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Diversity and distribution of snakes in Trashigang Territorial Forest Division, eastern Bhutan

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Abstract: This paper presents the results of a study conducted on the species composition of serpent fauna in Trashigang Territorial Forest Division (TTFD), Bhutan. The survey was conducted from August 2019 to September 2020. The study aimed to assess the diversity, conservation threats, and distribution of both venomous and non-venomous snakes in different habitat types using time constrained visual encounter survey technique. A total of 34 species of snakes belonging to five families and 23 genera were recorded. Of the total observed species, nine were identified as venomous species. These include four species of Elapidae, four species of Viperidae, and one Colubridae. Geographically, snakes occurred throughout the landscapes, although species composition and their geographical distribution differed notably amongst various localities. We documented survival threats to local snakes where deliberate killing and road mortality were found to be the most common cause of death. The increasing trend of diversity, species richness, and relative abundance of serpent fauna was noticed as the radial distance increased from urban residential areas towards less disturbed landscapes such as rural agricultural land and natural forests indicating that the habitat mosaic plays an important role in the structure and composition of the snake community. Considering the limited information currently available on diversity and geographical distribution of the serpent fauna of the region, the present study can be considered very significant.

Keywords: Elevation, relative abundance, serpent fauna, species richness, venomous snakes.

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For **Author details** and **Author contribution** see end of this article.

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INTRODUCTION

Globally, living snakes (Reptilia: Squamata: Serpentes) as of December 2020 comprise of 3,889 recognized species belonging to 30 families distributed amongst 531 genera (Uetz et al. 2020). In southern Asia, India alone is abode to 310 species of snakes belonging to 16 families (Uetz et al. 2020), and 256 species distributed amongst 18 families and 73 genera are known to occur in China (Wang et al. 2020).

Until quite recently, in Bhutan, there has remained a long gap in the knowledge of serpent fauna, although many herpetological explorations already had gathered momentum in neighboring states of India. For example, in the year 1908, Wall (1909) examined 48 different species of snakes, which include a large part of his own collection and a few specimens he referred belonged to Darjeeling Museum and St. Joseph's College. The type locality of his collection comes from Darjeeling District, Indian state of West Bengal, which shares similar topographic complexity and climatic conditions of Himalayan region. The earliest record of serpent fauna of Bhutan that is within its political boundary, however, dates back to mid 1960s when a juvenile specimen of the King Cobra *Ophiophagus hannah* (Cantor, 1836) and Buff-striped Keelback *Amphiesma stolatum* (Linnaeus, 1758) were recorded in 1966 from Trashigang and Samdrup Jongkhar districts, respectively (Biswas 1976). After five years, a few more specimens of Bhutanese serpents were collected in an expedition by the Natural history Museum Basel in 1972, where 11 species of snakes belonging to four families were added as new country records for Bhutan (Bauer & Günther 1992). Since then, Bhutan had remained a herpetological terra incognita until 2000s, except for a few exclusive studies by Bustard (1979, 1980a,b) on the status of crocodiles in Bhutan.

Subsequent herpetological studies in Bhutan include Das & Palden (2000), Mitra (2009), Wangyal & Tenzin (2009), Wangyal (2011, 2012, 2013), and Mitra et al. (2012). These studies conducted at different times and spaces altogether resulted in up-to-date checklist of 49 species of snakes found in Bhutan. Koirala et al. (2016) reported 17 species of snakes from Jigme Dorji National Park, western Bhutan, but without any new country record. Das et al. (2016) in the Royal Manas national Park recorded 10 species of snakes, of which *Boiga siamensis* Nutaphand, 1971 was reported as new record for Bhutan. Subsequently, Wangyal & Gurung (2017) summarized all earlier herpetological reports and added new distribution information that raised the number to 67 species. The recent report of Assamese Cat Snake *Boiga quincunciata* (Wall, 1908) by Chaida et al. (2020), and addition of 15 new records by Wangyal et al. (2020) increased the snake checklist of Bhutan to 85 recognized species.

Snakes are of great conservation and ecological value (Mullin & Seigel 2009), and associated population declines has been suggested to have negative implications for the ecosystems in which snakes play significant roles (Reading et al. 2010). Despite snakes having occupied an important place in ecology and ethnozoology, venomous snakes in particular, also command medical attention owing to the propensity of their retaliatory bites on people and the ensuing medical emergencies. It is important, therefore, to be able to recognize local venomous snakes. Snakes are poorly studied in Bhutan and substantial proportion of prior studies on snakes in Bhutan exclude vital information on type locality, abundance, and classification based on their medical importance. The baseline information obtained from this current study would assist relevant authorities, conservationists, and Trashigang Territorial Forest Division (TTFD) to develop and implement conservation action plan so that species of concern and their critical habitats are protected. The aim of this study was to document the diversity, richness, distribution, and also to explore the venomous and non-venomous snakes in TTFD.

