of camera trap locations (Jenks et al., 2011; Rovero et al., 2014; Hedwig et al., 2018).

Acknowledgements

The authors would like to acknowledge Mr. Lobzang Dorji, Director, Department of Forests and Park Services (DoFPS) for his kind approval (Approval receipt No.237, dated 24th November 2020 vide letter No. SFD/RPES/RIU-03/2020-2021/358, dated 20th November 2020). Likewise, Ms. Dimple Thapa, Chief Forestry Officer, Tsirang Forest Division, Mr. Phub Dhendup, Chief Forestry Officer and Mr. Tshering Dorji, BFL Focal are also acknowledged for their timely support rendered during the course of the field survey. Meanwhile, Mr. Tashi Wangdi, SFR-I, Kezang Dhendup, SFR-I, Chencho Nidup, SFR-III, Tshering, FR-II, Chophel, SFR-II and Sonam Penjor, Sr. Frs of Divisional Forest Office, Sarpang and Mr. Tshering Wangchuk, SFR-II, Dorji Drukpa, Sr. Frs, Yeshi Wangdi, Sr. Frs and Lhakpa Tshering, Sr. Frs from Tsirang Forest Division are also equally acknowledged for assisting data collection. Finally, we would like to thank the Bhutan for Life Secretariat (BFL) for funding RBA inside BC-03. Finally, thanks are given to the reviewers for refinement of the article.

Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

References

Barlow, J., Lennox, G. D., Ferreira, J., Berenguer, E., Lees, A. C., Mac Nally, R., Thomson, J. R., Ferraz, S. F., Louzada, J., Oliveira, V. H., Parry, L., Solar, R. R., Vieira, I. C., Aragão, L. E., Begotti, R. A., Braga, R. F., Cardoso, T. M., de Oliveira, R. C. Jr., Souza, C. M. Jr., Moura, N. G., Nunes, S. S., Siqueira, J. V., Pardini, R., Silveira, J. M., Vaz-de-Mello, F. Z., Veiga, R. C., Venturieri, A. and Gardner, T. A. (2016). Anthropogenic disturbance in tropical forests can double biodiversity loss from deforestation. *Nature*, 535 (7610): 144–7. https://doi.org/10.1038/nature18326

Butchart, S. H., Walpole, M., Collen, B., van Strien, A., Scharlemann, J. P., Almond, R. E., Baillie, J. E., Bomhard, B., Brown, C., Bruno, J., Carpenter, K. E., Carr, G. M., Chanson, J., Chenery, A. M., Csirke, J., Davidson, N. C., Dentener, F., Foster, M., Galli, A., Galloway, J. N., Genovesi, P., Gregory, R. D., Hockings, M., Kapos, V., Lamarque, J. F., Leverington, F., Loh, J., McGeoch, M. A., McRae, L., Minasyan, A., Hernández Morcillo, M., Oldfield, T. E., Pauly, D., Quader, S., Revenga, C., Sauer, J. R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S. N., Symes, A., Tierney, M., Tyrrell, T. D., Vié, J. C. and Watson, R. (2010). Global biodiversity: indicators of recent declines. *Science*, 328 (5982): 1164–8. https://doi.org/10.1126/science.1187512

Dhendup, T. and Dorji, R. (2018). Camera-trap records of small carnivores from Gedu Territorial Forest Division, Bhutan. *Small Carnivore Conservation*, 56: 1–6.

Dhendup, T., Thinley, K. and Tenzin, U. (2019). Mammal diversity in a montane forest in central Bhutan. *Journal of Threatened Taxa*, 11 (13): 14757–14763. https://doi.org/10.11609/jott.5058.11.13.14757-14763

DFO-Sarpang and Tsirang. (2022). Draft Biological Corridor 03: Connecting Jigme Singye Wangchuck National Park, Phibsoo Wildlife Sanctuary and Royal Manas National Park Conservation Management Plan (2023–2032). Department of Forests and Park Services, Ministry of Agriculture and Forests, Bhutan. 86 pp.

Dorji, D. P. and Santiapillai, C. (1989). The status, distribution and conservation of the tiger (*Panthera tigris*) in Bhutan. *Biological Conservation*, 48: 311–319. https://doi.org/10.1016/0006-3207(89)90105-5

DoFPS. (2015). Counting the Tigers in Bhutan: Report on the National Tiger Survey of Bhutan 2014–2015. Department of Forests and Park Services, Ministry of Agriculture and Forests, Thimphu, Bhutan. 60 pp.

