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Autor(en): **Hore, Upamanyu / Uniyal, Virendra Prasad**

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Influence of space, vegetation structure, and microclimate on spider (Araneae) species composition in Terai Conservation Area, India

UPAMANYU HORE & VIRENDRA PRASAD UNIYAL*
Wildlife Institute of India, P. O. Box # 18, Chandrabani, Dehradun–248001, Uttarakhand, India
*Corresponding author: uniyalvp@wii.gov.in

Abstract

We investigated the relative contribution of vegetation structure and microclimate to species composition of spider assemblage in Terai Conservation Area. In particular, we examined the similarity of spider communities among 20 sites in relation to vegetation structure, microclimate and geographic location. Mantel's randomization tests were conducted to detect significant association, after partialling out the effect of geographic distance between sites. Species composition of spider assemblages was found significantly correlated with vegetation structure after partialling out the effect of microclimate. Based on our results and previous studies, we hypothesise that the structural heterogeneity of vegetation affects both the suitability of microsites for web-location and the distribution of prey that are similarly responsive to microhabitat variables.

INTRODUCTION

It has often been assumed that invertebrate communities are primarily dependent upon the vegetation species composition and structure (Curry 1987) and that management practice for the vegetation should therefore be of equal benefit to the invertebrate communities (Panzer & Schwartz 1998). Spiders are of such group those extremely sensitive to small changes in habitat structure including vegetation complexity, litter depth and microclimate characteristics (Uetz 1991). Their high relative abundance, ease of collection, and diversity in habitat preferences and foraging strategies allows for effective monitoring of site differences. The species composition of spider communities in managed habitats is known to be affected by numerous biotic and abiotic factors. In many cases these factors can be related to obvious proximal habitat components like vegetation and microclimate (Entling et al. 2007). Microclimate could be considered the 'pulse' of an ecosystem because of the direct and indirect effects of microclimate on most ecosystems processes, and vice versa. For example, temperature functions as an indicator or final product of ecological processes associated with energy budget and its dynamics, such as received solar radiation, evapotranspiration, soil heat flux, and convection. Vegetation structure plays a critical role in shaping the microclimate through the change of energy and water balance across a landscape (Xu & Qi 2000). Whilst environmental conditions may be spatially autocorrelated, the distribution of individual species of invertebrates may also be spatially autocorrelated. This may arise from the spiders being correlated with some underlying biotic or abiotic factor which is spatially autocorrelated, or from the behaviour of the spiders, particularly dispersal activity. Understanding the structure of plant and spider communities in relation to their environment is likely to be complicated by the presence of spatial autocorrelation. Non-spatial statistical techniques, both univariate and multivariate, are often inappropriate for the analysis of spatially autocorrelated data, because the requirement for independence between observations is violated (Cliff & Ord 1981). When such tests are used on autocorrelated data there is increased risk of making a 'Type I Error' (Legendre & Troussellier 1988); i.e. identification of spurious correlations between variables. Errors due to spatial autocorrelation can be avoided by explicitly incorporating space into analyses. One way of investigating these relationships is to treat spatial location as an additional environmental variable, and analyse the data using one of a range of spatially articulated analyses; e.g. Mantel tests, spatial correlograms (Legendre & Fortin 1989). These analyses can provide powerful tools for the exploration of interactions between species and their environments. Keeping this in view, the present study is conducted in Terai Conservation Area to quantify the importance of spatial variation in factors as vegetation structure or microclimate on the spider communities of Terai.

