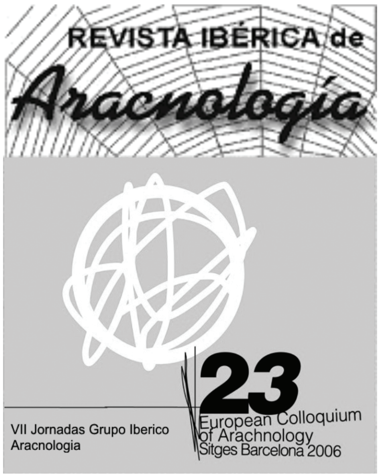

ARTÍCULO:

Spider Assemblage in the Heterogeneous Landscape of Terai Conservation Area, India

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ARTÍCULO:

Spider Assemblage in the Heterogeneous Landscape of Terai Conservation Area, India

V. P. Uniyal & Upamanyu Hore

Abstract

The Terai is a complex ecosystem including Sal forests, tall grassland and swamps maintained by periodic flooding, being one of the most diverse ecosystems of India. The knowledge on diversity and distribution of spiders in this ecosystem is sparse as compared to other Indian regions. A survey was carried out to explore spider species diversity in various habitats based on prominent vegetation and land cover map mainly of the tropical semi-evergreen forest, grasslands and riverine area. Through stratified random sampling, spiders were collected from various microhabitats within respective habitats. 20 transects of 50 m (for pitfall trapping) and 10 transects of 50 m (for sweep netting) were laid per habitat in order to obtain comprehensive representation of different spider species. All adult specimens were identified up to species level and sorted to morphospecies when species level identification was not possible. A total of 73 species belonging to 36 genera of 17 families were recorded during the entire study period from the land cover and vegetation types sampled. Species diversity of the riverine area was found to be maximum (Shannon – Pielou evenness index: 0.77, Simpson reciprocal index: 8.38) although the estimated species richness (according to Chao1, Chao2 and Jackknife 2) gave same results for both riverine and tropical semi ever-green habitats, with 31 species each. The most dominant species in the grassland and riparian habitat types were *Oxyopes* spp, while in the evergreen forest was *Hippasa* spp. The Family composition of the spider assemblage showed a higher occurrence of Oxyopidae and Lycosidae in the riparian and grassland habitats and a high occurrence of Araneidae in the tropical semi-evergreen habitat patch. The riparian site had substantially higher species diversity and more uncommon species, perhaps because a wide variety of microhabitats and a more dynamic habitat structure due to the frequent effects of flooding.

Key words: spider assemblage, Terai ecosystem, sampling effort, habitat complexity, functional group.

Composicion araneológica en un paisaje hetereogéneo de la zona protejida deTerai, India

Resumen

El Terai es un complejo ecosistema que incluye bosques de Sal (*Shorea robusta* Gaertn.), praderas de herbáceas de porte alto y pantanos que se mantienen por inundaciones periódicas, lo que hace que sea uno de los ecosistemas más diversos de India. El conocimiento de la diversidad y la distribución de las arañas en este ecosistema es escaso comparado con otras regiones de India. Se llevo a cabo un censo para explorar la diversidad de especies de arañas en varios hábitats basándose en mapas de vegetación y cobertura principalmente del bosque tropical semiperenne, de las praderas y de las zonas de ribera. Mediante un muestreo estratificado al azar, se recolectaron arañas de varios microhábitats de cadauno de los tres hábitats. Con el objetivo de obtener datos objetivos de la representatividad de las diferentes especies de arañas. En cada hábitat se ubicaron 20 transectos (50 m) con trampas de caída y en otros 10 (50 m) se utilizó la manga entomológica. Todos los especímenes adultos fueron identificados a nivel de especie o etiquetados como morfoespecies cuando no fue posible su identificación a nivel específico. En este estudio se recolectaron un total 73 especies que pertenecientes a 36 géneros y 17 familias incluyendo todo el período de muestreo y los diferentes tipos de hábitat. La máxima diversidad se encontró en las zonas de ribera (índice de equidad de Shannon–Pielou: 0.77, Índice recíproco de Simpson: 8.38), aunque la estima de riqueza de especies (según Chao1, Chao2 y Jackknife 2) arrojó los mismos resultados para el hábitat de ribera y el hábitat de bosque tropical semiperenne, con 31 especies encontradas en cada uno. La especie de mayor dominancia en las praderas y el hábitat de ribera fue *Oxyopes* spp, mientras que en el bosque tropical semiperenne fue *Hippasa* spp. La composición de especies de arañas mostró una mayor abundancia de Oxyopidae y Lycosidae en los hábitats de ribera y de praderas, con una alta abundancia de Araneidae en la mancha de bosque tropical semiperenne. El bosque de ribera presenta mayor diversidad de especies y más especies raras, quizás debido a una mayor variedad de microhábitats y una estructura del hábitat más dinámica como consecuencia de los frecuentes efectos de las inundaciones.