MATERIALS AND METHODS

Study site

Tashigang Territorial Forest Division (Figure 1) is located at 27.366 to 27.483 latitude and 91.366 to 92.116 longitude. It encompasses two districts (Tashigang and Trashiyantse) of eastern Bhutan and it shares its administrative border with Mongar and Pemagatshel, and towards the north and east it borders with India. Geographically the division covers an area of 2447.40km^2. The division spreads over 20 geogs (geog = sub-district) covering over 10,000 households under two districts. Majority of the people in these two districts sustain and generate their income through agricultural practices and depend heavily on natural resources.

Monsoons occur from May to September and annual rainfall ranges from 1,000mm to 2,000mm. The altitude ranges from 476–4,382m. The tropical and subtropical zone of the study area experience a hot summer with moderate rainfall, whereas in the warm temperate and cool temperate zones at higher altitudes, the climatic conditions are characterized by warm summers and cold winters.

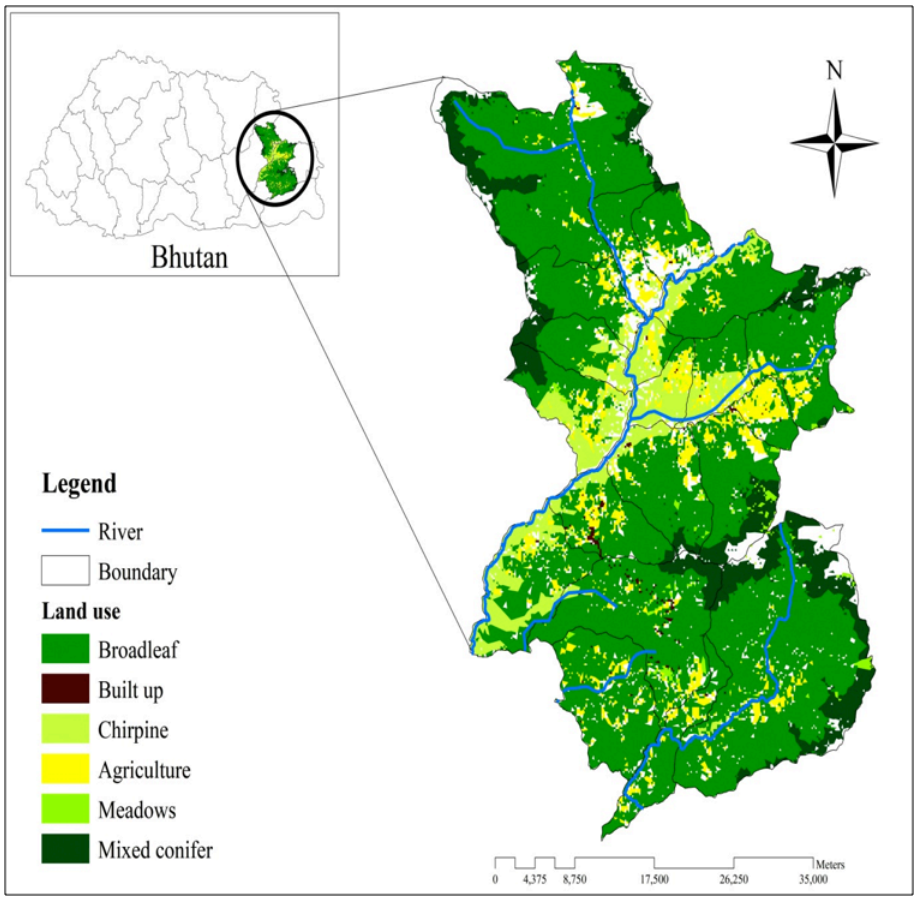

Figure 1. Land use map of study site: Trashigang Territorial Forest Division.

About 79 % and 70% of the total area of Trashigang and Trashiyangtse respectively is under forest cover (FRMD 2017). The corresponding vegetation types across the landscape are characterized by tropical and sub-tropical forests, warm and cool broadleaved forests, mixed conifer, and alpine meadows that harbour rich repositories of biodiversity. Drangmechuu River, one of the major rivers of Bhutan, with its tributaries spread across the landscape, flows through mountainous terrains towards south-west, and finally enters Mongar District. Scrub vegetation, sub-tropical forest belt, and rock outcrops are prominent geophysical features found along the rivers, which provides ideal habitats for various snake species.

Methods

Taking into account the rugged terrain with steep slopes and vast elevation range of the study area, the sites were surveyed by following time constrained visual encounter method (Heyer et al. 1994; Rödel & Ernest 2004) along with active search covering all potential habitats in TTFD from August 2019 to September 2020. Agricultural lands, open forest, grass lands, roads, and river banks were searched using the standard visual encounter surveys (VES) method with three hours' time constrained (Doan 2003) by three observers in each survey bout. Areas accessible by roads were surveyed using a motor vehicle travelling at 10 to 20 km/h. Standardized road searches were conducted at 18.00–21.00 h thrice a month, covering all potential areas with the clearest ground visibility. In total, 120 man-hours were spent to cover the entire study area searching for nocturnal species.

