USE OF SPIDERS (ARANEAE) AS INDICATOR FOR MONITORING OF HABITAT CONDITIONS IN TARAI CONSERVATION AREA, INDIA

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Introduction

Monitoring indicators has been proposed (Montreal Process, 2000) as a mechanism for assessing sustainability for forest management and monitoring a few indicator species is an intuitively appealing method of measuring the ecological sustainability of forest management because it is impossible to measure and monitor the effects of forest management on all species or environmental conditions of interest (Landres *et al.*, 1988).

As abundant and ubiquitous generalist predators, spiders play important roles in most terrestrial ecosystems (Wise, 1993). Previous studies also emphasize the value of spiders as bioindicators (Clausen, 1986; Yen, 1995; Churchill, 1997, Pearce and Venier, 2006). Spiders are 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 (Yen, 1995).

The present study was carried out in the Tarai Conservation Area (TCA), which represents the Tarai (floodplain) ecosystem, one of the most threatened ecosystems of India (Kumar *et al.,* 2002). Once, the Tarai forests constituted a lush belt of green vegetation in the extensive tract of alluvial Gangetic floodplains 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). The TCA is the last and best remnant of the Tarai ecosystem remaining in north India outside Nepal and Assam. De (2001) has described the global to local significance of the protected areas within the TCA, and potentially the nearby managed forests under the landscape management strategy. Researches on Swamp deer (Singh, 1984; Qureshi *et al.,* 1991); reintroduced Rhinos (Hajra and Shukla, 1983; Sale and Singh, 1987; Sinha and Sawarkar, 1991); Bengal florican (Sankaran and Rahmani, 1991); Black necked stork (Maheshwaran, 1998) have shown that the area supports a rich fauna, including array of threatened species, though long term conservation of species depend on multi-scale model of forest ecosystem management that integrates ecologically and administratively fragmented forest units and recognize to manage key habitats like wetlands and grasslands (Kumar *et al.,* 2002).

Under the above background and keeping in view the role of spider assemblages as generalist predators of forest ecosystem, this study was designed to assess the spiders as an indicator taxa to evaluate the changes in habitat conditions of different forest patches in Tarai Conservation Area (TCA).

Methods

Study area : The study was conducted in alluvial floodplain of TCA lying between the Himalayan foothills and the Gangetic Plains in the state of Uttar Pradesh, India from March 2005 to August 2006.

Five different vegetation types viz., Riparian swamp forest, Grassland, Pure sal (*Shorea robusta*) woodland, Mixed sal woodland and Eucalyptus (*Eucalyptus citriodora*)-Teak (*Tectona grandis)* plantation were selected, based on the vegetation classification by Kumar *et al.* (2002). Descriptions of sampled vegetation and dominant plant species are listed in Table 1.

Sampling methods : Spiders were collected along 50m x 10m transects, with 20 transects per habitat type. These transects were treated as the basic sampling units, hereafter sites. Transects were placed randomly within stratified vegetation types. Sampling was carried out each month from March 2005 to August 2006. Spiders were sampled along transects using pitfall traps and semi-quantitative sampling. Pitfall sampling was operated for 64 weeks and other semi-quantitative sampling performed on 64 occasions (once every week) at the same sampling sites.

Pitfall sampling : Pitfall traps consisted of cylindrical plastic bottles of 10 cm diameter and 11 cm depth (Churchill and Arthur, 1999). 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 processing in the laboratory and identification. Other time constrained semi-quantitative collection methods were also employed to maximize capture (Coddington *et al.,* 1996).

Semi-quantitative sampling : Aerial sampling (for upper layer spiders up to 1.5 m) involved searching leaves, branches, tree trunks, and spaces in between, from knee height up to a maximum overhead arm's reach. Ground collection (for ground layer spiders) involved searching on hands and knees, exploring the leaf litter, logs, rocks, and plants below low knee level. Beating (for middle layer spiders up to 1 m) consisted of striking vegetation with a 1 m long stick and catching the falling spiders on a tray held horizontally below the vegetation. Litter sampling was done by hand sorting spiders from leaf litter collected in a litter collection tray. Sweep netting (for middle layer spiders up to 1 m) was carried out in order to access foliage dwelling spiders. Each sampling method comprised 1 hour active sampling, measured with a stopwatch.

