

Biodiversity of Toorsa Strict Nature Reserve - Jigme Dorji National Park Conservation Corridor, Western Bhutan

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The corridor is an important watershed besides being the habitat of many endangered flora and fauna.



Introduction

Bhutan clings to the southern slopes of the Himalayas, a mountain range best known for containing the world's highest and youngest mountain peaks, including the highest on earth, Mount Everest. Bhutan, having abrupt altitudinal variation, has diverse ecosystems with rich biodiversity (Sherpa et al. 2004). Because of this rich biodiversity, Bhutan is included in several global priorities for biodiversity conservation. It is within a Global 200 ecoregion complex (Olson and Dinerstein 1998) and also part of the Himalayan hotspot (Mittermeier et al. 2005). With the recent paradigm shift in conservation approaches, Bhutan has conceptualised a new approach to conservation by developing the Bhutan Biological Conservation Complex (B2C2) with 26% of its land under a protected area network connected by an additional nine per cent

of land in corridors (Sherpa et al. 2004). The Toorsa Strict Nature Reserve (TSNR) to Jigme Dorji National Park (JDNP) corridor is an important connecting link to the proposed Kangchenjunga landscape. It is one of the six corridors identified by ICIMOD for re-establishing natural connectivity among the protected areas in the Kangchenjunga landscape (Sharma and Chettri 2005). A stakeholders' consultation on 'Planning and Improvement of Corridors between Protected Areas within the Kangchenjunga Landscape', held from 12th to 13th March, 2004 in Thimphu, recommended an immediate survey of biodiversity in the proposed corridor area. This report combines the findings of three individual rapid biodiversity surveys carried out for mammals, birds, and vegetation within the Toorsa Strict Nature Reserve-Jigme Dorji National Park conservation corridor.

Vegetation Analysis

Located between Haa and Paro districts, the corridor covers an area of 149 sq.km and encompasses 10 of the 14 ecosystem types classified (Sherub 2004). It has a continuous north-south mountain range and a topographic variation from 2,500 to 4,500m. The minimum and maximum temperature ranges from -3°C to 25°C in both the Paro and Haa valleys of the corridor. The Paro Valley has an average annual precipitation of 132 mm while the Haa has about 80 mm.

A total of 85 random points, falling within the spatial extent of the corridor, were stratified on the basis of ecosystem coverage and uploaded to a GPS unit and a topographical sheet. During the survey, the general forest type, ground and canopy level vegetation, altitude, topography, soil types, ecosystem, and tree details were recorded.

Ecosystem types and floral diversity

Ten of the 14 ecosystem zones classified for Bhutan are found in the corridor area (Figure 1). The results of the analysis indicated that 38% of the corridor area is covered by a temperate moist coniferous ecosystem, followed by 15% of temperate scrub forest and 12% of subalpine temperate coniferous ecosystem. A total of 208 plant species from 62 families were recorded including 39 tree species, 43 shrubs, and 113 herbs (Annex 1).

1. The cool broad-leaved forest ecosystem (CBFE) represents the transition between temperate conifers at higher elevations (3800m) and broad-leaved forests at lower elevations (2400m). *Quercus semecarpifolia* with *Picea spinulosa* and *Pinus wallichiana* form the dominant tree canopy. Other deciduous communities include *Quercus griffithii*, *Betula utilis*, *Acer campbellii*, *Gamblea ciliata*, *Sorbus cuspidata*, *Enkianthus deflexus*, and evergreen species such as *Pieris formosa*, *Ilex diphyrena*, and a few species of *Rhododendron*. The bamboo habitat of *Borinda grossa* and *Yushania* species is a potential habitat for wild ungulates and domestic cattle and yaks. The endangered red panda (*Ailurus fulgens*) is also associated with this ecosystem.
2. The temperate dry coniferous ecosystem (TDCE) is dominated by *Pinus wallichiana*, *Picea spinulosa*, and *Larix griffithiana*. Species such as *Acer cappadocicum*, *Rhododendron arboreum*, *Lyonia ovalifolia*, and *Populus rotundifolia* form the understory. Ground orchids

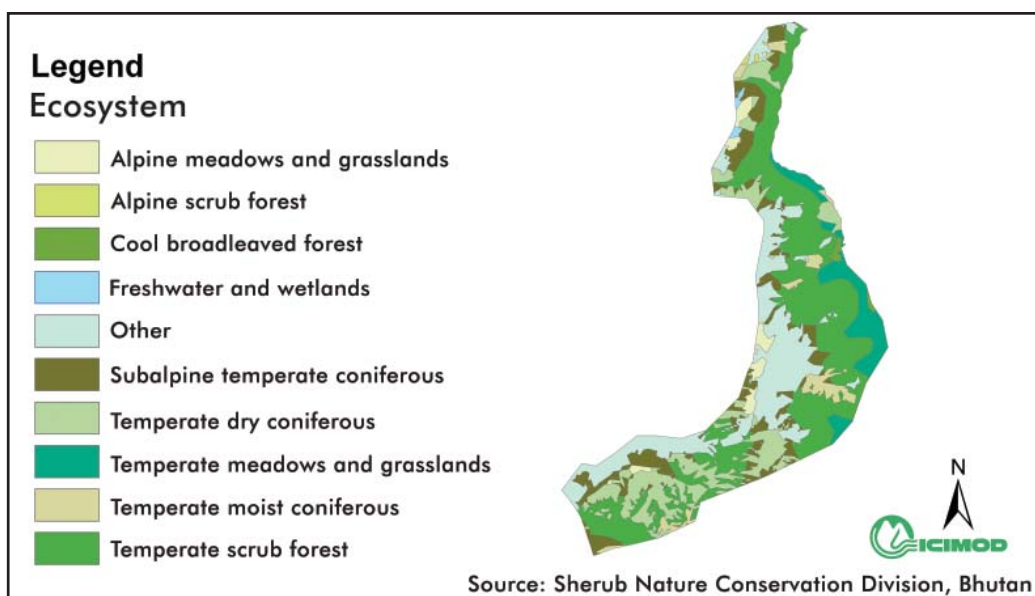


Figure 1: The 10 ecosystem types in the Toorsa Strict Nature Reserve-Jigme Dorji National Park corridor, Bhutan

along with abundant grass species comprise the bulk of ground vegetation where grazing is common. The ecosystem is prone to forest fires as the forest floor is covered with thick layer of pine needles and the soil has a very low moisture level.

