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Cover: Dorsal view of Mantis Shrimp *Cloridina ichneumon* (Fabricius, 1798) & *Gonodactylus demanii* (Henderson, 1893). © Fisheries Research Station, Junagadh Agricultural University, Sikka.



Occurrence patterns of herpetofauna in different habitat types of western Terai Arc Landscape, India

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Abstract: The Terai Arc Landscape (TAL) is an important region of biodiversity in India. Situated in the foothills of the Himalaya, it is spread across India and Nepal. We describe the herpetofauna of the western part of TAL encompassing Ramnagar Forest Division, which falls in Uttarakhand state of India. We primarily used visual encounter survey method for sampling. A total of 47 species of herpetofauna belonging to three orders, 17 families and 36 genera were recorded from 10 habitat types (6 terrestrial and 4 aquatic). Highest species richness (n=32) was recorded from the human settlement and least (n=4) species richness was reported from pond habitat. In this paper, the diversity of amphibians and reptiles in each habitat type is discussed.

Keywords: Amphibians, biodiversity, ecoregion, habitat type, Himalaya, Ramnagar Forest Division, reptiles, Uttarakhand, visual encounter survey.

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INTRODUCTION

Terai Arc Landscape (TAL) is situated in the foothills of the Himalaya spread across India and Nepal, and is listed among 200 important ecoregions of the globe (Olson & Dinerstein 1998, 2002). The total area of TAL is 49,500 km² out of which 30,000 km² falls in India and 19,500 km² in Nepal (Semwal 2005). TAL harbors various habitat types such as Sal forest, Sal mixed forest, mixed forest, grassland, riverbed, swamp forest, moist riverine forest, dry riverine forest, scrubland, rivers, barren land, and wetlands (Jhala et al. 2015). Ramnagar Forest Division (RFD) is situated in the western part of Indian TAL with an area of approx. 593 km². RFD is a region with rich biodiversity, and shares its western boundary with Corbett Tiger Reserve (CTR). RFD serves as a corridor in TAL from CTR to Nandhaur Wildlife Sanctuary (both in Uttarakhand), which is contiguous to Shuklaphanta National Park of Nepal (Poudyal & Chaudhary 2019).

Habitat is the place where a species survives and thrives (Odum 1971), while 'habitat type' refers to the kind of vegetation of an area (Hall et al. 1997). Intervention by humans may modify habitat types such that these areas differ from original vegetation types.

Amphibians and reptiles are collectively called herpetofauna, and they can be found in various habitat types and are adapted for various modes of living (Bowo et al. 2018). Although amphibians and reptiles provide various ecological services (Aguilar 2013) most of the time herpetofauna are not given proper consideration in decision making for forest management (de Maynadier & Hunter 1995). Some species of herpetofauna are habitat generalist and utilize various habitats, while some are habitat specialist species which reside in a specific habitat only. Habitat loss in general is destructive to the whole biodiversity but is the most severe threat for herpetofauna (Gibbons et al. 2000). Specialist species which are restricted to less number of habitats are more prone to extinction than generalist species living in multiple habitat types (Segura et al. 2007).

Although this part of western TAL is a well-known destination for wildlife enthusiasts and the information about other vertebrates such as tigers, elephants, and avifauna are available, the status of herpetofauna is still unknown. Hence this study was undertaken with the objectives to determine the diversity of herpetofauna species and their distribution in various habitat types of RFD.

METHODS

Study area

Ramnagar Forest Division (RFD) falls in the Nainital district of Uttarakhand state, on the latitudes 29.552–20.503 °N and longitudes 79.079–79.544 °E (Image 1) with an altitudinal range of 300–700 m. Annual temperature range is 5–40 °C, and is the lowest in January and the highest in June. The average annual rainfall is around 2,000 mm, which occurs mainly during monsoons with some showers during the winters. In this study, sampling was done in 10 different habitat types, out of which six were terrestrial and four were aquatic. These habitat types were selected on the basis of vegetation, ecology and terrain, to avoid resampling in similar habitat type in different location (Table 1).

All 10 habitat types vary in locations and vegetation (Table 1, Image 1). The terrestrial habitat types surveyed in the study were boulder region (BR), grassland (GL), scrubland (SL), mixed forest (MF), Sal forest (SF), and human settlement (HS) (Image 2). The aquatic habitat types surveyed were pond (PN), monsoon river (MR), perennial river (PR), and marshland (ML) (Image 3).