Locality data along with habitat parameters were collected for all individual specimens encountered, irrespective of them being alive or dead. Wherever possible, the digital photographs were taken for specimens using Nikon COOLPIX P900 (83x optical zoom) digital camera, elevation and geo- location of each individual sighted was recorded using a GPS (global positioning system) Garmin eTrex. Species were identified using standard field guide books Daniel (2002), Vasudevan & Sondhi (2010), Ahmed et al. (2009), Whitaker & Captain (2004), and Das (2002, 2015).

RESULTS

Diversity

In total, 96-day field trips or 1,152 man-hours were spent searching for snakes in TTFD, of which 120 man-hours covering a total distance of 400km were dedicated to standardized road survey at night searching for nocturnal snakes.

A total of 34 species of snakes belonging to five families and 23 genera were recorded in different habitats and around the human habitations of TTFD (Table 1). The observations include eight singletons (species with only one observation) and five doubletons (species with two observations). Recorded families were Colubridae, Elapidae, Viperidae, Pareidae, and Typhlopidae. During the present survey, three species of snakes could not be confirmed at species level, hence conferred to closely related species (e.g., *Amphiesma* sp., *Trachischium* cf. *fuscum,* and *Trimeresurus* cf. *salazar*).

A total of 217 sightings were obtained during the entire study period. The family Colubridae was found to be the most diverse in terms of species richness, generic richness and abundance. The family Colubridae accounted for 14 genera and 24 species, followed by the Elapidae (four genera, four species). The third most speciose family was Viperidae (three genera, four species), and Paeridae & Typhlopidae were found to be the least diverse families, each being represented by one genus with a single species (Figure 2).

Of the total observed species, nine were identified as venomous. These include four species of elapids, viz., King Cobra *Ophiophagus hannah* (Cantor, 1836), Monocled Cobra *Naja kaouthia* (Lesson, 1831), MacClelland's Coral Snake *Sinomicrurus macclellandi* (Reinhardt, 1844), and Greater Black Krait *Bungarus niger* (Wall, 1908), four species of viperids, viz., Jerdon's Pitviper *Protobothrops jerdonii* (Günther, 1875), Kaulbacki's Pitviper *Protobothrops kaulbacki* (Smith, 1940), Mountain Pitviper *Ovophis monticola* (Günther, 1864), and Salazar's Pitviper *Trimeresurus* cf. *salazar* Mirza, Bhosale, Phansalkar, Sawant, Gowande & Patel, 2020, one species of dangerously venomous rear-fanged colubrid, viz., Red-necked Keelback *Rhabdophis subminiatus* (Schlegel, 1837).

Relative abundance

A total of 217 sightings were recorded during the entire study period. Relative abundance data indicated that snakes belonging to Colubridae were found to be the most common (n=143, 65.89%), followed by Elapidae (n=53, 24.42%), Viperide (n=16, 7.37%), Pareidae (n=3, 1.38%), and species belonging to Typhlopidae were observed as least common (n=2, 0.92%) of the total individuals recorded (Figure 3). Colubrids were most dominant in the data because of their high richness and comprised 70.58% of total species recorded.

At species level, the abundance of snakes varied from 1–24 sightings. Analyses of species composition and relative abundance revealed that *N. kaouthia* (Image 1) was the most frequently encountered species with 24 sightings and made up 11.05% of the snake community at Trashigang Forest Division. This was followed by *O. hannah* (Image 2) with 18 sightings contributing 8.29%, *Orthriophis cantoris* (Boulenger, 1894) and *Pseudoxenodon macrops* (Blyth, 1855) (Image 3) with 14 individuals contributing 6.45% each. Other 17 commonly encountered species, altogether contributed 59.44%. Five doubletons species together accounted 4.60%, and remaining eight singletons species, viz., *Amphiesma* sp., *Hebius parallelum* (Boulenger, 1890), *Dendrelaphis proarchos* (Wall, 1909), *Dendrelaphis cyanochloris* (Wall, 1921), *Lycodon septentrionalis* (Günther,1875),

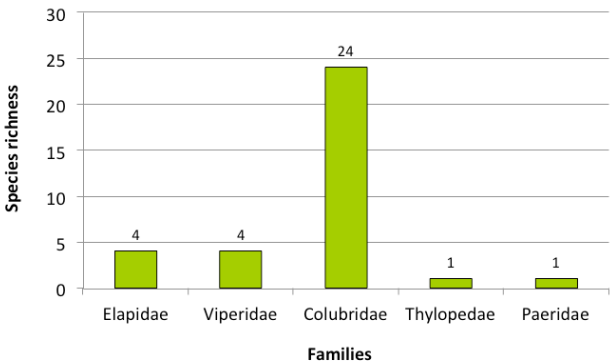

Figure 2. Species richness of snakes with respect to families recorded during the study period in TTFD.