3. The temperate moist coniferous ecosystem (TMCE) is comprised of comparatively wet habitats. *Abies densa* and *Tsuga dumosa* form the dominant tree canopy. *Larix* and *Picea spinulosa* occur in patches. The greatest number of ornamental *Rhododendron* species grows here. High humidity and unpolluted air support carpets of spongy *Sphagnum* and other mosses. The endangered musk deer (*Moschus chrysogaster*) uses this mossy habitat during winter.
4. The temperate scrub forest ecosystem is composed of dry short-stature shrubs and a variety of grass species. Plant species characteristic of the vegetation communities are *Desmodium elegans*, *Elaeagnus parviflora*, *Cotoneaster griffithii*, and *Quercus semecarpifolia*. The prevalent species include *Rosa sericea*, *Berberis cooperi*, *Rhododendron arboreum*, and *Artemesia* spp.
5. The temperate meadows and grasslands ecosystem is comprised of large patches of herbaceous glades and open grasslands with broad-leaved and temperate coniferous forests. Representative species include *Berberis cooperi*, *Agrostis micrantha*, *Arundinella hookeri*, *Brachypodium sylvaticum*, *Primula capitata*, *Gentiana polyanthes*, *Senecio diversifolia*, and *Aster* sp, all valued for their medicinal properties.
6. The subalpine temperate coniferous ecosystem occurs from 3,800 to 4,200m. Plant communities are comprised of *Rhododendron* sp, *Juniperus recurva*, *Juniperus pseudosabina*, *Morina nepalensis*, and *Pedicularis megalantha*.
7. The alpine scrub forest ecosystem is characterised by dwarf rhododendron, dwarf juniper, berberis, and willow shrubs. Snow forms a significant part of this ecosystem. Many

medicinally important herbs such as *Pedicularis* sp, *Neopicrorhiza scrophulariiflora*, and *Meconopsis paniculata* are present.

8. The alpine meadows and grassland ecosystem is characterised by species of grasses such as *Festuca*, *Agrostis*, *Poa*, and *Stipa* that provide palatable food resources for yak.
9. The freshwater and wetland ecosystem (FWWE) is comprised of marshes, alpine lakes, and swamps. Freshwater aquatic plants in the open lakes and rivers include *Ranunculus trichophyllus*, *Hydrilla verticillate*, and *Potamogeton crispus*. Open marshlands are characterised by *Acorus calalmus*, *Shenoplectus juncoides*, *Equisetum*, *Carex*, *Juncus*, and others.
10. The category 'other' includes exposed surfaces of bedrock and permanently snow-covered mountains and glaciers. Rocky cliffs, deep gorges, and a conglomerate of boulder rocks support species like *Frittilaria delavaye*, *Rheum australe*, *Corydallis species*, and *Saussurea gossipiphora* and many Bryophytes and Crustose lichens.

Bird Diversity

The survey of bird species' diversity was carried out using 85 pregenerated, stratified random points entered on GARMIN GPS etrex VISTA, and (mainly) the species-richness frequency method (MacKinnon and Philips 1993) corroborated by Inskipp et al. (1996). Species' identification was based on Inskipp et al. (1999). The survey data was used to determine species richness and species' habitat affinity. The survey was carried out in October/November 2004.

Species' richness

The survey recorded 108 species of birds representing five major ecoregions of the corridors; the annotated list raised the number to 143 (Annex 2). The temperate dry coniferous ecosystem had the most species, 89, followed by the cool broad-leaved forest ecosystem with 55. The freshwater and wetland ecosystem had the least diversity with 10 species (Table 1). Two totally protected bird species under the Bhutan Schedule I of the Forest and Nature Conservation Act 1995 were also found in the corridor, viz., the Himalayan monal (*Lophophorus impejanus*) and Tibetan snowcock (*Tetraogallus tibetanus*). Of the 15 globally-threatened species recorded in Bhutan, two species were found in the corridor, viz., the satyr tragopan (*Tragopan satyra*) and wood snipe (*Gallinago nemoricola*) and out of 11 birds from the restricted world-breeding range species recorded in Bhutan, one, viz., the hoary-throated barwing (*Actinodura nipalensis*), was found in the corridor. At least two of the bird species recorded were confirmed to breed in the survey corridor where juveniles of lammergeier (*Gypaetus barbatus*) and blue-fronted redstart (*Phoenicurus frontalis*) were observed. The survey also added to the district record.

Species' habitat affinity

The analysis of habitat affinity enabled us to understand which species used specific ecosystems during a particular time of the year. During autumn, the CBFE harbours species such as the black-faced laughing thrush (*Garrulax affinis*), long-tailed minivet (*Pericrocotus ethologus*), rufous-fronted tit (*Aegithalos iouschistos*), and many species of *Garrulax*. The TDCE is the richest habitat in terms of bird diversity with species such as rufous sibia (*Heterophasia capistrata*),

Table 1: Bird species' richness in different ecosystems of the Toorsa Strict Nature Reserve-Jigme Dorji National Park corridor, west Bhutan