Sampling methods

Sampling was primarily carried out by area constrained visual encounter survey (VES) method (Crump & Scott 1994; Sutherland 2006). A total of 118 surveys were done in all 10 habitat types starting from September 2016 to February 2018. Totally, 12 surveys per habitat type were done by two or three persons. A total of 720 man-hours were spent on the sampling. The locations of all habitat types were at least 10 km away from each other. Photographs were taken for identification and no specimen was collected during the study. Data was also gathered by using other methods such as opportunistic observation (Behangana 2014), road kill survey (Langenet et al. 2009), night searches (Bennett 1999), and rescue and release program. Species identification was made in the field, with the help of field guides, identification keys (Daniel 2002; Vasudevan & Sondhi 2010) and some recent taxonomic works (Lajmi et al. 2016; Bisht et al. 2021; Ganesh et al. 2021; Gowande et al. 2021; Amarasinghe et al. 2022; Bandara et al. 2022).

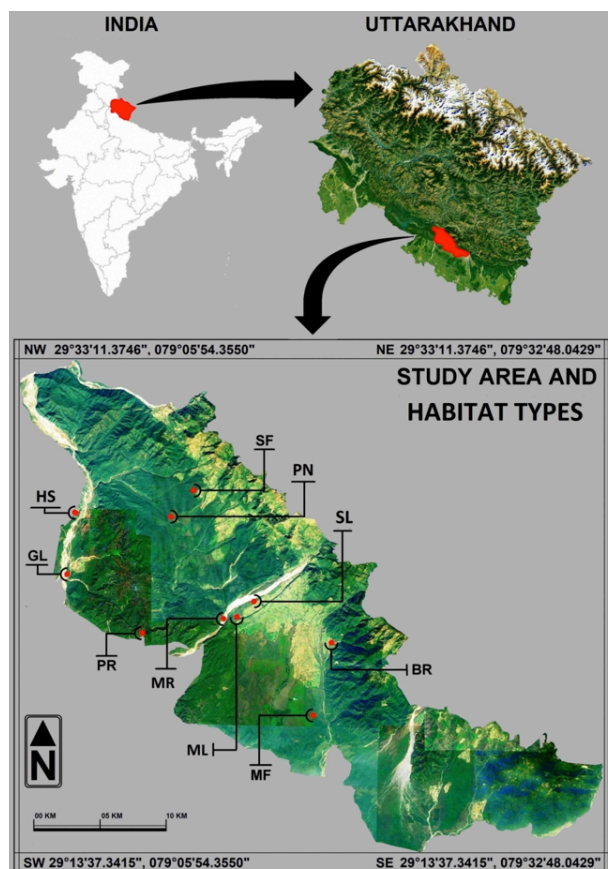


Image 1. Map showing the locations of different habitat types in Ramnagar Forest Division.

RESULTS

A total of 47 species were recorded from RFD. We recorded 10 anurans, 13 lizards, 20 snakes and four species of turtles (Table 2). The occurrence patterns of herpetofauna species in different habitat types of RFD is presented in Table 3.

TERRESTRIAL HABITAT TYPES

Boulder Region (BR) (Image 2A)—A total of six species of herpetofauna out of 47 (13%) were encountered in BR. This includes five species of lizards and one species of snake – *Amphiesma stolatum*. No species of Testudinata or anurans were found.

Grassland (GL) (Image 2B)—A total of seven species out of 47 species of herpetofauna were encountered in this habitat type. Presence of four species of anurans, two species of lizards—*Calotes vultuosus* & *Eutropis carinata*, one species of snake – *Amphiesma stolatum*, was reported, but no species of Testudinata was found. In total, around 15% of species of herpetofauna were encountered in GL.

Scrubland (SL) (Image 2C)—A total of seven species of herpetofauna, were recorded from this habitat type. Four species of anurans and three species of lizards were found, but no species of snake or Testudinata were encountered. Around 15% of species of herpetofauna were encountered in SL.

Mixed forest (MF) (Image 2D)—A total of nine species of herpetofauna species were reported from this habitat type. One anuran – *Sphearotheca breviceps*, four lizards, two snakes – *Trimerurus septentrionalis* & *Sibynophis sagittarius*, and two turtles – *Melanochelys trijuga* & *Melanochelys tricarinata* were recorded; 19% of the total species were encountered in MF.

Sal forest (SF) (Image 2E)—A total of 12 species of herpetofauna were encountered in SF. One species of anuran – *Sphearotheca breviceps*, three species of lizards, seven species of snakes, and one species of tortoise—*Indotestudo elongata* were recorded; 25% of species of herpetofauna were encountered in SF.