STUDY AREA

Terai Conservation Area (TCA), which represents the *Terai* landscape, is one of the most diverse ecosystems of India. This landscape is characterized by a complex of sal forest, tall grassland, and swamps maintained by periodic flooding. Once, the *Terai* forests constituted a lush belt of green vegetation in the extensive tract of alluvial Gangetic floodplains which are today reduced to smaller fragments lying within a mosaic of private agricultural lands, human habitation and land encroachment for homesteads, replacing the rich natural vegetation (Kumar et al. 2002). TCA covered an area of 7,896.6 km^2 between the Himalayan foothills and the Gangetic plains in the state of Uttar Pradesh, India (27°49′–28°43′N, 81°01′–81°18′E). The study was conducted in TCA from March 2006 to August 2007. The terrain is on the flat flood plains of the Suheli, Mohana, and Sharda rivers. The climate of TCA is tropical monsoon type. The TCA experiences three distinct seasons: winter (November–March), summer (April–June), and monsoon (July–October). We sampled spiders in 20 localities across ten vegetation types (Fig. 1), that contained contiguous and relatively homogeneous areas of each vegetation community.

METHODS

A total of 200 transects (50 m in length each) were sampled across the 10 vegetation types. Spiders were collected along 50 m x 10 m transects, with 20 transects per vegetation type. These transects were treated as our basic sampling units, hereafter sites. Transects were placed randomly within stratified vegetation types. Spiders were sampled along the transects using pitfall traps and semi-quantitative sampling. Pitfall sampling was operated for 64 weeks and other semiquantitative sampling performed on 64 occasions (once every week) at the same sampling sites.

Pitfall traps consisted of cylindrical plastic bottles of 10 cm diameter and 11 cm depth. Six pitfall traps were laid along each transect line at an interval of 10 m each. Traps were filled with preservative (69% water, 30% ethyl acetate, and 1% detergent). After seven days, specimens were removed from traps, which allowed us to maintain spider specimens in good condition before laboratory processing and identification.

Since the limitations of this method are that the number of individuals trapped is affected by environmental, weather and species-specific factors (Krasnov & Shenbrot 1996), we have employed other time constrained semi-quantitative collection (aerial hand collection, ground hand collection, vegetation beating, sweep netting, lit-