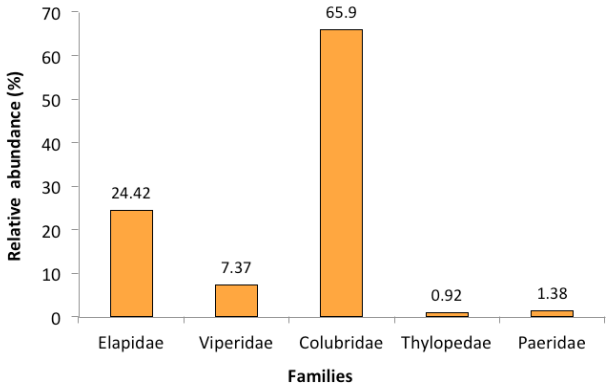

Figure 3. Relative abundance of snakes with respect to families in TTFD.

Table 1. List of snake species documented in TTFD during August 2019–September 2020.

Families	Scientific name	Common name	IUCN status
Elapidae	*Bungarus niger*	Greater Black Krait	Not assessed
	Naja kaouthia	Monocled Cobra	Least Concern
	Ophiphagus hannah	King Cobra	Vulnerable
	Sinomicrurus macclellandi	Macclellandi's Coral Snake	Not assessed
Viperidae	*Ovophis monticola*	Mountain Pit Viper	Least Concern
	Protobothrops jerdonii	Jerdon's Pit Viper	Least Concern
	Protobothrops kaulbacki	*Kaulback's* Lance-headed Pit Viper	Data Deficient
	Trimeresurus cf. *salazar*		
Colubridae	*Ahaetulla prasina*	Short-nosed Vine Snake	Least Concern
	Amphiesma sp.		
	Amphiesma platyceps	Himalayan Keelback	Not assessed
	Boiga ochracea	Tawny Cat Snake	Not assessed
	Boiga multifasciata	Many-banded Cat Snake	Data Deficient
	Coelognathus radiatus	Copper-headed Trinket	Least Concern
	Dendrelaphis proarchos	Assam Bronzeback	Not assessed
	Dendrelaphis cyanochloris	Wall's Bronzeback	Least Concern
	Hebius parallelum	Yunnan Keelback	Not assessed
	Lycodon septentrionalis	Large-toothed Wolf Snake	Not assessed
	Lycodon gammiei	Gammiei's Wolf Snake	Not assessed
	Oligodon albocinctus	White-barred Kukri Snake	Not assessed
	Oligodon taeniolatus	Streaked Kukri Snake	Least Concern
	Oreocryptophis porphyraceus	Black-banded Trinket	Not assessed
	Orthriophis cantoris	Eastern Trinket	Not assessed
	Pseudoxenodon macrops	Large-eye False Cobra	Least Concern
	Ptyas korros	Indo-Chinese Rat Snake	Not assessed
	Ptyas mocosa	Indian Rat Snake	Not assessed
	Ptyas nigromarginata	Green Rat Snake	Not assessed
	Rhadobphis himalayanus	Orange-collared Keelback	Not assessed
	Rhadobphis subminiatus	Red-necked Keelback	Least Concern
	Sibynophis collaris	Collared Black Headed Snake	Least Concern
	Trachischium tenuiceps	Oriental Worm-eating Snake	Not assessed
	Trachischium cf. *fuscum*		
Pareidae	*Pareas monticola*	Slug-eating Snake	Not assessed
Typhlopidae	*Indotyphlops braminus*	Common Blind Snake	Not assessed

Lycodon gammiei (Blanford, 1878), *Ptyas mucosa* (Linnaeus, 1758), and *Rhabdophis subminiatus* were least common and collectively contributed to only 3.68% of the total abundance.

Distribution

Geographically, snakes in study area occurred throughout the landscape up to 2,300m (Figure 4), although species composition and their geographical distribution differed notably amongst various localities (Figure 5). The study showed that snakes are sparsely distributed towards the higher elevation, however majority of them demonstrated uniform distribution pattern along the river valleys particularly below 1,800m. Among the observed snakes, species such as *O. hannah*, *S. collaris*, *N. kaouthia*, *O. albocinctus* (Image 4), *O. monticola*, *O. porphyraceus*, *A. prasina*, *P. korros* (Image 5), *Boiga ochracea* (Image 6), *O. cantoris*, and