Palabras clave: composición de arañas, ecosistema Terai, esfuerzo de muestreo, complejidad del hábitat, grupo funcional.

Introduction

The Terai ecosystem, which the Terai Conservation Area (TCA) represents, is one of the most threatened ecosystems of India. The region is a vast flat alluvial plain lying between the Himalayan foothills and the Gangetic Plains. It forms an integral part of the Terai-Bhabhar biogeographic sub-division of the Upper Gangetic biotic province and the Gangetic plains biogeographic zone (Rodgers and Panwar, 1988).

Once, the Terai forests constituted a lush belt of green vegetation in the extensive tract of alluvial Gangetic floodplains. The forest is mainly moist deciduous, dominated by the most valuable Sal (Shorea robusta) forests of India. A significant attribute of the sal forest ecosystem is the interspersed swamps, wet tall grasslands, and dry grasslands or 'phanta' variously dominated by *Saccharum spontaneum*, *Saccharum narenga*, *Sclerostachya fusca*, *Imperata cylindrica*, or *Vetiveria zizaniodes*. The high water table, annual flooding and the synergistic influence of traditionally practiced annual burning of grasslands are primary factors defining the characteristics of this tract. The resulting complex woodland - grassland – wetland ecosystem harbours a variety of floral and faunal life. The TCA is the last and best remnant of the Terai ecosystem remaining in north India outside Nepal and Assam. Spiders are found in a great variety of biotopes (Coddington and Levi, 1991; Foelix, 1996), play key ecological roles as predators (Riechert and Lockley, 1984; Riechert and Bishop, 1990; Wise, 1993; Nyffeler et al., 1994), and have been recognized as relatively sedentary organisms (Pinkus-Rendón, León-Cortés and Ibarra-Núñez, 2006).

Therefore, spiders comprise a suitable group for assessing changes in diversity patterns as regards habitat modification.

This paper is the first publication of spider fauna of Terai ecosystem so no prior information regarding the study was mentioned. In the present study, the diversity and richness of spider assemblage in different habitats of Terai Conservation Area (Terai ecosystem) were documented. Using this information, habitats with high conservation priority were identified.

Materials and Methods

Study Area

The study was conducted in alluvial flood plain of TCA lying between the Himalayan foothills and the Gangetic Plains in the state of Uttar Pradesh, India (Latitude N 27º49' and 28º43' and Longitude E 81º01' and 81º18') (Figure 1) from August 2005 to January 2006.

Three different forest types mainly tropical semi evergreen, riparian and grassland were identified and delineated (using FRAGSTATS* ArcView 3.02) (McGarigal, Cushman, Neel, and Ene, 2002) based on physiognomic aspects of vegetation, as well as on the recognition of the landscape elements and descriptions were detailed in the following.

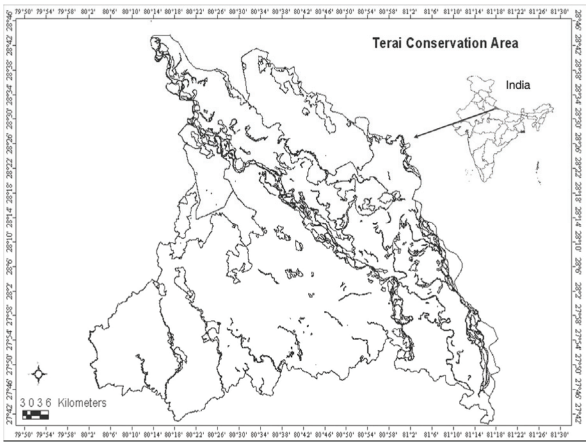

Fig. 1 Map of Terai Conservation Area. (Source Kumar et al. 2002)

Tropical Semi evergreen Forest- This forest type occurred in more or less permanently wet/moist soils consist of fine clay and are rich in humus. It prominently occurred along the perennial streams (nalahs) and near swamps (taals). Prominent tree species viz., *Syzygium cumini*, *Ficus racemosa* and *Mallotus philippensis* occurred in this forest. Other associated tree species were *Trewia nudiflora*, *Schleichera oleosa* and *Syzygium cerasoides*. *Ardisia solanacea* and *Murraya koenigii* were prominent shrubs.