DoFPS. (2020). Depositing of data of the revised protected area systems of Bhutan by Department of Forests and Park Services (DoFPS/NCD/PAS-01/2020-2021/0808, dated 3rd August 2020). Nature Conservation Division, Department of Forests and Park Services, Ministry of Agriculture and Forests, Bhutan. 1 pp.

Jones, K. E. and Safi, K. (2011). Ecology and evolution of mammalian biodiversity. *Philosophical Transactions of the Royal Society B Biological Science*, 366: 2451–2461. https://doi.org/10.1098/rstb.2011.0090

Karanth, K. U. and R. Gopal. (2005). An ecology-based policy framework for human-tiger coexistence in India. *Conservation Biology Series-Cambridge*, 9: 373. https://doi.org/10.1017/CBO9780511614774.024

Keesing, F., Belden, L. K., Daszak, P., Dobson, A., Harvell, C. D., Holt, R. D., Hudson, P., Jolles, A., Jones, K. E., Mitchell, C. E., Myers, S. S., Bogich, T. and Ostfeld, R. S. (2010). Impacts of biodiversity on the emergence and transmission of infectious diseases. *Nature*, 468: 647–652. https://doi.org/10.1038/nature09575

Kunz, T. H., Braun de Torrez, E., Bauer, D., Lobova, T. and Fleming, T. H. (2011). Ecosystem services provided by bats. *Annals of the New York Academic of Science*, 1223: 1–38.

Mace, G. M. et al. (2005). Biodiversity, *In*: Hassan, R., Scholes, R. and Ash, N. (Eds.), *Ecosystems and human well-being*. Volume 1. Millennium Ecosystem Assessment, Washington, DC, pp. 53–98. https://doi.org/10.1111/j.1749-6632.2011.06004.x

Menon, V. (2014). *The field guide of Mammal of Indian*. Manipal Technologies Ltd, Manipal, India. 528 pp.

Mittermeier, R. A., Gil, P. R., Hofmann, M., Pilgrims, J., Brooks, T., Mittermeier, C. G., Lamoreux, J. and Da Fonseca, G. A. B. (2004). *Hotspots revisited: earth's biologically richest and most endangered terrestrial ecoregions*. CEMEX, USA. 391 pp.

National Biodiversity Centre. (2017). Biodiversity Statistics of Bhutan: A Preliminary Baseline, National Biodiversity Centre, Ministry of Agriculture and Forests, Thimphu.

Nature Conservation Division [NCD]. (2004). Bhutan Biological Conservation Complex: A Landscape Conservation Plan: a way forward. Nature Conservation Division, Department of Forests and Park Services, Ministry of Agriculture, Thimphu, Bhutan. 58 pp.

National Environment Commission [NEC]. (2011). Biodiversity. National Environment Commission, Thimphu, Bhutan. 33 pp.

Olson, D. M. and Dinerstein, E. (2002). The Global 200: Priority ecoregions for global conservation. *Annals of the Missouri Botanical Garden*, 89 (2): 199–224. https://doi.org/10.2307/3298564

Paro Forest Division [PFD]. (2020). Conservation Management Plan for Biological Corridor-01 (Connecting Jigme Dorji National Park (JDNP) and Jigme Khesar Strict Nature Reserve (JKSNR), Paro Forest Division, Department of Forests and Park Services, Ministry of Agriculture and Forests, Bhutan. 97 pp.

Penjor, U., Wangdi, S., Tandin, T., David, W. and Macdonald, D. W. (2021). Vulnerability of mammal communities to the combined impacts of anthropic land-use and climate change in the Himalayan conservation landscape of Bhutan. *Ecological Indicator*, 121: 107085. https://doi.org/10.1016/j.ecolind.2020.107085

Penjor, U., MacDonald, D. W., Wangchuck, S., Tandin, T. and Tan, C. K. W. (2018). Identifying important conservation areas for the Clouded Leopard *Neofelis nebulosa* in a mountainous landscape: Inference from spatial modeling techniques. *Ecology and Evolution*, 8: 4278–4291. https://doi.org/10.1002/ece3.3970

RGoB. (2008). *The Constitution of Bhutan*. Royal Government of Bhutan, Thimphu, Bhutan. 33 pp.

Sanderson, J. and Harris, G. (2013). Automatic data organization, storage, and analysis of camera trap pictures. *Journal of Indonesian Natural History*, 1 (1): 1–10.