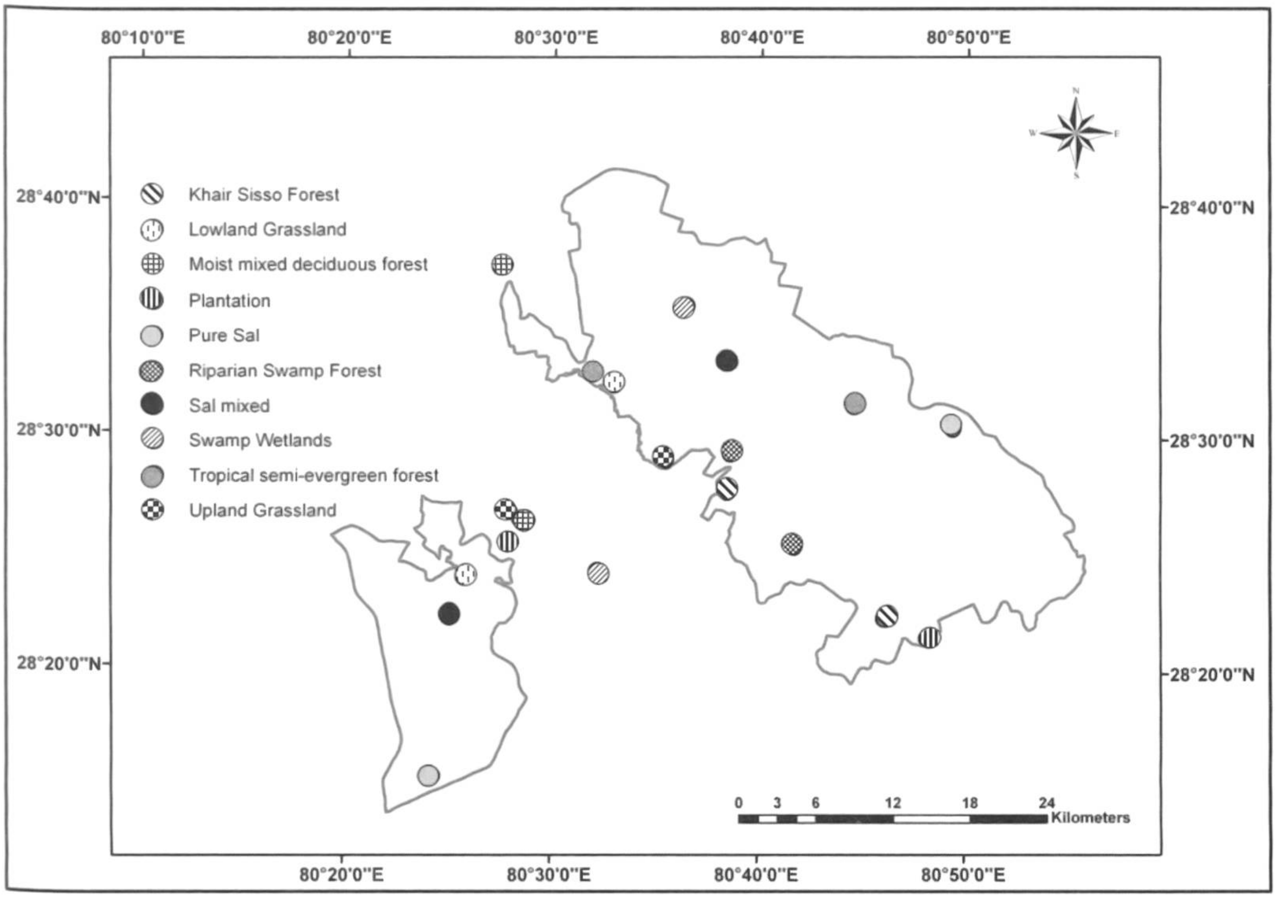

Fig. 1. Study Area – Sampling Locations.

ter collection) methods after Coddington et al. (1996) to maximize capture. Spiders were identified to family and species using existing identification keys wherever possible (Pocock 1900, Tikader & Malhotra 1980, Tikader 1982, 1987).

Habitat heterogeneity: To determine the heterogeneity of each vegetation type where spider sampling was carried out, the following set of variables were measured and categorized as follows:

(a) Microclimate variables: Six random quadrats of 1 m x 1 m were used at each sampling point (within 5 m of each pitfall trap laid along the 50 m line transect) to calculate several physio-chemical features such as soil pH, soil moisture, soil temperature, ambient humidity and ambient temperature.

(b) Vegetation structure: The cover of the different vegetation layers (trees, shrubs, herbs, and grasses) was estimated irrespective of the constituent plant species, as a measure of the structural composition of the habitat. Ground vegetation height (shrub height and abundance) was measured. At each sampling point (point where pitfall traps were set) we measured canopy cover of the sampling point using a spherical densitometer. As eighth structural habitat parameter, we measured the depth of the litter layer. Litter depth (cm) was estimated using a ruler on four random points around the sampling point.

ANALYSIS

We investigated correlations between the dissimilarity matrices representing the spider composition (using Bray-Curtis distance) with matrices representing habitat variables (using Euclidean distance) and microclimate variables (using Euclidean distance), using

Contrasted matrices		Mantel r	P
species composition	geographic distance	0.355	<0.001
(a) Partial out geographic distance			
species composition	microclimate	0.407	<0.001
	vegetation structure	0.419	<0.001
microclimate	vegetation structure	0.241	0.044
(b) Partial out geographic distance & vegetation structure			
microclimate	species composition	0.139	0.912
(c) Partial out geographic distance & microclimate			
vegetation structure	species composition	0.488	<0.001

Table 1. Association between spider species composition, microclimate, vegetation structure, and distance between sites, as shown by Mantel test across habitats in Terai Conservation Area.