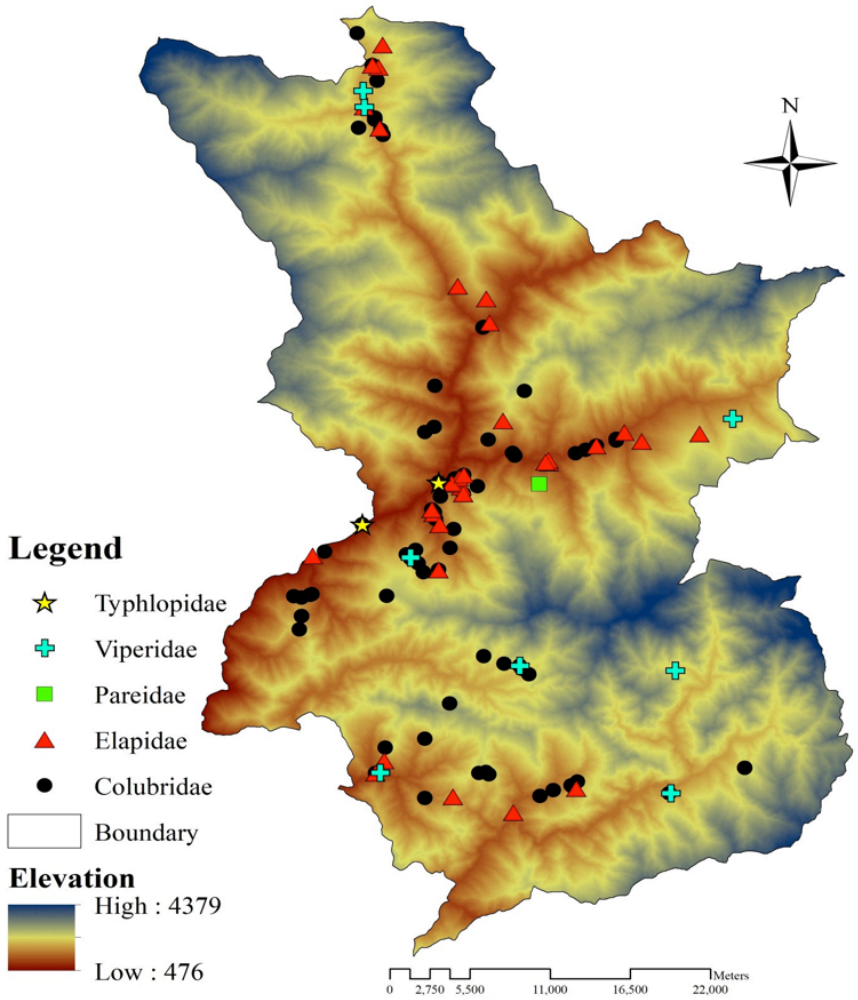

Figure 4. Distribution of snakes along the elevation gradients in Trasigang Territorial Forest Division.

T. tenuiceps were most widely sighted species across the landscape. Whereas, *P. kaulbacki*, *Trimeresurus* cf. *salazar*, *A. platyceps*, *Amphiesma* sp., *D. cyanochloris*, *L. gammiei*, *Trachischium* cf. *fuscum* (Image 7), and *P. mucosa* were recorded from a few specific localities. Range extension of these species, however, is not limited to present study locations because the type locality of observed species, shares similar climatic conditions and bio-geographic elements of eastern Himalayan locations from where most of the snakes in Bhutan have been reported.

The geo-physical features and biogeographic elements within the study area and adjoining landscapes are mainly forged by two major rivers. These rivers originate from China and flow through mountainous landscape of eastern Bhutan before entering the Indian state of Assam; Kurichu River flows through mountainous terrains of adjoining district of Mongar and meets with the Drangmechu River about 70km south-west of Trashigang. These two major rivers, with their tributaries create continuous stretch of biologically rich valleys across the landscape of eastern Bhutan. These climatically suitable warm valleys with habitat mosaic presumably support more ophidian faunal diversity and distribution than already recorded in the present study.

Threats and conservation issues

Among the total sightings (n=140 specimens; 64.51%) were recorded live and (n=77 specimens; 35.48%) were found dead. After close examination of all dead specimens, cause of deaths was estimated to be of anthropogenic origin, including road mortality and direct persecution. Virtually all kinds of snakes were killed instantly in first encounter, the most frequently killed species were *B. niger*, *N. kaouthia*, *O. hannah*, *A. prasina* (Image 8), *C. radiatus*, *P. korros*, *O. cantoris*, and *O. monticola*. We observed a few cases of human-caused death of forest dwelling species, although most of the dead snakes were recorded from rural agricultural lands and in close proximity to urban residential areas.