Riparian Forest- This forest type was found in swampy depressions along streams, which remain under water continuously for a long period during the rains or where deep black heavy waterlogged soils occurred. Previous forest plans relevant to TCA have described two subtypes viz., *Barringtonia* swamp forests and *Syzygium cumini* dominated forests. In the present study, both these types have been grouped together and designated as the Tropical Seasonal Swamp forest. Soil aeration is usually poor and the soils are rich in humus. *Syzygium cumini* was the main constituent tree species in such forests. *Barringtonia acutangula* dominated patches occurred along the Ull and Katna rivers in SKFD. *Trewia nudiflora*, *Terminalia alata*, *Lagerstroemia parviflora* and *Ficus racemosa* were the prominent co-associates. *Clerodendrum viscosum*, *Glycosmis pentaphylla* and *Murraya koenigii* were the prominent shrubs. *Corchorus aestuans*, *Dioscorea belophylla* and *Ageratum conyzoides* were the important herbs in this type of forest. *Syzygium cumini* formed a dense crop with long clean boles.

Grassland- Grasslands occurred in low-lying areas/depressions, which were water logged or marshy in nature. Such areas had alluvial soils, mostly sandy with clayey patches. Depressions mark the old river channels. Frost was common especially in the low-lying areas. These areas got annually burnt. The prominent species occurring in the higher area were *Bombax ceiba, Haldina cordifolia*, *Butea monosperma*, *Dalbergia sissoo*, *Albizia lebbeck*, *Scheleichera oleosa* and *Syzygium cumini*. In the low-lying areas, prominent species were *Bombax ceiba*, *Ficus racemosa* and *Syzygium cumini*.

Prominent grasses were Saccharum spontaneum, *Arundo donax*, *Phragmites karka*, *Themeda arundinacea*, *Sclerostachya fusca* and *Saccharum narenga*. These grasslands have interspersed swamps.

METHODS

A total of 90 transects (50 m in length each) were sampled across the 3 habitat types. Spiders were collected along 50 m transect length of 30 transects per habitat. Six pitfall traps were laid along a single transect line with the spacing interval of 10m each. Transects were selected randomly within stratified stratum of classified forest types to ensure the independent sampling protocol and minimizing spatial autocorrelation. Sampling was carried out each month and concentrated from August 2005 to January 2006.

One pitfall trap was set (pitfall traps consisted of cylindrical plastic bottles with 10 cm diameter and 11 cm depth; (Churchill and Arthur, 1999) every 50 m along each transect, for a total of six traps per transect. Traps were filled with preservative liquid (69 % water, 30% ethyl acetate and 1% detergent). After 7 days, specimens were removed from traps, which allowed us to maintain spider specimens in good conditions before taking them for laboratory processing

Since the limitations of the pitfall method is that, the number of individuals trapped is affected by environmental, weather and species-specific factors (Mitchell, 1963; Krasnov and Shenbrot, 1996; Parmenter et al., 1989; Ahearn, 1971) and specific to free- and burrow-living ground wanderers spider assemblage, a time-constrained sweep-netting collection method intended to capture maximum diversity, including plant wanderers and web building spider assemblage was employed.

All adult and sub adult (if possible) spiders were identified at the species level based on the specialized keys of Tikader (1980, 1982), Gajbe (2003), Biswas and Biswas (2004) and with taxonomic revisions according to the check-list of Siliwal, Molur and Biswas (2005). Those specimens that were not being identified at the species level were classified as morphospecies. Abundance of each species and morphospecies for each sampling method and for each habitat type were also recorded.

ANALYSES

SPECIES DIVERSITY .- To determine alpha diversity values (local diversity) for each habitat, the species richness were recorded and/or calculated, and two commonly used diversity indices, the evenness Shannon - Pielou index (J'=H'/ln S) and Reciprocal Simpson index (1/D) (using Biodiv software, Baev and Penev, 1996). These indices were chosen because they reflect different aspects of diversity as Shannon is sensitive to rare species, whereas Simpson is more sensitive to changes in abundance of common species. In this case, Simpson indicates dominance, so if the index value increases, diversity decreases (Magurran, 1988). Diversity indices were calculated for each habitat types.