Ecosystems	Total Count	Species Richness	Elevation Range
Cool broad-leaved forest (CBFE)	805	55	2,450-3,800
Freshwater and wetlands (FWWE)	92	10	2,700-3,600
Temperate dry coniferous (TDCE)	2394	89	2,550-3,600
Temperate moist coniferous (TMCE)	1046	49	2,900-3,650
Scrub and meadows ^a	406	29	3,050-4,300
^a includes RTSFE, TMGE, ASFE, AMGE			

red-billed chough (*Pyrrhocora pyrrhocorax*), white-collared blackbird (*Turdus albocinctus*), green-backed tit (*Parus monticolus*), and russet sparrow (*Passer rutilans*) being found. The TMCE supported spotted laughing thrush (*Garrulax ocellatus*), grey-crested tit (*Parus dichrous*), white-winged gross beak (*Mycerobas carripes*), black-faced laughing thrush (*Garrulax affinis*), and rufous-fronted tit (*Aegithalos iouschistos*). The temperate and alpine scrub, alpine meadows, and grasslands are inhabited by blue-fronted redstart (*Pyrrhocorax pyrrhocorax*), plain mountain finch (*Leucosticte nemoricola*), common kestrel (*Falco tinnunculus*), and Himalayan griffon (*Gyps himalayensis*). The FWWE has species such as the plumbeous water redstart (*Rhyacornis fuliginosus*), blue-whistling thrush (*Myophonus caeruleus*), white-capped water redstart (*Chaimarrornis leucocephalus*), and brown dipper (*Cinclus pallasii*). The juniper and scrub forests of Sagala are an important habitat for blood pheasant (*Ithaginis cruentus*) and white-winged gross beak (*Mycerobas carripes*). High rocky cliffs and gorges form the nesting sites for the lammergeier (*Gypaetus barbatus*) and Himalayan griffon (*Gyps himalayensis*).

Mammal Diversity

The survey on mammal diversity was carried out for 40 days covering about 30% of 85 randomised plots. Evidence (scats, kills, digging, wallowing, dung, feeding sites, nest sites, mud or tree markings, and remains) and sightings of free-ranging mammals were recorded along with the associated habitat type. Local people and herders were also approached for additional information.

List of mammals

A total of 18 mammalian species was recorded of which nine were globally threatened according to the IUCN categories (Table 2). The occurrence of sambar (*Cervus unicolor*) was the highest followed by wild pig (*Sus scrofa*), Himalayan serow (*Capricornis sumatraensis*), common leopard (*Panthera pardus*), blue sheep (*Pseudois nayaur*), and grey langur (*Presbytis entellus*). The other mammals include striped squirrel (*Funambulus species*), goral (*Nemorhaedus goral*), Himalayan black bear (*Selenarctos thibetanus*), musk deer (*Moschus chrysogaster*), tiger (*Panthera tigris*), wild dog (*Cuon alpinus*), and yellow-throated marten (*Martes flavigula*). Evidence of tiger was found at the remarkably high elevation of 3,371 m. All 18 mammals were confined to an altitudinal range of 2,266 m to 4,130 m. The highest frequency of mammals was

Table 2: Mammalian species recorded in the Toorsa Strict Nature Reserve-Jigme Dorji National Park corridor, west Bhutan

Name	Scientific Name	Status		
		FNCA ^a	IUCN ^b	CITES ^c
Tiger	<i>Panthera tigris</i>	Totally protected	EN	App-I
Snow leopard	<i>Uncia uncia</i>	Totally protected	-	App-I
Clouded leopard	<i>Neofelis nebulosa</i>	Totally protected	VU	App-I
Common leopard	<i>Panthera pardus</i>	Totally protected		App-I
Himalayan black bear	<i>Selenarctos thibetanus</i>	Totally protected	VU	App-I
Musk deer	<i>Moschus chrysogaster</i>	Totally protected	NT	App-I/II
Blue sheep	<i>Pseudois nayaur</i>	-	-	-
Barking deer	<i>Muntiacus muntjac</i>	-	-	-
Goral	<i>Nemorhaedus goral</i>	-	NT	App-I
Grey langur	<i>Presbytis entellus</i>	-	NT	App-I
Three-striped squirrel	<i>Funambulus species</i>	-	-	-
Sambar	<i>Cervus unicolor</i>	-	-	-
Himalayan serow	<i>Capricornis sumatraensis</i>	Totally protected	VU	App-I
Pika	<i>Ochotona species</i>	-	NT	-
Wild dog	<i>Cuon alpinus</i>	-	VU	App-I
Wild pig	<i>Sus scrofa</i>	-		-
Yellow throated marten	<i>Martes flavigula</i>	-	-	App-III

^a CITES = Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES undated);
^b FNCA = Forest and Nature Conservation Act of Bhutan (FNCA 1995); IUCN = International Union for Conservation of Nature (IUCN 2004)

recorded between elevations of 2,600m to 3,600m. Interestingly, most of the species were found in the juniper-rhododendron forest, where pika (*Ochotona* sp) and sambar (*Cervus unicolor*) were the dominant species. Twelve mammalian species, including the tiger and Himalayan black bear, were recorded in the blue pine habitat.

Importance of the Corridor

Two hundred and eight plant species belonging to 62 families were identified within the corridor area, among which *Taxus baccata*, *Panax pseudoginseng*, and *Gentiana crassoloides* are protected as Schedule I plants under Bhutan's Forest and Nature Conservation Act 1995. The presence of globally-protected species such as *Rheum nobile* and *Podophyllum hexandrum* make the area desirable for conservation. In addition, the corridor also has high-value timber species such as *Pinus wallichiana*, *Picea spinulosa*, and *Tsuga dumosa* and many other medicinal herbs that are constantly in demand and overexploited. The corridor also hosts at least 108 bird species (identified in the rapid survey), and probably more than 143 species (according to the annotated list), including two of the 15 globally threatened bird species found in Bhutan, and two totally protected species. The bird diversity will be higher in summer when transborder migratory species and high-altitude migrants are present. The corridor is home to many

important mammals including some on the IUCN endangered species' list. Besides being the habitat of many endangered species of flora and fauna, the corridor serves as an important watershed. The two major tributaries of the Wangchu River system have their catchments here.

Conservation and Development Issues

Yaks form an integral part of the pastoral system and domestic biodiversity in Bhutan. The pastoral groups in Nubri village near Paro and communities of Bji geog in Haa keep yaks for meat and dairy products. Yak husbandry is, therefore, a major part of their livelihoods and economy. The corridor is under severe grazing pressure during the warm summer months when the herds return from the low pastures to the highlands. Degradation happens at times when plants are struggling to grow after the severe winter. The requirement here is for mitigation measures that integrate communal grazing rights with conservation issues.