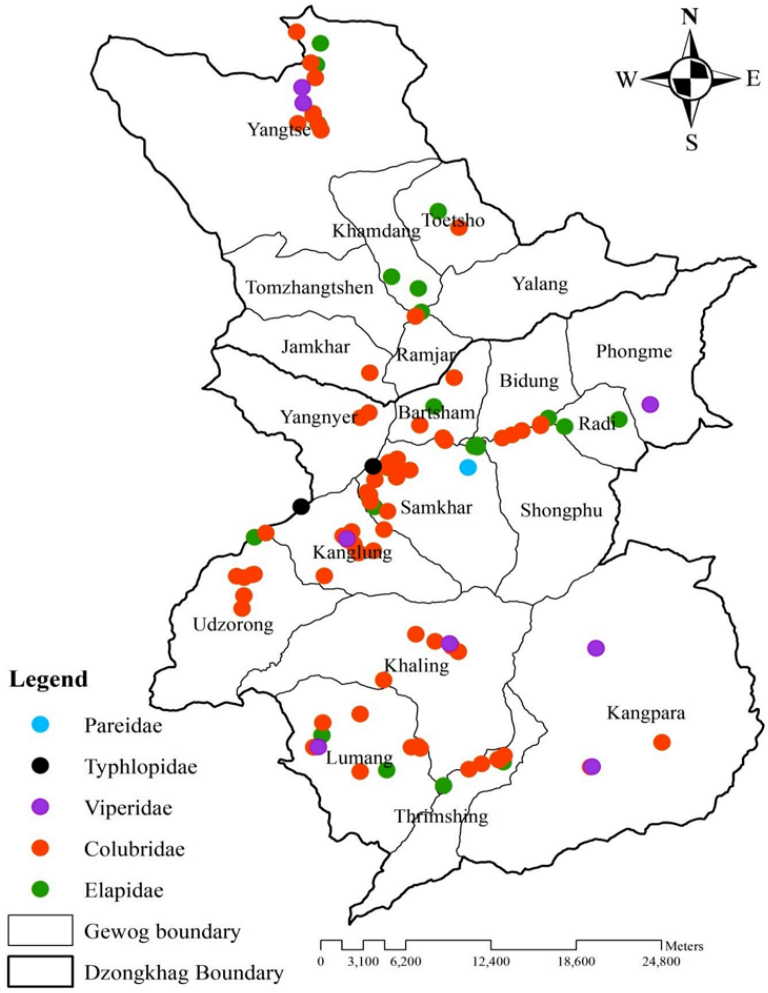

Figure 5. Spatial distribution of snakes in TTFD. Circular coloured dots indicate the geo-locations where snakes were sighted.

Species such as *O. hannah*, *P. korros*, *C. radiatus*, and *O. cantoris* were found to be most vulnerable to human killing as 33–60 % of total sightings encountered were recorded dead, wherein the cause of mortality was identified to be direct human persecution.

DISCUSSION

Straddling the two major Indo-Malayan and Palaearctic biogeographic realms, Bhutan, a part of eastern Himalaya, is one of the biologically richest areas on earth and encompasses an incredible wealth of biodiversity. TTFD is one of the important conservation areas in eastern Himalaya which encompasses a wide range of habitats from sub-tropical to alpine ecosystems of Bhutan. Considering the limited information currently available on diversity, distribution and natural history of the serpent fauna of the region, the present study can be considered very significant.

As per IUCN Red List Category, 10 species belong to LC (Least Concern) category, two species DD (Data Deficient), one species VU (Vulnerable), 18 are not assessed, and three species could not be identified at species level thus its status is excluded. This indicates that for about 59% of the species there are not sufficient data available for evaluating their conservation status in this region.

Serpent fauna of Bhutan as of April 2020 was represented by 70 recognized species (Chaida et al.2020), and new records of 15 additional species by Wangyal et al. (2020) elevate the number of snakes species in Bhutan to 85. The number of snake species found in this research represented 40.47% of all snake species found in Bhutan. Of the eight families and 33 genera of snake fauna found in the country, five families and 23 genera were recorded in TTFD. This implies that TTFD is an important repository for serpent fauna conservation.

Three species of venomous snakes, viz., *O. hannah*,

Table 2. Locality records of Snakes in Trashigang Forest Division. Localities data indicate geogs (geog = sub-district) within Trashigang Forest Division where species were sighted.

Species name	Localities	Latitude (°N)	Longitude (°E)	Altitude (m)
Ophiophugus hannah	Thrimshing	27.111	91.590	650–2,057
	Barsam	27.373	91.587	
	Radi	27.363	91.723	
	Samkhar	27.325	91.558	
	Kanglung	27.283	91.522	
	Lumang	27.138	91.495	
	Yangte	27.612	91.499	
Naja kaouthia	Samkhar	27.331	91.552	670–1,471
	Shongphu	27.359	91.644	
	Toetsho	27.481	91.605	
	Khamdang	27.436	91.574	
	Thrimshing	27.122	91.609	
	Udzorong	27.258	91.451	
Bugarus niger	Lumang	27.147	91.501	700–1,400
	Shongphu	27.358	91.683	
	Khamdang	27.455	91.576	
	Samkhar	27.330	91.556	
Sinomicrurus macclellandi	Lumang	27.122	91.548	1,300–1,400
	Thrimshing	27.127	91.634	
Ovophis monticola	Khaling	27.209	91.596	1,700–2,300
	Yangtse	27.595	91.493	
	Udzorong	27.235	91.444	
	Phogmey	27.443	91.798	
	Kanglung	27.282	91.521	
Protobothrops kaulbacki	Kangpara	27.123	91.699	1,642
Protobothrops jerdonii	Khaling	27.205	91.703	1,800–2,000
	Yangtse	27.634	91.490	
Trimeresurus cf. *salazar*	Lumang	27.138	91.496	995
Ahaetulla prasina	Samkhar	27.335	91.555	700–1,300
	Shongphu	27.360	91.665	
	Khamdang	27.436	91.574	
	Udzorong	27.258	91.451	
Amphiesma platyceps	Yangtse	27.565	91.506	1,805
Amphiesma sp.	Yangtse	27.570	91.489	1,800
Boiga ochracea	Jamkhar	27.397	91.540	800–1,834
	Yangyeer	27.366	91.533	
	Samkhar	27.332	91.541	
	Lumang	27.138	91.495	
	Yangtse	27.603	91.493	
Boiga multifasciata	Yangtse	27.612	91.499	1,400–1,821
	Kanglung	27.274	91.541	
Coelognathus radiatus	Samkhar	27.333	91.556	800–1,300
	Udzorong	27.258	91.451	
	Shongphu	27.360	91.665	
Dendrelaphis proarchus	Samkhar	27.337	91.559	1,000–1,200
	Udzorong	27.244	91.445	
Dendrelaphis cyanochloris	Bartsham	27.361	91.576	1,400
Hebius parallelum	Yangtse	27.633	91.489	1,890