Human settlement (HS) (Image 2F)—A total of 32 species out of 47 (68.08%) were reported from HS. Among these, seven species of anurans out of total 10 species, eight species of lizards out of total 13 species, 15 species of snakes out of total 20 species, and two species of Testudinata out of a total four, were recorded in HS. Two species of anurans – *Duttaphrynus melanostictus* & *Duttaphrynus stomaticus*, and two species of lizards – *Hemidactylus flaviviridis* & *Hemidactylus kushmorensis*, and eight species of snakes were encountered only in HS (Table 2).

AQUATIC HABITAT TYPES

Pond (PN) (Image 3A)—Four species of herpetofauna were found in this habitat type. Three species of anurans and one species of lizard – *Varanus bengalensis* were observed, but no species of snakes or Testudinata were encountered. Only 9% of total species of herpetofauna were encountered in PN.

Monsoon river (MR) (Image 3B)—A total of six species of herpetofauna, were recorded from MR. Four species of anurans, one species of lizard – *Calotes vultuosus*, one species of snake – *Fowlea piscator*, were found, but no species of Testudinata was encountered; 13% of species of herpetofauna were encountered in MR.

Perennial river (PR) (Image 3C)—A total of nine species of the total herpetofauna were reported from this habitat type. From this habitat type three species of anurans, four species of lizards, and two species of Testudinata – *Indotestudo elongata* & *Lissemys punctata*, were recorded. However, no species of

Table 1. Description of the habitat types in Ramnagar Forest Division.

Habitat types	Geographic location	Description of habitat type
Boulder Region (BR)	29.367N, 79.339E	This site is a rocky terrain occupied with huge boulders and very less vegetation. Vegetation consist of <i>Senegalia catechu</i> trees, shrubs of <i>Lantana camara</i> and <i>Adhatoda vasica</i> .
Grassland (GL)	29.411N, 79.135E	This site is located nearby Kosi river and surrounded by scrubland. Major grass species on the site are <i>Cynodon dactylon</i> , <i>Sorghum halepense</i> , and <i>Eleusine indica</i> .
Scrubland (SL)	29.394N, 79.279E	It is <i>Lantana camara</i> dominated bushland, along with other shrub species like <i>Ziziphus mauritiana</i> , <i>Murraya koenigii</i> and <i>Acacia himalayana</i> .
Mixed forest (MF)	29.3185N, 79.325	This is a forest with two-layered canopy and variety of plant species. Among these primary canopy consist of trees like, <i>Treva nudiflora</i> , <i>Syzygium cumini</i> , <i>Mallotus philippensis</i> , and <i>Ficus benghalensis</i> . While the secondary canopy consists of shrubs such as <i>Adhatoda vasica</i> , <i>Glycosmis pentaphylla</i> , and <i>Murraya koenigii</i> .
Sal forest (SF)	29.468N, 79.233E	This site is a Sal- <i>Shorea robusta</i> dominated area, along with Sal associated tree species like <i>Mallotus philippensis</i> , <i>Lagerstroemia parviflora</i> and <i>Clerodendrum viscosum</i> .
Human settlement (HS)	29.452N, 79.143E	This site is located in Dhikuli village. Surveys were done around houses, drains, lawns, gardens, and courtyards.
Pond (PN)	29.450N, 79.215E	A man-made waterhole near <i>Tectona grandis</i> forest, which remains filled with water throughout the year.
Monsoon river (MR)	29.380N, 79.254	This site is a monsoon river with a broad river bed occupied by sand and pebbles, remains dry beyond monsoons and floods during the rainy season.
Perennial river (PR)	29.372N, 79.193E	This site is on an ever-flowing river, with the narrow river bed. River bed is occupied by sand, rocks and boulders with scanty vegetation on the banks.
Marshland (ML)	29.384N, 79.266E	A marshy area which remains water-logged for around eight months of the year. Major vegetation found are <i>Bacopa monnieri</i> , <i>Amaranthus viridis</i> , <i>Senna tora</i> and <i>Equisetum diffusum</i> .

snake was found; 19% of species of herpetofauna were encountered in PR.

Marshland (ML) (Image 3D)—Seven species of herpetofauna were recorded. Five species of anurans, one lizard –*Calotes vultuosus*, and one species of snake –*Ptyas mucosus*, were recorded, but no Testudinata was observed; 15% of species were encountered in ML.