Pastoralists, especially those living in the southwest, also pose a threat to the birds and other mammals, as evident from the piles of bird feathers dumped close to yak ranches, and the traps and snares encountered during the survey. The age-old 'tsamdro' (grazing right ownership) also seems to influence practices such as girdling of old trees. In the high-altitude area of dry alpine scrub, the population of blue sheep seems to compete with yaks. Snow leopards in these areas seem to exist in balance with the number of blue sheep and any reduction in the population of blue sheep poses a threat to the population of snow leopards.

Recommendation for Priority Action

A strong conservation measure needs to be adopted within the corridor to mitigate the degradation of biodiversity caused by grazing. Research on issues related to grazing should be a top priority for management. Within the corridor area, Shingkharap top, and Tatsilakham areas of Sagala, Takha, Damthang, Haala, and Lajab have good canopy cover, and can therefore be potential habitats for wildlife and their movement. Northeast of Tshomibjilam and north of Damthang, however, the connectivity of the corridor seems to be broken.

Regarding bird diversity, a second survey is highly recommended to cover those migratory species of birds which had already crossed the corridor area before the first survey. Opening of the primary hemlock, fir, and juniper forest for pasture expansion must be regulated and practices such as fire letting and slash and girdling should be restricted. Law enforcement is required to stop poaching of wild bird fauna.

The mammal distribution map showed that observations were mostly made on the eastern slope and at the upper and lower part of the corridor; another survey is required for a more detailed list of mammals. As some of the mammals were also recorded from the area adjoining the corridor, the boundary of the corridor might have to be revised or broadened. It is very important to save indicator species, such as wild pigs and sambar, because their predators, such as wild dogs and common leopards, would then not be interested in the human communities and their possessions around the corridor. In cases of conflict, however, compensation schemes

should be made clear to communities at the grass roots' level. Regular patrolling will be necessary to stop poaching of the endangered musk deer.

Conclusion

Improvement in the living standards of the local people would reduce pressure on the local natural resources, including wildlife. Therefore, alternative income-generating activities for the local communities are recommended, especially for communities dependent on rearing yaks and other cattle. A supply of improved breeds of cattle, and training in improved animal husbandry, would benefit local people. Ecotourism, controlled trekking, bird watching and so on can be planned through local initiatives so that the conservation issues are understood and acted upon at grass roots' level.

Bibliography

- CITES (no date) Convention on International Trade in Endangered Species of Wild Fauna and Flora. Gland: IUCN. URL: [http:// www.cites.org/eng/disc/species.shtml](http://www.cites.org/eng/disc/species.shtml)
- FNCA (1995) *Forest and Nature Conservation Act of Bhutan*. Thimphu: RGOB, Ministry of Agriculture
- Inskipp, C.; Inskipp, T.; Grimmett, R. (1999) *Birds of Bhutan*, London: Christopher Helm
- Inskipp, T.; Lindsey, N.; Duckworth, W. (1996) *An Annotated Checklist of Birds of the Oriental Region*. Sandy: Oriental Birds' Club UK
- IUCN (2004) *The 2004 IUCN Red List of Threatened Species: A Global Species Assessment*. Baillie, J.E.M.; Hilton-Taylor, C.; Stuart, S.N. (eds). Gland: IUCN
- Mackinnon, J.; Phillips, K. (1993) *A Field Guide to the Birds of Borneo, Sumatra, Java and Bali*. Oxford: Oxford University Press
- Mittermeier, R.A.; Gils, P.R. ; Hoffman, M.; Pilgrim, J.; Brooks, T.; Mittermeier, C.G.; Lamoreaux, J.; da Fonseca, G.A.B. (eds) (2005) *Hotspots Revisited. Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*. Virginia: CEMEX
- Olson, D.M.; Dinerstein, E. (1998) 'The Global 200: A Representation Approach to Conserving the Earth's Most Biologically Valuable Ecoregions'. In *Conservation Biology*, 12: 502-515
- Sharma, E.; Chettri, N. (2005) 'ICIMOD's Transboundary Biodiversity Management Initiative in the Hindu Kush-Himalayas.' In *Mountain Research and Development*, 25(3): 280-283
- Sherpa, M.N.; Wangchuk, S.; Wikramanayake, E.D. (2004) 'Creating Biological Corridors for Conservation and Development: A Case Study from Bhutan'. In Harmone, D.; Worboys, G.L. (eds) *Managing Mountain Protected Areas: Challenges and Responses for the 21st Century*, pp 128-134. Italy: Andromeda Editrice
- Sherub (2004) 'Using Habitat Models to Predict the Distribution of Birds in Bhutan: Implications for Future Research and Conservation'. A Thesis submitted in partial fulfilment of the requirements for the degree of Master of Science. Madison: University of Wisconsin