partial Mantel tests (Smouse et al. 1986) to test congruence between the matrices. Partial Mantel tests were used to examine the relationship between two dissimilarity matrices while eliminating the linear effect of a third matrix. Significance of the association was tested by 10,000 Monte Carlo permutations. Because the relationships between spider assemblages and their environment may be obscured by spatial autocorrelation (identification of spurious correlations), a matrix based on the geographic distances between the sampling locations was calculated and also compared with the other distance matrices. The geographic distances were computed from the GPS reading of location data and significance level was fixed of α as $P \leq 0.05$ in all tests. A positive correlation indicates that sites that are similar in terms of given habitat and microclimate variables have similar spider assemblages. The dissimilarity matrices were derived using PRIMERv6, while partial mantel tests were performed with software zt version 1.0 (Bonnet & Van de Peer 2002).

RESULTS

Geographic distance between sampling locations was found to have weak, yet statistically significant influence over similarities in spider composition across habitat (Table 1).

Partial Mantel tests, after controlling for distance effect, found significant association between species composition and vegetation structure or microclimate (Table 1a). Inexplicably, vegetation structure and microclimate were found to be correlated, so strength of correlation was spurious and scale variant for explaining species composition. As an effect, we partialled out both vegetation structure and distance once (Table 1b), and microclimate and distance another (Table 1c) to compare congruence of species matrix with microclimate and vegetation structure (matrix) independently. Henceforth, significant association was found between species composition and vegetation structure, but not with microclimate across habitat at regional level.

DISCUSSION

Despite the scale of our study, Mantel tests indicate that there is weak spatial component to the spider community composition. This may be explained by the passive dispersal behaviour of the studied species (Sanderson et al. 1995). Since, after controlling for spatial effect, the degree to which each of the components independently contributes to variations in spider assemblage is found to be almost less than 50%. In the present study, vegetation structure across sites explained about 48% of spider species composition and microclimate only about 14%. Though vegetation structure, microclimate and species differences in our study were significantly correlated, the small proportion of species variation explained by vegetation and microclimate differences suggests that other factors were important in organizing the community as well.

Habitat choice plays a critical role in the survival and reproductive success of animals (Riechert & Tracy 1975, Stearns 1977), and litter (leaves, grasses, sticks, etc.) offers arthropods a diversity of microhabitats that can ameliorate extreme physical conditions such as temperature, humidity, light intensity, and wind speed (Wise 1993). Litter structure and complexity can have a profound effect on species assemblages (Riechert & Gillespie 1986). Species composition of spider assemblage in TCA was significantly correlated with vegetation structure. This is apparently inconsistent with the study by Sanderson et al. (1995) in which soil conditions (microclimate) or vegetation structure was not found as key habitat feature explaining species composition of spiders. This incongruity is probably due to the difference of ecological scale of study, as evident from the regional extent of this present study, which included selection of wide array of habitats in sampling regime. Samu et al. (1999) found that spider abundance/diversity and environmental (including microclimate, habitat, and disturbance) diversity were, in general, positively and variably correlated at different scales in agricultural ecosystems. In TCA, we found thar habitat heterogeneity is mediated largely by structural diversity of the vegetation rather than microclimate variation. Structural changes in vegetation tend to override imminence much before any microclimatic change takes effect in space. Henceforth, vegetation structure functioned as primary habitat cue for spider assemblage at regional scale. The idea that spider assemblage select habitats first on basis of vegetation structure and then on basis of microclimate. Structural features of the vegetation determine initial site selection, but how long the spiders remain at the site depends on their foraging success there. Studies have demonstrated that residence time is related to disturbance or web destruction (which may occur more in open sites) (Enders 1976, Hodge 1987), microhabitat features such as temperature or humidity (Biere & Uetz 1981), growth of the spider and a commensurate change in the structural requirements of web construction (Lubin et al. 1993), and / or prey capture success (Bradley 1993, Miyashita 1994, McNett & Ryptra 1997). Alterations in vegetation structure are expected to facilitate changes in diversity and abundance of arthropods. Because spiders depend heavily on arthropod prey, dynamic shifts in the prey base likely limit the spider assemblage from the bottom up.

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