Species name	Localities	Latitude (°N)	Longitude (°E)	Altitude (m)
Lycodon septentrionalis	Kanglung	27.273	91.537	1,700–1,900
	Yangtse	27.585	91.494	
Lycodon gammiei	Khaling	27.585	91.494	2,100
Oligodon albocinctus	Kangpara	27.207	91.597	700–1,821
	Kanglung	27.139	91.751	
	Khamgang	27.273	91.537	
	Samkhar	27.436	91.574	
	Yangtse	27.351	91.593	
Oligodon taeniolatus	Khamdang	27.576	91.501	750–1,800
	Yangtse	27.436	91.574	
	Yangtse	27.612	91.499	
Oreocryptophis porphyraceus	Kanglung	27.612	91.499	1,200–1,800
	Thrishing	27.282	91.522	
	Udzorong	27.131	91.635	
	Yangtse	27.259	91.453	
	Lumang	27.576	91.501	
Orthriophis cantoris	Lumang	27.138	91.576	1,300–2,205
	Phogmey	27.138	91.576	
	Samkhar	27.443	91.798	
	Udzorong	27.329	91.568	
Pseudoxenodon macrops	Khaling	27.244	91.445	1,800–2,100
	Kanglung	27.209	91.596	
	Lumang	27.272	91.530	
Ptyas korros	Udzorong	27.138	91.572	750–1,800
	Samkhar	27.258	91.451	
	Kanglung	27.314	91.537	
	Shongphu	27.283	91.522	
Ptyas mocosa	Udzorong	27.359	91.665	2,000
Ptyas nigromarginata	Kanglung	27.235	91.444	1,400–2,300
	Yangtse	27.287	91.525	
	Khaling	27.577	91.501	
	Lumang	27.211	91.585	
Rhadobphis himalayanus	Lumang	27.121	91.529	1,500–1,700
	Kanglung	27.126	91.618	
Rhadobphis subminiatus	Thrimshing	27.278	91.527	1,600
Sibynophis collaris	Thrimshing	27.129	91.630	650–1,870
	Samkhar	27.128	91.631	
	Kanglung	27.312	91.538	
	Yangtse	27.283	91.522	
Trachischium tenuiceps	Khaling	27.602	91.503	900–2,300
	Shongphu	27.209	91.596	
	Yangtse	27.356	91.651	
	Kanglung	27.576	91.501	
Trachischium cf. *fuscum*	Lumang	27.283	91.522	1,800–2,300
Pareas monticola	Samkhar	27.131	91.567	1,200–1,400
	Lumang	27.331	91.611	
Indotyphlops braminus	Samkhar	27.100	91.466	700–900

Image 1. *Naja kaouthia*

Image 2. *Ophiphagus hannah*

Image 3. *Pseudoxenodon macrops*

Image 4. *Oligodon albocinctus*

Image 5. *Ptyas korros*

Image 6. *Boiga ochracea*

O. monticola (Image 9), and *N. kaouthia*, were previously reported by Biswas (1976) and Mitra (2009) from Trashigang District, which are also recorded in present study. Nonetheless, our records of five more species of venomous snakes, viz., *P. jerdonii* (Image 10), *P. kaulbacki* (Image 11), *Trimeresurus* cf. *salazar* (Image 12), B. niger (Image 13), and *S. macclellandi* (Image 14) are recorded for the first time from TTFD. This population was previously called as *T. albolabris* till the species *Trimeresurus salazar* got described (Mirza et al. 2020). Discovery of higher diversity of venomous snakes which is more than (52%) of total venomous snakes found in Bhutan warrants better medical attention to this problem.