Annex 1: Checklist of Plant Species

Plant species recorded from the corridor connecting Toorsa Strict Nature Reserve and Jigme Dorji National Park, Bhutan		
Latin name	Life form	Family
<i>Abies densa</i>	Tree	Pinaceae
<i>Acanthus</i> sp	Herb	Acanthaceae
<i>Acer campbellii</i>	Tree	Aceraceae
<i>Acer cappadocicum</i>	Tree	Aceraceae
<i>Acer pectinatum</i>	Tree	Aceraceae
<i>Acer sikkimensis</i>	Tree	Aceraceae
<i>Acer sterculiaceum</i>	Tree	Aceraceae
<i>Aconitum</i> sp	Herb	Ranunculaceae
<i>Adonis</i> sp	Herb	Ranunculaceae
<i>Agrostis micrantha</i>	Herb	Graminae
<i>Allium hookeri</i>	Herb	Liliaceae
<i>Allium</i> sp	Herb	Liliaceae
<i>Amaranthus</i> sp	Herb	Amaranthaceae
<i>Anaphalis</i> sp	Herb	Compositae
<i>Ancanthus</i> sp	Herb	Labiatae
<i>Anemone vitifolia</i>	Herb	Ranunculaceae
<i>Ainsliaea aptera</i>	Herb	Compositae
<i>Argimonia pilosa</i>	Herb	Rosaceae
<i>Aristolochia</i> sp	Shrub	Aristolochiaceae
<i>Artemisia</i> sp	Herb	Compositae
<i>Aster neoelegans</i>	Herb	Compositae
<i>Aster</i> sp	Herb	Compositae
<i>Astilbe rivularis</i>	Herb	Saxifragaceae
<i>Berberis aristata</i>	Shrub	Berberidaceae
<i>Berberis cooperi</i>	Shrub	Berberidaceae
<i>Berberis griffithiana</i>	Shrub	Berberidaceae
<i>Berberis hookeri</i>	Shrub	Berberidaceae
<i>Berberis</i> sp	Shrub	Berberidaceae
<i>Betula utilis</i>	Tree	Betulaceae
<i>Bistortia</i> sp	Herb	Polygonaceae
<i>Borinda grossa</i>	Shrub	Graminae
<i>Brachypodium sylvaticum</i>	Herb	Graminae
<i>Brassiopsis</i> sp	Tree	Araleaceae
<i>Bromus himalaicus</i>	Herb	Graminae
<i>Calamagrostis</i> sp	Herb	Graminae
<i>Carex</i> sp	Herb	Graminae
<i>Cassiope flexusa</i>	Herb	Ericaceae
<i>Schisandra grandiflora</i>	Herb	Chisendraceae
<i>Circium</i> sp	Herb	Compositae
<i>Clematis montana</i>	Herb	Ranunculaceae

Latin name	Life form	Family
<i>Cobrasia</i> sp	Herb	Graminae
<i>Coriaria nepalensis</i>	Shrub	Coriariaceae
<i>Corylus ferox</i>	Tree	Betulaceae
<i>Cotonaster griffithii</i>	Shrub	Rosaceae
<i>Cremanthodium</i> sp	Herb	Rosaceae
<i>Cyananthus</i> sp	Herb	Companulaceae
<i>Dandelion</i> sp	Herb	Compositae
<i>Danthonia cumminsii</i>	Herb	Graminae
<i>Daphne bholua</i>	Shrub	Thymeliaceae
<i>Daphne</i> sp	Shrub	Thymeliaceae
<i>Desmodium elegans</i>	Shrub	Leguminosae
<i>Dryopteris</i> sp	Herb	Ferns
<i>Rubus</i> sp	Herb	Rosaceae
<i>Elaeagnus parvifolia</i>	Shrub	Elaegnaceae
<i>Elatostema</i> sp	Herb	Urticaceae
<i>Elsholtzia fruticosa</i>	Shrub	Labiatae
<i>Elymus nutans</i>	Herb	Graminae
<i>Enkianthus deflexus</i>	Tree	Ericaceae
<i>Epilobium</i> sp	Herb	Onagraceae
<i>Eragrostis</i> sp	Herb	Graminae
<i>Euonymus</i> sp	Tree	Celastraceae
<i>Euphorbia griffithiana</i>	Shrub	Euphorbiaceae
<i>Euphorbia ignipectus</i>	Shrub	Euphorbiaceae
<i>Euphorbia</i> sp	Shrub	Euphorbiaceae
<i>Eurya</i> sp	Tree	Theaceae
<i>Festuca</i> sp	Herb	Graminae
<i>Fragaria</i> sp	Herb	Rosaceae
<i>Fraxinus florubunda</i>	Tree	Oleaceae
<i>Gamblea ciliate</i>	Tree	Araliaceae
<i>Gaultheria fragrantissima</i>	Shrub	Ericaceae
<i>Gentiana capitata</i>	Herb	Gentianaceae
<i>Gentiana crassuloides</i>	Herb	Gentianaceae
<i>Gentiana urnula</i>	Herb	Gentianaceae
<i>Geranium polyanthes</i>	Herb	Gereniaceae
<i>Gnaphalium</i> sp	Herb	Compositae
<i>Hedera nepalensis</i>	Shrub	Araliaceae
<i>Halenia elliptica</i>	Herb	Gentianaceae
<i>Hemifragma heterophylla</i>	Herb	Scrophulariaceae
<i>Heracleum</i> sp	Herb	Umbelliferae
<i>Ilex dipyrena</i>	Tree	Aquifoliaceae
<i>Impatiens</i> sp	Herb	Balsaminaceae
<i>Inula</i> sp	Herb	Compositae
<i>Ipomoea</i> sp	Herb	Convolvulaceae
<i>Iris</i> sp	Herb	Iridaceae