Schipper, J. et al. (2008). The status of the World's land and marine mammals: diversity, threat and knowledge. *Science*, 322: 225–230.

Seidensticker, J. (2010). Saving wild tigers: a case study in biodiversity loss and challenges to be met for recovery beyond 2010. *Integrative Zoology*, 5: 285–299. https://doi.org/10.1111/j.1749-4877.2010.00214.x

Sherpa, M., Wangchuk, S. and Wikramanayake, E. D. (2004). Creating biological corridors for conservation and development: A case study from Bhutan, *In:* Harmone, D. and Worboys, G. L. (Eds.), *Managing Mountain Protected Areas: Challenges and Responses for the 21st Century*. Andromeda Editrice, Italy. pp. 128–134.

Sarpang Forest Division [SFD]. (2016). Zero Poaching: Ensuring Tiger Protection beyond Protected Areas (2016–2018). Divisional Forest Office, Sarpang, Department of Forests and Park Services, Bhutan.

Tempa, T., Hebblewhite, M., Goldberg, J. F., Norbu, N., Wangchuk, T. R., Xiao, W. and Mills, S. L. (2019). The spatial distribution and population density of tigers in mountainous terrain of Bhutan. *Biological Conservation*, 238: 108192. https://doi.org/10.1016/j.biocon.2019.07.037

Tenzin, J. and Dhendup, P. (2017). Habitat characteristics, relative abundance and conservation threats of Himalayan Bull frogs (*Nanorana leibigii* Günther, 1860) in primary tributaries of Simkhar River, Bhutan. *Bhutan Journal of Natural Resources and Development*, 4: 29–38. https://doi.org/10.17102/cnr.2017.07

Tenzin, J., Dhendup, T., Dhendup, P, Dorji, T., Choki, K., Wangchuk, S., Dorji, S., Nidup, C. and Dorji, T. (2019). Six felid species occur outside protected areas in south-central Bhutan. *Catsnews*, 70: 25–27.

Tenzin, J. and Wangyal J. T. (2019). New record of Blue-eyed Eastern Spadefoot Toad *Leptobrachium bompu* (Amphiia: Megophryidae) from Sarpang District in Bhutan. *Journal of Threatened Taxa*, 11: 13385–13389. https://doi.org/10.11609/jott.4134.11.3.13385-13389

Tenzin, J., Dhendup, P., Choki, K., Wangdi, T., Tshering, D., Dorji, D., Bomjan, M., Tenzin, K. and Thinley, P. (2021a). Increase in tiger numbers outside a protected area: the case of Sarpang Forest Division in south-central Bhutan. *Catnews*, 73*:* 27–28.

Tenzin, J., Dhendup, P., Dorji, D., Nidup, S. and Thinley, P. (2021b). Annotated checklist and conservation status of mammal species in Sarpang District, Bhutan. *Indonesian Journal of Social and Environmental Issues*, 2 (3): 258–270. https://doi.org/10.47540/ijsei.v2i3.398

Thinley, P., Dorji, T., Leki, L., Phuntsho, S., Dorji, N., Phuntshok P., Dorji, P., Lassoie, J. P., Morreale, S. J. and Curtis, P. D. (2015). Estimating Wild tiger (*Panthera tigris* Linnaeus) abundance and density using a spatially-explicit capture-recapture model in Jigme Dorji National Park, Bhutan. *Bhutan Journal of Natural Resources and Development*, 2 (1):1–10. http://dx.doi.org/10.17102/cnr.2015.01

Tshewang, G. and Wangchuk, U. (2019). Conservation management plan for Biological Corridor No. 5 that connects Royal Manas National Park and Jomotsangkha Wildlife Sanctuary (2020–2029), Pemagatshel Forest Division, Department of Forests and Park Services, Thimphu, Bhutan.

Wangchuk, T., Thinley, P., Tshering, K., Tshering, C., Yonten, D., Pema, B. and Wangchuk, S. (2004). Field Guide to the Mammals of Bhutan. Department of Forests and Park Services. Ministry of Agriculture, Royal Government of Bhutan. 180 pp.

WWF Bhutan. (2021). Biological corridors. Accessed from https://www.wwfbhutan.org.bt/projects_/bhutan_biological_conservation_complex/biological_corridors/#:~:text=Biological%20Corridors%20were%20first%20established,nine%20of%20Bhutan's%20protected%20areas