Adjacent to spider sampling, eleven (11) different habitat variables were quantified on sampled transects for each habitat type. These included litter cover (%), litter depth (cm), bare ground (ground debris > 6 cm, %), canopy openness (%), number of dead woods, shrub height, soil depressions, soil pH, soil humidity, soil temperature and atmospheric humidity.

Table 1

Description of the habitats sampled during the study in the Tarai Conservation Area and surrounding plantation areas.

Habitat	Physiography	Vegetation/ Land use type	Indicative plant species
Pure Sal	Regular mainly on old alluvial plain and 'damar' (upland) areas	Dense Sal forest (>60%)	*Shorea robusta* *Mallotus philippensis* *Syzygium cumini* *Terminalia alata*
Mixed Sal	On gentle slopes, old river terraces and around grasslands	Sal mixed forest	*Shorea robusta* *Mallotus philippensis* *Syzygium cumini* *Lagerstroemia parvifolia* with plantations of *Tectona grandis*
Riparian swamp forest	Along perennial rivers viz. Suheli, Ull, Barachha, and Katna	Tropical seasonal swamp forest	*Syzygium cumini* *Mallotus philippensis* *Barringtonia acutangula* *Trewia nudiflora* *Ficus racemosa*
Eucalyptus-Teak plantation	Along the road, railway lines and clear felled Sal forests	Plantations	*Tectona grandis* *Eucalyptus citriodora*
Grassland	In low land areas and along fresh alluvial of Suheli, Ull, Sharda and Ghagra rivers	Lowland grassland	*Sclerostachya fusca* *Phragmites karka* *Saccharum spontaneum* *Saccharum narenga*

Spiders were identified to family and species using existing identification keys wherever possible (Pocock, 1900; Tikader and Malhotra, 1980; Tikader, 1982, 1987; Koh, 2000; Cushing, 2001). Due to lack of available identification keys for many families and the time required for conventional taxonomic work, a morpho-species approach was used to classify spiders. This approach has been found to be effective for poorly known and species-rich taxa such as spiders and other invertebrates (Oliver and Beattie, 1996; Krell, 2004). In total more than 3,500 adult spiders were identified, resulting in data on the occurrence of 160 species. Voucher specimens of each spider species collected were deposited at the Wildlife Institute of India, Dehra Dun and will be finally placed in the Arachnida Section, Zoological Survey of India, Kolkata. Of these, 93 species were represented by more than 18 individuals (0.5% of total capture) caught, and were considered resident species and not vagrants, were used for analysis.

Analysis

Spiders captured by pitfall traps and semi-quantitative methods were pooled for each habitat. Indicator species for all groups at the different habitat cluster, (classification based on physiognomic aspects of vegetation) were determined with the IndVal-method (Indicator value method) (Dufrêne and Legendre, 1997). With this methodology, an indicator value is calculated for a species in each habitat group. Because pitfall data record (species specific) activities instead of absolute densities, data was analyzed only by presence/absence in IndVal calculation. In this way, biases to different climatic conditions between years were eliminated (Bonte *et al*., 2002). IndVal method is a non-parametric technique in which indicator value of a species is computed as a product of 'faithfulness' (proportion of sites/samples within the habitat in which the species present) and 'exclusivity' (inverse of the total number of habitat in which species occurs), expressed as percentage. The values range from zero (poorest indicator) to 100% (perfect indicator). The statistical significance of indicator values is estimated by means of Monte Carlo Randomizations (999 permutations). At each level of cluster (species group), indicator values (IndVal) and their associated P-values of all spider species were calculated and averaged across habitats (McCune and Grace, 2002). IndVal method was performed in PC-ORD Version 4.0 (McCune and Mefford, 1999). As a consequence the maximal indicator value can be interpreted as a measure for habitat specificity.