Latin name	Life form	Family
<i>Jasminum</i> sp	Herb	Oleaceae
<i>Juncus</i> sp	Herb	Juncaceae
<i>Juniperus pseudosabina</i>	Shrub	Cuppressaceae
<i>Juniperus recurva</i>	Tree	Cuppressaceae
<i>Juniperus squamata</i>	Tree	Cuppressaceae
<i>Larix griffithiana</i>	Tree	Pinaceae
<i>Lepidiopodium</i> sp	Herb	Graminae
<i>Lilium</i> sp	Herb	Liliaceae
<i>Lindera</i> sp	Tree	Lauraceae
<i>Listera pinetorum</i>	Herb	Orchidaceae
<i>Lonicera</i> sp	Herb	Caprifoliaceae
<i>Lyonia ovalifolia</i>	Shrub	Ericaceae
<i>Meconopsis paniculata</i>	Herb	Papavaraceae
<i>Meconopsis superba</i>	Herb	Papavaraceae
<i>Microcloa</i> sp	Herb	Graminae
<i>Morina longifolia</i>	Herb	Dipsacaceae
<i>Onosma hookeri</i>	Herb	Boraginaceae
<i>Panax pseudoginseng</i>	Herb	Araliaceae
<i>Pedicularis megalantha</i>	Herb	Scrophulariaceae
<i>Fagopyrum</i> sp	Herb	Polygonaceae
<i>Phlomis tibetica</i>	Herb	Labaitae
<i>Phyllodendron tomentosa</i>	Shrub	Hydringiaceae
<i>Phytollacca</i> sp	Herb	Phytollacaceae
<i>Picea spinulosa</i>	Tree	Pinaceae
<i>Picrorhiza kurroa</i>	Herb	Scrophulariaceae
<i>Pieris formosa</i>	Herb	Ericaceae
<i>Pilea</i> sp	Herb	Urticaceae
<i>Pinus wallichiana</i>	Tree	Pinaceae
<i>Piptanthus nepalensis</i>	Shrub	Leguminosae
<i>Poa</i> sp	Herb	Graminae
<i>Podophyllum emodi</i>	Herb	Polygonaceae
<i>Podophyllum hexandrum</i>	Herb	Rubiaceae
<i>Polygonatum hookerii</i>	Herb	Liliaceae
<i>Populus rotundifolia</i>	Tree	Salicaceae
<i>Populus</i> sp	Tree	Salicaceae
<i>Potentilla</i> sp	Herb	Rosaceae
<i>Potentilla heterophylla</i>	Herb	Rosaceae
<i>Potentilla microphylla</i>	Herb	Rosaceae
<i>Primula capitata</i>	Herb	Primulaceae
<i>Primula denticulate</i>	Herb	Primulaceae
<i>Primula sikkimensis</i>	Herb	Primulaceae
<i>Prunus serrata</i>	Tree	Rosaceae
<i>Prunus</i> sp	Tree	Rosaceae
<i>Pueraria</i> sp	Herb	Leguminosae

Latin name	Life form	Family
<i>Pyrola</i> sp	Herb	Pyrolaceae
<i>Pyrolia sikkimensis</i>	Herb	Pyrolaceae
<i>Quercus griffithii</i>	Tree	Fagaceae
<i>Quercus semecarpifolia</i>	Tree	Fagaceae
<i>Rheum australe</i>	Herb	Polygonaceae
<i>Rheum nobile</i>	Herb	Polygonaceae
<i>Rhododendron arboreum</i>	Tree	Ericaceae
<i>Rhododendron ciliata</i>	Shrub	Ericaceae
<i>Rhododendron cinnabarinum</i>	Shrub	Ericaceae
<i>Rhododendron campanulatum</i>	Shrub	Ericaceae
<i>Rhododendron hodgsonii</i>	Tree	Ericaceae
<i>Rhododendron keysii</i>	Shrub	Ericaceae
<i>Rhododendron lanatum</i>	Tree	Ericaceae
<i>Rhododendron lepidotum</i>	Shrub	Ericaceae
<i>Rhododendron nivale</i>	Shrub	Ericaceae
<i>Rhododendron setosum</i>	Shrub	Ericaceae
<i>Rhododendron</i> sp	Shrub	Ericaceae
<i>Rhus</i> sp	Tree	Anacardiaceae
<i>Ribes</i> sp	Shrub	Grossulariaceae
<i>Rosa brunonii</i>	Shrub	Rosaceae
<i>Rosa macrophylla</i>	Shrub	Rosaceae
<i>Rosa sericea</i>	Shrub	Rosaceae
<i>Rosa</i> sp	Shrub	Rosaceae
<i>Rubia cordifolia</i>	Herb	Rubiaceae
<i>Rubia heterophylla</i>	Herb	Rubiaceae
<i>Rubus hypoleuca</i>	Herb	Rosaceae
<i>Rubus</i> sp	Shrub	Rosaceae
<i>Rumex nepalensis</i>	Herb	Polygonaceae
<i>Salix</i> sp	Tree	Salicaceae
<i>Saussurea gossypiphora</i>	Herb	Compositae
<i>Selinum</i> sp	Herb	Umbelliferae
<i>Senecio diversifolia</i>	Herb	Compositae
<i>Senecio</i> sp	Herb	Compositae
<i>Smilacina oleracea</i>	Herb	Liliaceae
<i>Smilax</i> sp	Herb	Liliaceae
<i>Sorbus cuspidata</i>	Tree	Rosaceae
<i>Sorbus microphylla</i>	Tree	Rosaceae
<i>Sphagnum</i> sp	Herb	Bryophyte
<i>Stipa</i> sp	Herb	Graminae
<i>Stycharis</i> sp	Herb	Orchidaceae
<i>Swertia</i> sp	Herb	Gentianaceae
<i>Taxus baccata</i>	Tree	Taxaceae
<i>Thalictrum</i> sp	Herb	Ranunculaceae
<i>Thamnolia vermicularis</i>	Herb	Fungi

Latin name	Life form	Family
<i>Tsuga dumosa</i>	Tree	Pinaceae
<i>Usnea</i> sp	Herb	Lichen
<i>Vaccinium nummularia</i>	Shrub	Ericaceae
<i>Vaccinium</i> sp	Herb	Ericaceae
<i>Veleriana</i> sp	Herb	Velerianaceae
<i>Verbascum thapsus</i>	Herb	Scrophulariaceae
<i>Vitis semicordata</i>	Herb	Vitaceae
<i>Viburnum nervosum</i>	Tree	Sambucaceae
<i>Viola</i> sp	Herb	Violaceae
<i>Yushiana</i> sp	Shrub	Graminae
<i>Zanthoxylum</i> sp	Shrub	Rutaceae

Annex 2: Checklist of Bird Species

Bird species recorded from the corridor connecting Toorsa Strict Nature Reserve and Jigme Dorji National Park, Bhutan