SPECIES RICHNESS- To evaluate what proportions of the actual species richness were captured, Estimate S 6.01 Software (Colwell, 2000) was used to compute non-parametric estimators: Chao1 (Chao, 1984), Chao2 (Chao, 1987), Jacknife 1 and Jacknife 2 (Burnham and Overton, 1978, 1979; Heltsche and Forrester, 1983). Chao1 estimator is generally agreed to be used for inventory completeness values (Sorensen et al., 2002; Scharff et al., 2003: Cardoso et al., 2004), estimate percentage completeness for capturing of species as a ratio between observed and estimated richness.

The completeness of the species was also assessed using species accumulation curves calculated using Estimate S 6.01 statistical software (Colwell, 2000). First the accumulation curve was calculated using the raw data in the sequence in which the samples were collected. The average species accumulation curve was then calculated using the same software by iteratively resampling the raw data 999 times and averaging the results.

HABITAT SIMILARITY AND SPECIES COMPOSITION- In order to show potential habitat and spider community relationships across the landscape and association patterns of habitat types we performed a cluster analysis based on Bray-Curtis distances and used a flexible beta linkage by considering species composition.

FAMILY COMPOSITION AND FUNCTIONAL GROUPS- Functional groups include species that potentially compete for jointly exploited limited resources (Polis and McCormick, 1986). Spiders live in a well-defined environment with limitations set by both physical conditions and biological factors (Foelix, 1996). They can be grouped into specific functional groups based on available information on their habitat preferences and predatory methods (Bultman et al., 1982). Describing the spider diversity in terms of these groups allows for greater insight into how habitat differences may be reflected in life-history strategies. For the present study three main functional groups were recognized, namely Ground wanderers, Plant Wanderers and Web builders, with further subdivisions based on microhabitat and general behaviour (Dippenaar-Schoeman, Leroy, De Jager and Van den Berg, 1999; Table1).

Results

SPECIES DIVERSITY

A total of 90 samples were obtained, 1260 adult spiders were collected representing 17 families, 36 genera and 73 species. Of all the species collected, 15.6 % were identified to species level, the remainder 84.4 % were identified to genus and could not be identified beyond genus. Several immature specimens were difficult to identify hence were excluded from analyses and remaining others were identified up to morphospecies level. Relatively high species richness and Shannon – Pielou evenness diversity value was recorded in Tropical semi evergreen but a high dominance value was detected in Grassland (Figure 2).

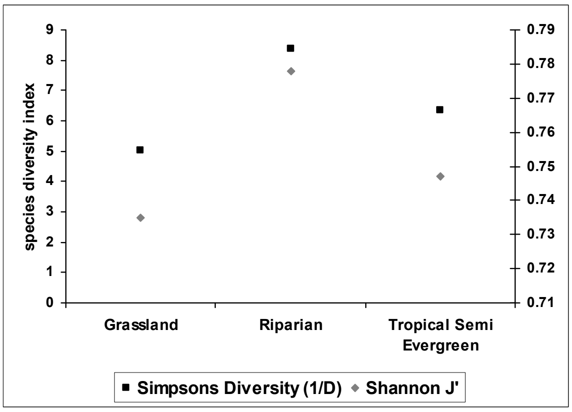

Fig. 2 Diversity measure for three habitat types of the study area

Thus, relatively tropical semi evergreen contained an important proportion (57.5%) of spider diversity, with respect to the total number of species recorded. In contrast, diversity indices and species richness were low in Grassland and Reciprocal Simpson's index values indicated that this managed habitats of grassland contained poor diversity of spiders compared to other habitat types.

Species richness

Considering all habitat types, for an equal sampling effort completeness of the inventory is 100% for the grassland habitat, which suggests that the maximum richness was captured with minimal effort, reflected by the presence of only one singleton species (Table 2).

The average species accumulation curve for the entire sample (Figure 3) shows a typical initial rapid increase in species with increasing number of samples, which gradually sloped down with more samples until there were few new species recorded with further sampling.

This shows that the number of species continued to increase more for tropical evergreen compared to riparian and grassland habitats for the same sampling effort and this corroborates that more sampling effort is necessary in complex habitats in order to obtain an entire representation of species.