Results

Indicator values (IV) of all spider species were computed for each habitat type and only those species with statistically significant values ($P < 0.001$) were considered in the main result part (Table 2). Out of 93 species, 34 species qualified as indicators for respective habitat type. Of all habitats, riparian swamp forest were characterized species with high indicator values, while Eucalyptus-Teak plantation showed generally low mean indicator values. Clusters of species group respective to habitat categories were found significantly different along canopy cover and moisture regime when means were observed with degree of overlaps in 95% confidence interval (Fig. 1).

Discussion

Over all spider assemblages varied among habitats and revealed a pattern of assemblage response in relation to high and low structural complexity (including cover) and moisture regime (including temperature) of habitats. Study revealed that forest species tend to prefer cooler temperatures and higher humidity, and open habitat species prefer warmer temperatures and lower humidity. Greater temperature fluctuations and reduced humidity levels may disturb the closed habitat community, as the habitat becomes less suitable for some species and more suitable for others (Pearce and Venier, 2006). Closed canopies act as windbreaks and sources of shade which moderate ground surface conditions. Forest disturbances such as road construction, logging and fire, result in partial or total removal of the tree canopy. More open canopy results in increased insolation,

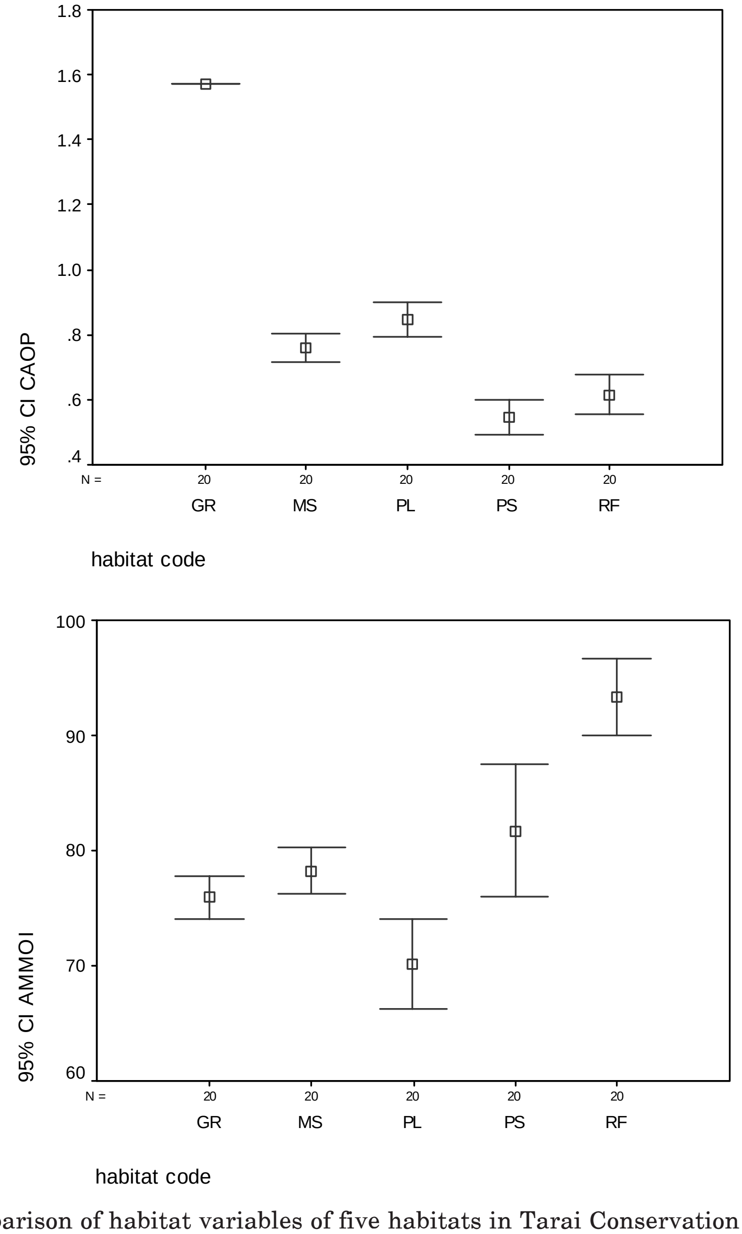
Table 2

Indicator species of five vegetation types of Tarai Conservation Area along with their indicator values (IV) and associated P-values as estimated by IndVal method.