Species	Common Name	Ecosystem ^a	Altitude range(m)
GALLIFORMES			
Phasianidae			
<i>Lerwa lerwa</i>	Snow partridge	SM	4,200
<i>Arborophila torqueola</i>	Common hill partridge	TDCE	2,800-3,600
<i>Ithaginis cruentus</i>	Blood pheasant	CBFE,TDCE,TMCE	3,050-3,650
<i>Tragopan satyra</i>	Satyr tragopan	CBFE	3,600
<i>Lophophorus impejanus</i>	Himalayan monal	TMCE,SM	3,340-4,200
<i>Lophura leucomelanos melanota</i>	Kalij pheasant	TDCE	2,700
PICIFORMES			
Picidae			
<i>Dendrocopos hyperythrus</i>	Rufous-bellied woodpecker	TDCE,TMCE	2,700-3,600
<i>Dendrocopos darleyensis</i>	Darjeeling woodpecker	TDCE,TMCE	2,800
UPUIFORMES			
Upupidae			
<i>Upupa epops</i>	Common hoopoe	TDCE	2,800-3,000
CORACIIFORMES			
Coraciidae			
<i>Coracias benghalensis</i>	Indian roller	TDCE	2,600
Cerylidae			
<i>Megaceryle lugubris</i>	Crested kingfisher	FWWE	2,700
COLUMBIFORMES			
Columbidae			
<i>Columba leuconata</i>	Snow pigeon	TMCE,SM	3,000-4,200
<i>Columba hodgsonii</i>	Speckled wood pigeon	CBFE	2,800-3,600
<i>Streptopelia orientalis</i>	Oriental turtle dove	CBFE,TDCE	2,600-3,000
CINCONIFORMES			
Charadriidae			
Recurvirostrinae			
Recurvirostrini			
<i>Ibidorhyncha struthersii</i>	Ibis bill	FWWE	2,800
Accipitridae			
Accipitrinae			
<i>Gypaetus barbatus</i>	Lammergeier	TDCE	2,800
<i>Gyps himalayensis</i>	Himalayan griffon	SM	3,300-4,300
<i>Accipiter nisus</i>	Eurasian sparrowhawk	CBFE,TDCE,TMCE	2,800-3,800
<i>Buteo buteo</i>	Common buzzard	TDCE	2,700-4,200
<i>Ictinaetus malayensis</i>	Black eagle	TDCE	2,700
<i>Spizaetus nipalensis</i>	Mountain hawk eagle	CBFE,TDCE,TMCE	2,700-3,600

Species	Common Name	Ecosystem ^a	Altitude range(m)
Falconidae			
<i>Falco tinnunculus</i>	Common kestrel	CBFE,TDCE,SM	2,700-4,200
PASSIRIFORMES			
Laniidae			
<i>Lanius tephronotus</i>	Grey-backed shrike	CBFE	2,800
Corvidae			
<i>Garrulus glandarius</i>	Eurasian jay	CBFE	2,800-3,600
<i>Urocissa flavirostris</i>	Yellow-billed blue magpie	TDCE,TMCE	2,700-3,500
<i>Nucifraga caryocatactes</i>	Spotted nutcracker	TDCE,CBFE,TMCE,SM	2,700-3,900
<i>Pyrrhocorax pyrrhocorax</i>	Red-billed chough	SM,TMCE,TDCE	2,700-4,200
<i>Corvus macrorhynchos</i>	Large-billed crow	TDCE,TMCE,SM	2,700-3,800
<i>Pericrocotus ethologus</i>	Long-tailed minivet	CBFE,TDCE,TMCE,SM	2,700-3,900
<i>Rhipidura hypoxantha</i>	Yellow-bellied fantail	CBFE,TDCE,TMCE	2,800-3,600
<i>Dicrurus leucophaeus</i>	Ashy drongo	TDCE	2,800
Cinclidae			
<i>Cinclus cinclus</i>	White-throated dipper	FWWE	3,200
<i>Cinclus pallasii</i>	Brown dipper	FWWE	2,700-3,600
Muscicapidae			
<i>Monticola rufiventris</i>	Chestnut-bellied rock thrush	CBFE,TDCE	2,700-3,200
<i>Myophonus caeruleus</i>	Blue whistling thrush	FWWE,TDCE,CBFE,TMCE	2,700-3,600
<i>Zoothera dixonii</i>	Long-tailed thrush	CBFE,TDCE	2,800-3,200
<i>Zoothera mollissima</i>	Plain-backed thrush	CBFE	3,100
<i>Zoothera monticola</i>	Long-billed thrush	TDCE	2,800
<i>Turdus albocinctus</i>	White-collared blackbird	CBFE	2,800-3,600
<i>Turdus boulboul</i>	Grey-winged blackbird	CBFE,TDCE	2,400-3,000
<i>Brachypterix montana</i>	White-browed shortwing	CBFE	3,500
<i>Ficedula strophilata</i>	Rufous-throated flycatcher	CBFE,TDCE,TMCE	2,700-3,600
<i>Ficedula supercilialis</i>	Ultramarine flycatcher	TDCE	
<i>Ficedula t. tricolor</i>	Slaty blue flycatcher	CBFE,TDCE	2,800-3,350
<i>Niltava sundara</i>	Rufous-bellied niltava	TDCE	2,750-2,900
<i>Culicicapa ceylonensis</i>	Grey-headed canary flycatcher	CBFE,TDCE	2,700-2,900
<i>Tarsiger chrysaeus</i>	Golden bush robin	CBFE,TDCE,TMCE	2,750-3,900
<i>Tarsiger cyanurus</i>	Orange-flanked bush robin	CBFE	2,750-3,200
<i>Tarsiger indicus</i>	White-browed bush robin	CBFE	3,250-3,800
<i>Phoenicurus frontalis</i>	Blue-fronted redstart	CBFE,TDCE,TMCE,SM	2,700-4,200
<i>Phoenicurus hodgsoni</i>	Hodgson's redstart	CBFE,TDCE	2,750-3,200
<i>Chaimarrornis leucocephalus</i>	White-capped water redstart	FWWE	2,700-3,600
<i>Rhyacornis fuliginosus</i>	Plumbeous water redstart	FWWE	2,700-3,600
<i>Enicurus scouleri</i>	Little forktail	FWWE	2,750-3,600
<i>Enicurus maculatus</i>	Spotted forktail	FWWE	3,200
<i>Saxicola torquata</i>	Common stonechat	TDCE	2,800
<i>Saxicola ferrea</i>	Grey bushchat	TDCE	2,660-2,800