DISCUSSION

The maximum number of species of herpetofauna was recorded from the human settlement. Of 47 species of herpetofauna, 32 were encountered in human settlements while only four were observed in the pond. The higher number of species in human settlement might be due to the availability of a wider variety of microhabitats such as drains, lawns, leaf litter, kitchen gardens, and front & backyards. Night bulbs present around human settlement might also attract more insects, which could lure amphibians and reptiles for easy prey. In southern India, a similar result was observed in the Kalpakkam area (12.551°N & 80.168°E) where reptilian diversity was found high in human-dominated regions (Ramesh et al. 2013). Herpetofauna diversity was also found higher in human habitation in Sri Lanka (Karunarathna et al. 2008). In another study in Sri Lanka, the home gardens were found to be the second most diverse habitat for herpetofauna, after forest habitat, in a tea plantation ecosystem (Kottawa-Arachchi et al. 2014).

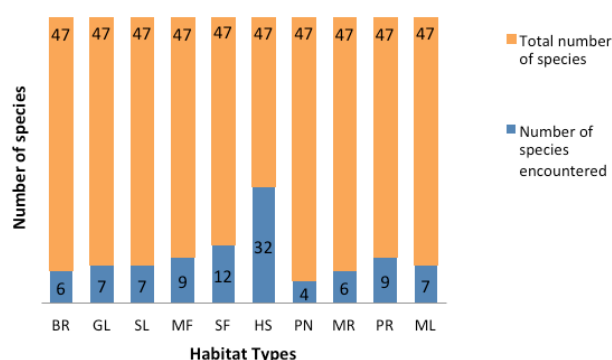


Figure 1. Habitat types in Ramnagar Forest Division with number of species encountered in them. BR—Boulder region | GL—Grassland | SL—Scrubland | MF—Mixed forest | SF—Sal forest | HS—Human settlement | PN—Pond | MR—Monsoon river | PR—Perennial river | ML—Marshland.

In RFD no anuran or testudine species were encountered in the Boulder region. Karunarathna et al. (2008) also found fewer herpetofauna species in the boulder habitat type, and considered it as a xeric habitat for herpetofauna. In Kalpakkam area of southern India, the highest number of herpetofauna species were reported from scrubland (Ramesh et al. 2013). However, we did not find the same pattern of herpetofauna diversity in this habitat type in RFD. In contrast, we found only 15% species diversity in scrubland, with comparison to human settlement which had the highest diversity (68.08%) among all 10 habitat types studied.

Sal forest which is the dominant habitat type in the

Table 2. Occurrence patternsof herpetofauna in the various habitat types of Ramnagar Forest Division.