Our records of 10 additional species, viz., *Pareas monticola* (Cantor, 1839) (Image 15) *Trachischium* cf. *fuscum* (Blyth, 1854), *P. kaulbacki, D. cyanochloris*, *D. proarchos* (see Vogel & van Rooijen 2007, 2011), (Image 16), *P. mucosa*, *R. subminiatus*, *L. gammiei, Indotyphlops braminus* (Daudin, 1803), and *A. platyceps* are the first records of these species for TTFD. Although Mitra (2009) mentioned two species of Kukri snakes viz., *Oligodon juglandifer* (Wall, 1909) and *Oligodon cyclurus* (Cantor, 1939), and *Boiga multifasciata* (Blyth, 1861) (Image 17) from present area but we did not detect former two species in this present study but later were found around 78km away from the previously recorded locality. Our records of *Trachischium tenuiceps* (Blyth, 1854) (Image 18), *L. septentrionalis*, *Oreocryptophis porphyraceus* (Cantor, 1839) (Image 19), and *Boiga ochracea* (Theobald, 1868) extends the distribution range of these species by 74km from the previously recorded locality, Kanglung, Trashigang District (Mitra 2009) to Yangtse, Trashigangtse District in the north. The occurrence of *L. gammiei* and D. cyanochloris in Bhutan (Wangyal, 2014) was reported without locality data. We, however, confirmed the presence of these two species from TTFD based on dead specimens recorded from Khaling and Bartsham, respectively. We could not find Pope's Pitviper Trimeresurus popeiorum (Smith, 1937) in TTFD. Our record of *T. popeiorum* (Image 20) from adjoining locality (Pemagatshel District), however, suggests that the species probably also occurs in TTFD.

Information on habitats used by snakes can be an important tool for conservation efforts (Seigel & Mullin 2009). Our study revealed that snakes in Bhutan use a wide variety of habitats which forest habitat, grasslands, rural agricultural farm land, and urban residential areas. Modifications in each landscape showed different levels of disturbance. The study showed that as the distance from residential area increased, the abundance, richness, and diversity of snakes also increased. This result concurred with similar phenomenon reported by Janiawati et al. (2015). The monotonic increase in richness and diversity of snakes with the increase in redial distance from urban residential area could be due to majority of snakes responding to disturbance levels, availability of resources, vegetation cover, varied habitats, and increased space. A more varied habitat can accommodate more species because more resources can be utilized (Janiawati et al. 2015). Reptiles use vegetation cover to protect themselves from environmental changes or predators (Botejue & Wattavidanage 2012). Highly modified landscapes contain few remnant vegetation (McIntyre & Hobbs 1999), thus provide limited resources. In contrary, increased abundance of some of the Elapid species, viz., *N. kaouthia* and *B. niger* in urban residential area could be due to availability of preferred microhabitat and their ability to withstand high degree of environmental changes resulted from landscape modifications.

Overall, these data suggest that species richness and diversity in of TTFD is relatively high, and that small geographic localities can sustain a large number and diverse group of snakes species. We suggest more comprehensive surveys and intensive research, particularly in ecologically vulnerable areas containing high biodiversity to facilitate snake monitoring efforts, assess threats to snakes, foresee potential threats to vulnerable snake species (e.g., *O. hannah*), better understand the distribution and ecology of medically significant species of snakes, rare and data-deficient species, and to ultimately formulate effective conservation strategy for conservation of serpent fauna of eastern Bhutan.

Human-caused mortality of snakes was the most severe among the threats that we observed. Although there have been no records of live snakes or their parts being traded in Bhutan, there are sufficient evidences that they are killed indiscriminately because of fear of snakebite. People in Bhutan have very little knowledge about snakes; as a result, many harmless species get victimized mainly due to belief that all snakes are venomous. Road mortality and direct human persecution are primary threats to snakes in the region. Frequent forest fires may also contribute to overall snake mortality in TTFD. The recorded evidences of high mortality (35.48%) within short span of time due to human persecution highlights how precarious human-dominated landscapes are for snakes.

Historically, due to the rugged terrains, cold climatic condition, and largely inaccessible landscape,

Image 7. *Trachischium* cf. *fuscum*

Image 8. *Ahaetulla prasina*

Image 9. *Ovophis monticola*

Image 10. *Protobothrops jerdonii*

Image 11. *Protobothrops kaulbackii*

Image 12. *Trimeresurus* cf. *salazar*

biological diversity of Eastern Himalaya remained largely unexplored. Tremendous effort, however, had been made in recent decades and *frequent addition of new records in the eastern Himalayas demonstrates a serious need for further exploration in the region*. Our results are based on surveys constrained by time, and presumably do not represent actual diversity as there are still some potential areas which remained unexplored. Majority of conservation efforts in Bhutan are focused on conservation of biodiversity in protected areas, however, many areas outside protected areas are biologically rich and thus offers great opportunities to conserve at least a portion of its diversity. We hope that our findings may serve as a foundation for further studies in this and other regions of Bhutan. Furthermore, we also emphasize on more holistic, education-focused conservation strategy combined with ecological research to address the snake-human negative interaction in the region.

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Image 13. *Bungarus niger*

Image 14. *Sinomicrurus macclellandi*

Image 15. *Pareas monticola*

Image 16. *Dendrelaphis proarchos*

Image 17. *Boiga multifasciata*

Image 18. *Trachischium tenuiceps*

Image 19. *Oreocryptophis porphyraceus*

Image 20.*Trimeresurus popeiorum*

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