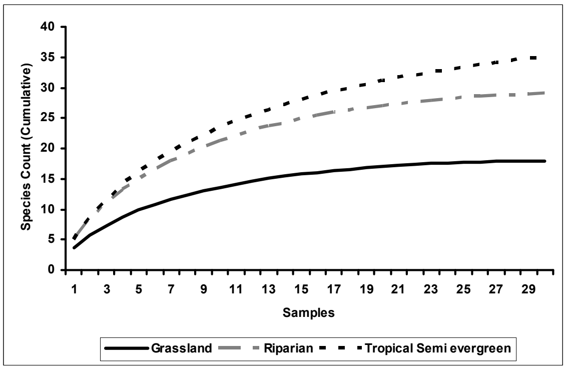

Fig. 3 Species accumulation curve for three habitat types of Terai Conservation Area

Habitat similarity and species composition

Results of the Bray- Curtis analysis using flexible beta distance showed (Figure 4) Riparian and Grassland had 100 % similarities in species composition while Tropical Semi evergreen forming separate and distinct cluster group indicates different patterns of species composition.

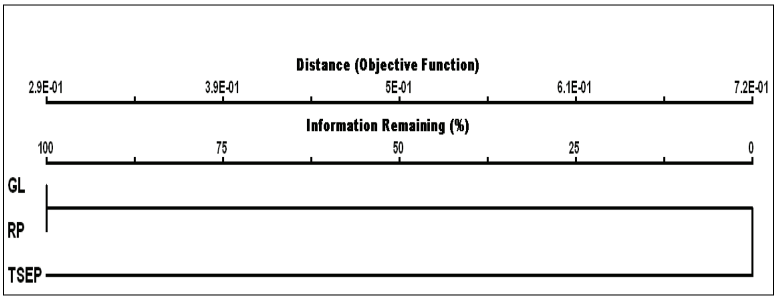

Fig. 4 Spider assemblage relationships according to species composition (presence – absence) for each habitat type. (Codes: RP = Riparian, TSEP = Tropical Semi evergreen, GL = Grassland)

Family Composition and Functional Groups

The family composition of the spider fauna for the study areas is shown in Figure 5.

Family composition of spider assemblage showed higher occurrence of Oxyopidae and Lycosidae to the riparian and grassland habitat where as high occurrence of Araneidae in the Tropical Semi-evergreen habitat patch. In Tropical Semi Evergreen habitat, Araneidae, Lycosidae and Linyphiidae accounted for the largest proportion of spider species, representing approximately 62.86 of all species, while in the Grassland habitat single Lycosidae family represents 55.56% of all spider species. Riparian areas also showed a high occurrence of both Lycosidae and Araneidae. The families Pholcidae, Zodariidae, Uloboridae, Dictynidae and Amaurobiidae were exclusively found in Tropical Semi evergreen habitat and Thomisidae, Sparassidae and Salticidae were exclusively captured in the Riparian habitat.

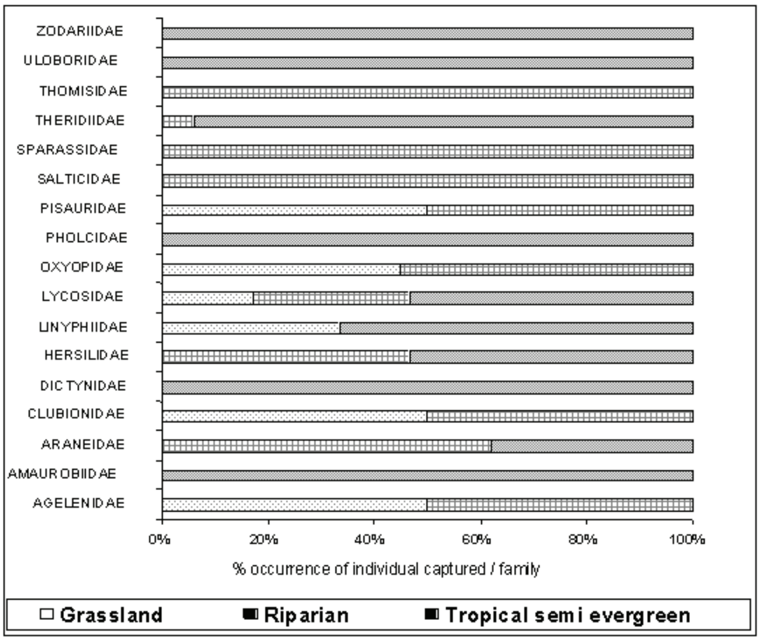

Figure 5 Family composition of spider assemblage in the Terai Conservation Area (TCA)