Habitat	Indicator Species	IV	*P*
Riparian swamp forest	*Argiope pulchella* Thorell 1881	70	0.001
	Pardosa birmanica Simon 1884	55	0.001
	Gasteracantha sp.1	52	0.001
	Leucauge celebasiana Walckenaer 1842	51	0.001
	Myrmarachne sp.1	43	0.001
	*Drassodes gangeticus** Tikader & Gajbe 1975	41	0.001
	Arctosa indica Tikader & Malhotra 1980	40	0.001
	Tetragnatha chamberlini Gajbe 2004	35	0.001
	Gnaphosa stocliczka O. P. Cambridge 1885	34	0.001
	Cyphalonotus sp.1	31	0.001
	Hippasa pisaurina Pocock 1900	30	0.001
	*Achaearanea budana** Tikader 1970	22	0.001
	Achaearanea sp.1	20	0.015
Grassland	*Linyphia* sp.5	66	0.001
	Linyphia sp.6	42	0.001
	Lutica sp.1	37	0.001
	Linyphia sp.9	31	0.002
	Diaea subdola O. P. Cambridge 1885	28	0.001
	Gea sp.1	28	0.001
	Linyphia sp.8	27	0.001
Pure Sal woodland	*Cyrtophora unicolor* Doleschall 1857	57	0.001
	Cyclosa confraga Thorell 1892	55	0.001
	Clubiona boxaensis Biswas & Biswas 1992	50	0.001
	Nephila pilipes * Fabricius 1793	43	0.001
	*Clubiona filicata** O. P. Cambridge 1874	31	0.002
Mixed Sal woodland	*Neoscona vigilans* Blackwall 1865	58	0.001
	Crossopriza lyoni Blackwall 1867	52	0.001
	Cyrtophora sp.3	46	0.001
	Cyclosa sp.1	34	0.001
Eucalyptus-Teak plantation	*Chrysso picturata* Simon 1895	45	0.001
	Tetrablemma sp.1	42	0.001
	Zelotes sp.1	36	0.001

*indicates endemic to India

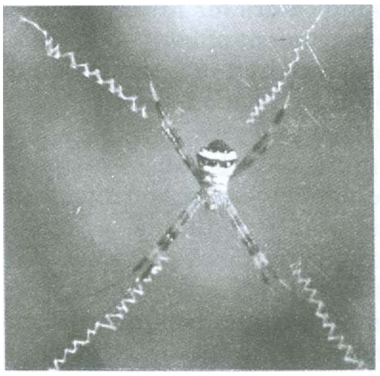
Fig. 1



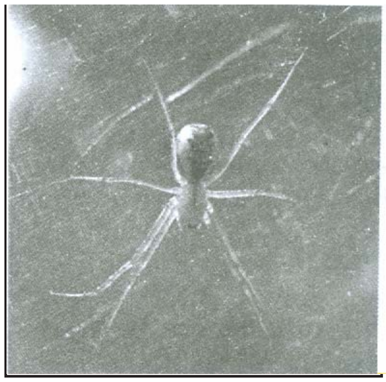
Comparison of habitat variables of five habitats in Tarai Conservation Area based on each level of spider species group in IndVal method.
The error bars correspond to lower and upper 95% confidence interval.
(Codes: GR = Grassland, MS = Mixed Sal woodland, PL = Eucalyptus-teak plantation, PS = Pure Sal woodland, RF = Riparian swamp forest, CAOP = canopy openness (%), AMMOI= atmospheric humidity).