	Species	Common names	Terrestrial habitat types	Aquatic habitat types
Anurans				
1.	<i>Euphyllotis cyanophlyctis</i>	Indian Skipper Frog	GL, PR, SL	ML, PN, MR, PR
2.	<i>Minervarya</i> sp.	Paddy Field Frog	HS, GL, PR, SL	ML, PN, MR, PR
3.	<i>Hoplobatrachus tigerinus</i>	Indian Bull Frog	HS, GL, PR, SL	ML, PN, MR, PR
4.	<i>Hoplobatrachus crassus</i>	Jerdon's Bull Frog		ML, MR
5.	<i>Sphaerotheca breviceps</i>	Indian Burrowing Frog	HS, SF, MF, SL	ML
6.	<i>Duttaphrynus melanostictus</i>	Common Indian Toad	HS	
7.	<i>Duttaphrynus stomaticus</i>	Marbled Toad	HS	
8.	<i>Uperodon systoma</i>	Indian Balloon Frog	GL	
9.	<i>Microhyla nilphamariensis</i>	Nilphamari Narrow-mouthed Frog	HS	
10.	<i>Polypedates maculatus</i>	Indian Tree Frog	HS	
Lizards				
11.	<i>Varanus bengalensis</i>	Indian Monitor Lizard	HS, SF, BR, SL	PN
12.	<i>Calotes vultuosus</i>	Bengal Garden Lizard	HS, GL, PR, BR, SL	MR, PR
13.	<i>Laudakia tuberculata</i>	Himalayan Rock Lizard	HS	PR
14.	<i>Asymblepharus himalayanus</i>	Himalayan Rock Skink		PR
15.	<i>Eutropis carinata</i>	Keeled Grass Skink	HS, GL, SF, PR, MF, BR, SL	PR
16.	<i>Eutropis</i> cf. <i>macularia</i>	Bronze Grass Skink	MF	
17.	<i>Eutropis trivittata</i>	Striped Grass Skink	MF	
18.	<i>Riopa punctata</i>	Dotted Grass Skink	HS, SF, MF	
19.	<i>Riopa albopunctata</i>	White-spotted Supple Skink	BR	
20.	<i>Cyrtodactylus fasciolatus</i>	Bent Toed Gecko	HS	
21.	<i>Hemidactylus kushmorensis</i>	Kusmore's House Gecko	HS	
22.	<i>Hemidactylus flaviviridis</i>	Northern House Gecko	HS	
23.	<i>Hemidactylus leschenaultii</i>	Leschenault's House Gecko	BR	
Snakes				
24.	<i>Ophiophagus hannah</i>	King Cobra	HS, SF	
25.	<i>Naja naja</i>	Indian Cobra	HS	
26.	<i>Bungarus caeruleus</i>	Common Krait	HS	
27.	<i>Daboia russelii</i>	Russell's Viper	HS	
28.	<i>Trimeresurus septentrionalis</i>	Himalayan White-lipped Pit Viper	MF	
29.	<i>Python bivittatus</i>	Burmese Python	HS, SF	
30.	<i>Dendrolephis tristis</i>	Bronze Back Tree Snake	HS, SF	
31.	<i>Ptyas mucosa</i>	Indian Rat Snake	HS	ML
32.	<i>Oligodon russelii</i>	Russell's Kukri	HS	
33.	<i>Boiga trigonata</i>	Common Cat Snake	HS, SF	
34.	<i>Boiga forsteni</i>	Forsten's Cat Snake	SF	
35.	<i>Coelognathus helena</i>	Common Trinket Snake	HS, SF	
36.	<i>Coelognathus radiata</i>	Copper-headed Trinket	SF	
37.	<i>Lycodon aulicus</i>	Common Wolf Snake	HS	
38.	<i>Lycodon jara</i>	Twin-spotted Wolf Snake	HS	
39.	<i>Sibynophis sagittarius</i>	Contor's Black-headed Snake	MF	
40.	<i>Fowlea piscator</i>	Checkered Keelback		MR
41.	<i>Amphiesma stolatum</i>	Striped Keelback	HS, GL, BR	
42.	<i>Indotyphlops braminus</i>	Brahminy Blind Snake	HS	
43.	<i>Argyrophis diardii</i>	Indochinese Blind Snake	HS	
Testudines				
44.	<i>Melanochelys tricarinata</i>	Tricarinate Hill Turtle	MF	
45.	<i>Melanochelys trijuga</i>	Indian Black Turtle	MF	
46.	<i>Lissemys punctata</i>	Indian Flap Shell Turtle	HS,	PR
47.	<i>Indotestudo elongata</i>	Elongate Tortoise	HS, SF	PR

BR—Boulder region | GL—Grassland | SL—Scrubland | MF—Mixed forest | SF—Sal forest | HS—Human settlement | PN—Pond | MR—Monsoon river | PR—Perennial river | ML—Marshland.



Image 2. Terrestrial habitat types in Ramnagar Forest Division: A—Boulder region | B—Grassland | C—Scrubland | D—Mixed forest | E—Sal forest | F—Human settlement. © Gajendra Singh Mehra.

Table 3. Presence of herpetofauna species in various habitat types of Ramnagar Forest Division.

Habitat types	Species of anurans	Species of lizards	Species of snakes	Species of Testudinata
BR	0	5	1	0
GL	4	2	1	0
SL	4	3	0	0
MF	1	4	2	2
SF	1	3	7	1
HS	7	8	15	2
PN	3	1	0	0
MR	4	1	1	0
PR	3	4	0	2
ML	5	1	1	0

BR—Boulder region | GL—Grassland | SL—Scrubland | MF—Mixed forest | SF—Sal forest | HS—Human settlement | PN—Pond | MR—Monsoon river | PR—Perennial river | ML—Marshland.

TAL region, was found to be the second most diverse region for herpetofauna diversity in this study. The least herpetofauna diversity was found in the pond habitat, possibly because it is a stagnant water body, hence only species preferring lentic water might live here.

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Image 3. Aquatic habitat types in Ramnagar Forest Division: A—Pond | B—Monsoon river | C—Perennial river | D—Marshland. © Gajendra Singh Mehra.



Image 4. A—*Duttaphrynus stomaticus* | B—*Minervarya* sp. | C—*Calotes vultuosus* | D—*Laudakia tuberculata* | E—*Amphiesma stolatum* | F—*Bungarus caeruleus* | G—*Indotestudo elongata* | H—*Lissemys punctata*. © Gajendra Singh Mehra.

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