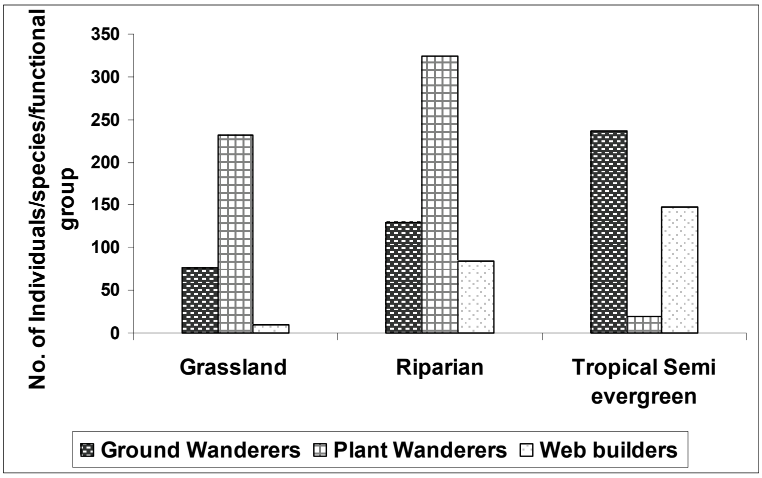

Figure 6 Functional Group Composition of spider assemblage in the Terai Conservation Area (TCA)

Overall, the number of wandering spiders (Figure 6) was greater than that of web builders.

Plant wanderers were the most abundant and widely distributed. They comprised 45.71% of all spiders sampled (total individuals = 1 260). Ground wanderers comprised 35.08% and web builders, 19.21%. Functional group analysis revealed that riparian habitat have harbored wide spectrum of space more equally for the three functional group as well, while Plant wanderers and Ground Wanderers more predominantly associated to the Grassland and Tropical Semi evergreen habitats respectively.

Discussion

The results show that habitats exhibiting high structural complexity, such as tropical semi ever green and riparian, recorded the highest diversity. However, for an equal sampling effort, a greater species richness and number of individuals were trapped in high complexity habitats, possibly reflecting resource availability (Gotelli and Colwell, 2001). The heterogeneity of the vegetation structure in high complexity habitats may support more potential niches for a functionally diverse suite of fauna, and is likely to support a greater range of food webs than less complex habitats (Kloper and MacArthur, 1960). Most of the singleton species recorded in the Tropical Semi evergreen, contributed high complementarity and the number of singletons species in low complexity habitats could have been either transient individuals passing between high complexity habitats or species with low population levels (Novotny and Basset, 2000).

An interesting finding emerging from this study is how family composition and functional groups of the spider assemblage were related to habitat types. Though the Tropical Semi evergreen habitat represented highly diverse communities, the association of different functional groups to the riparian habitat suggests that this habitat is less specific and holds a greater range of niches. A wide variety of microhabitats and more dynamic habitat structure of riparian sites might be due to the effects of frequent flooding.

Results clearly suggest a low occurrence of web builders in the grassland habitat, which could be probably due to the low vegetation complexity, high exposure to climatic variation, and factors associated with fire management practices. Plant wanderers, which were found to be comparatively abundant in the riparian habitat, may benefit from the relatively high plant diversity and the moisture regime.

In spite of the fact that a very special set of habitats were studied and for a very limited period of time, endemicity of species and unique assemblages found in these habitat types reflects the mosaic and heterogeneous nature of the Terai ecosystem. Although the habitat association of spider species often reflect their foraging habits, further examination of the consistency of their response to habitat types at multiple scales will offer an indication of the general pattern.

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Table 1
Functional group classification of spiders.

Functional groups	**Functional group explanation**
Free- and burrow-living ground Wanderers	Free-living spiders running on the soil surface when active including spiders living permanently or semi-permanently in burrows
Plant wanderers	Spiders foraging exclusively on the plant surface
Web builders	Spiders constructing webs including funnel-webs, orb-webs, retreat-webs,sheet-webs and space-webs

Table 2
Summary result for species abundance, species richness and estimated species richness for three different habitat types in Terai Conservation Area.

	Grassland	**Riparian**	**Tropical Semi evergreen**
Samples	30	30	30
Abundance	318	538	404
Observed species richness	18	31	35
Singletons	1	2	9
Doubletons	5	7	7
Chao 1	18	39.29	39.5
SD (±)	0.08	0.68	3.68
Chao 2	18	39.56	39.35
SD (±)	0.08	1.01	3.75
% completeness	100	79	89