Plate I

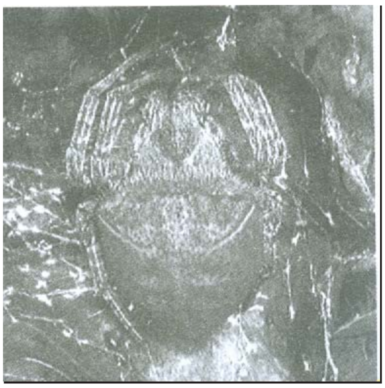
Indicator Species of spiders in different habitats in Tarai Conservation Area



Argiope pulchella
Indicator of riparian swamp habitat



Linyphia sp.
Indicator of grassland habitat



Cyrtophora unicolor
Indicator of pure Sal woodland habitat

Neoscona vigilans
Indicator of mixed Sal woodland habitat

Chrysso picturata
Indicator of Eucalyptus-Teak plantation habitat

greater temperature fluctuations, a drier environment and increased wind flow (Jiquan *et al.,* 1988; Chen *et al.,* 1993) which preferably exploited more by species related to grasslands and plantation patches.

Previous studies suggested habitat types that are characterized by presence of indicator species, dependent on cluster or group. Therefore, seasonal variation in population size of indicator species often hinder its use in monitoring habitat conditions, as a result, only absence/presence data were used, so that true indicators that are always present (independent of their yearly abundance) are unambiguously identified. Besides year-to-year fluctuations, species assemblages can vary as a function of habitat conditions and landscape structure. Present analysis is based on an extensive data set from five habitats representing different vegetation composition, so the determined indicator species can be used as bio-indicators for future monitoring of the management of both open (dominance of grasslands and plantations) and closed (trees & shrub dominated) habitats in Tarai landscapes. Thus, spiders at community level can serve as useful indicator for assessing and monitoring land use information, intensity and type of habitat management practices. With high degree of management, spider communities often lack diversity and are dominated by a few *r*-selected species affiliated with open habitat. Low intensity management produces structurally more complex habitat, introducing more niches for aerial web spinners and climbing spiders (Bell *et al.,* 2001). Therefore, in future more detailed study is needed on habitat patch size and connectivity related to population size of indicators, based on survey of more number of habitat patches.

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SUMMARY

The efficacy of spider as indicator of habitat conditions in Tarai Conservation Area was examined. To compare habitat specific spider communities, five vegetation types were sampled from March 2005 to August 2006 by using pitfall traps and other semi- quantitative collection methods along transects. Along with spider sampling 11 habitat variables on sampled transects for each habitat types were measured. Cluster analysis and subsequent indicator value analysis produced substantially different cluster numbers for the five habitat-specific spider communities. Indicator species of each habitat were identified and species found strongly influenced by canopy cover and moistures regime in the habitat.

Key words **: Spiders, Indicator species, Habitat conditions, Tarai, Conservation.**

तराई संरक्षण क्षेत्र, भारत की प्राकृतावास दशाओं की पड़ताल करते रहने में मकड़ियों (गोलवाय वंश) का संसूचक की तरह उपयोग

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सारांश

इस अभिपत्र में तराई संरक्षण क्षेत्र में प्राकृतावास दशाओं के संसूचक स्वरूप मकड़ियों की उपयोगिता की जांच की गई है। प्राकृतावास विशिष्ट मकड़ी समुदायों की तुलना के लिए पांच वनस्पति समुदायों से उनमें संक्षेत्र बनाकर गर्तपात पाशो तथा अन्य अर्द्धगुणात्मक संग्रह–विधियाँ अपनाते हुए मार्च 2005 से अगस्त 2006 तक नमूने इकट्ठे किए गए। मकड़ियों के नमूने लेने के साथ–साथ प्रत्येक प्राकृतावास प्ररूप के न्यादर्शित संक्षेत्र से 11 प्राकृतावास–विचर भी एकत्र किए गए। झुण्ड विश्लेषण और तदन्तर संसूचक अर्हा विश्लेषण किए जाने पर पांच प्राकृतावास–विशिष्ट मकड़ी समुदायों की परस्पर पर्याप्त भिन्न झुण्ड संख्याएं प्राप्त हुई। प्रत्येक प्राकृतावास की संसूचक जाति को पहचाना गया तथा ये जातियां वितान आवरण और प्राकृतावास के नमी स्तर से अत्यधिक प्रभावित होती पाई गई।

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