Species	Common Name	Ecosystem ^a	Altitude range(m)
Certhiidae			
<i>Certhia familiaris</i>	Eurasian treecreeper	CBFE,TDCE,TMCE,SM	2,450-3,700
<i>Certhia nipalensis</i>	Rusty-flanked treecreeper	TDCE	2,800
<i>Troglodytes troglodytes</i>	Winter wren	TMCE	2,900-4,200
Paridae			
<i>Parus rubidiventris</i>	Rufous-vented tit	TMCE,SM	3,500-3,900
<i>Parus ater</i>	Coal tit	CBFE,TDCE,TMCE,SM	2,700-3,900
<i>Parus dichrous</i>	Grey-crested tit	CBFE,TDCE,TMCE	2,700-3,800
<i>Parus monticolus</i>	Green-backed tit	CBFE,TDCE,TMCE,SM	2,700-3,900
Aegithalidae			
<i>Aegithalos iouschistos</i>	Rufous-fronted tit	CBFE,TDCE,TMCE	2,800-3,900
Hirundinidae			
<i>Delichon dasypus</i>	Asian house martin	TDCE	2,800-3,600
<i>Delichon nipalensis</i>	Nepal house martin	TDCE	2,800-2,800
Zosteropidae			
<i>Zosterops palpebrosus</i>	Oriental white eye	TDCE	2,700-2,800
Sylviidae			
<i>Tesia castaneocoronata</i>	Chestnut-headed tesia	CBFE,TDCE,TMCE	2,800-3,388
<i>Cettia brunnifrons</i>	Grey-sided bush warbler	CBFE,TDCE,TMCE,SM	2,700-3,900
<i>Phylloscopus affinis</i>	Tickell's leaf warbler	TDCE,CBFE,TMCE,SM	2,700-3,500
<i>Phylloscopus pulcher</i>	Buff-barred warbler	CBFE,TMCE	2,900-3,800
<i>Phylloscopus chloronotus</i>	Lemon-rumped warbler	CBFE,TDCE,TMCE,SM	2,800-3,600
<i>Phylloscopus magnirostris</i>	Large-billed warbler	TDCE	2,800
<i>Phylloscopus reguloides</i>	Blyth's leaf warbler	CBFE,TDCE,TMCE	2,550-3,200
<i>Phylloscopus maculipennis</i>	Ashy-throated warbler	CBFE,TDCE,TMCE	2,450-3,600
<i>Seicercus burkii</i>	Golden-spectacled warbler	CBFE	2,450-3,200
<i>Seicercus whistleri</i>	Whistler's warbler	TDCE,TMCE	2,800
<i>Seicercus poliogenys</i>	Grey-cheeked warbler	CBFE,TDCE,TMCE	2,450-3,600
<i>Garrulax albogularis</i>	White-throated laughing thrush	CBFE,TDCE	2,660-3,000
<i>Garrulax ocellatus</i>	Spotted laughing thrush	CBFE	2,450-3,900
<i>Garrulax affinis</i>	Black-faced laughing thrush	CBFE,TDCE,TMCE,SM	2,450-3,900
<i>Garrulax erythrocephalus</i>	Chestnut-crowned laughing thrush	CBFE	2,700-3,100
<i>Pnoepyga albiventer</i>	Scaly-breasted wren babbler	CBFE,TDCE,TMCE	2,450-3,250
<i>Pnoepyga pusilla</i>	White-throated wren babbler	TDCE	2,900
<i>Actinodura nipalensis</i>	Hoary-throated barwing	TDCE	2,800
<i>Leiothrix lutea</i>	Red-billed leiothrix	CBFE,TDCE	2,700-2,900
<i>Minla strigula</i>	Chestnut-tailed minla	CBFE,TDCE	2,700-3,600
<i>Alcippe vinipectus</i>	White-browed fulvetta	CBFE,TDCE,TMCE,SM	2,450-3,600
<i>Heterophasia capistrata</i>	Rufous sibia	CBFE	2,700-2,900
<i>Yuhina gularis</i>	Stripe-throated yuhina	CBFE,TDCE,TMCE	2,700-3,600
<i>Yuhina occipitalis</i>	Rufous-vented yuhina	TDCE	2,700-2,800
<i>Paradoxornis sp.</i>	Parrot bill	TDCE	2,800

Species	Common Name	Ecosystem ^a	Altitude range(m)
Nectariniidae			
<i>Aethopyga gouldiae</i>	Mrs Gould's sunbird	TDCE	2,450-3,000
Passeridae			
<i>Passer rutilans</i>	Russet sparrow	TDCE	2,700
<i>Passer montanus</i>	Eurasian tree sparrow	TDCE	2,800
<i>Motacilla alba</i>	White wagtail	FWWE,TDCE	2,660-2,900
<i>Anthus hodgsoni</i>	Olive-backed pipit	CBFE,TDCE,SM	2,450-3,450
<i>Prunella strophlata</i>	Rufous-breasted accentor	TDCE	2,700-4,300
Fringillidae			
<i>Carduelis spinoides</i>	Yellow-breasted greenfinch	TDCE	2,700
<i>Leucosticte nemoricola</i>	Plain mountain finch	SM	3,100-4,200
<i>Carpodacus thura</i>	White-browed rose finch	TMCE, SM	3,200-4,200
<i>Carpodacus nipalensis</i>	Dark-breasted rose finch	CBFE	3,100-3,250
<i>Loxia curvirostra</i>	Red crossbill	TDCE	2,700-2,800
<i>Pyrrhula erythrocephala</i>	Red-headed bullfinch	TMCE	3,650
<i>Pyrrhula nipalensis</i>	Brown bullfinch	TDCE, TMCE	2,800-3,600
<i>Mycerobas affinis</i>	Collared gross beak	TMCE	3,500
<i>Mycerobas carpinus</i>	White-winged gross beak	TMCE, SM	3,350-4,200

^a CBFE - cool broad-leaved forest, TDCE - temperate dry coniferous, TMCE - temperate moist coniferous, SM - scrubs and meadows, FWWE - freshwater and wetlands'