

AN ASSESSMENT OF SPIDER SAMPLING METHODS IN TROPICAL RAINFOREST FRAGMENTS OF THE ANAMALAI HILLS, WESTERN GHATS, INDIA

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ABSTRACT

Spiders are a highly diverse but poorly studied group of invertebrates in the tropics known to be sensitive indicators of habitat alterations. This study in three degraded tropical rainforest fragments in the southern Western Ghats assesses the utility of four sampling methods to document spider communities. Using belt transects, vegetation beating, leaf litter extraction, and pitfall traps, 103 spider morphospecies were detected in the three fragments. More species and individuals were recorded per unit effort in transects than vegetation beating, and in transects in the fragment with higher tree and shrub densities. Transects were also more appropriate for collection of natural history information and for identifying spiders to morphospecies. The composition of spider functional groups varied significantly across the four methods and a combination of methods is likely to yield a more complete inventory of the spider community.

KEYWORDS

Morphospecies, sampling, spiders, tropical rainforests, Western Ghats

Spiders form a diverse group of invertebrate predators in tropical ecosystems and are known to be sensitive indicators of environmental change (Jansen, 1997; New, 1999; Norris, 1999; Hodge & Vink 2000). A hectare of tropical forest may have about 300 to 800 species of spiders (Coddington *et al.*, 1991) often occurring in high abundance. Spiders also have an added advantage of being conspicuous, amenable to capture by relatively cheap, easily deployable, and replicable techniques. These attributes make spiders as a group suitable for statistical appraisals, comparisons, and monitoring of sites or habitats. Spiders have been sampled using many methods, each with its own limitations, such as direct searches, pitfall traps, canopy fogging, vegetation beating, litter sifting or extraction, sweep net, and suction sampling (Edwards, 1993; Ausden, 1996; Norris, 1999; Churchill & Arthur, 1999; Green, 1999). The different methods mostly target specific vegetation strata, spider guilds, or behaviours.

Little research has been carried out comparing sampling techniques and spider assemblages in Indian tropical forests (Gadagkar *et al.*, 1990; Patil & Raghavendra, 2003) and therefore information on spider diversity and assemblages remains scarce from the region. India has 59 of the 110 spider families and at least 1442 formally described species of the 39,000 known worldwide (Siliwal *et al.*, 2005). Documenting spider assemblages assumes greater importance in the context of current rates of loss and degradation of tropical forest, which is known to have detrimental effects on many invertebrate groups (Pik *et al.*, 2002).

The present study makes a preliminary assessment of spider sampling methods and assemblages in a tropical rainforest region of the Western Ghats, a global biodiversity hotspot (Myers *et al.*, 2000) facing the threats of past and ongoing deforestation and habitat fragmentation (Nair, 1991; Menon & Bawa, 1997). Four methods were chosen to sample spiders of contrasting foraging behaviours in different vegetation strata in three tropical rainforest fragments in the Anamalai hills. The study attempts to assess the relative efficiency of these methods in documenting spider species richness, abundance, and composition, in order to identify those suitable for inventorying and documentation of spider assemblages in tropical rainforests.

STUDY AREA AND METHODOLOGY

The study was carried out in the Valparai plateau of the Anamalai Hills in the southern Western Ghats. The Valparai plateau contains a large area (>220km²) of tea, coffee, and cardamom plantations surrounded by the Indira Gandhi Wildlife Sanctuary (958km²) in Tamil Nadu state and other protected areas and reserve forests in Kerala state. The natural vegetation of this region has been classified as mid-elevation tropical wet evergreen rainforest of the *Cullenia exarillata-Mesua ferrea-Palaquium ellipticum* type (Pascal, 1988). The area receives around 3500mm of rain annually, mostly during the southwest monsoon (June-September). At least 35 rainforest fragments occur within the private plantations in the Valparai plateau and these have been identified as important for conservation (Kumar *et al.*, 2002; Raman & Mudappa, 2003; Mudappa & Raman, in press) as they contain significant proportions of the native fauna besides being important for landscape level connectivity between fragments. Three such fragments were chosen for sampling: Puthuthottam (92ha), Korangumudi (56ha), Injipara (19.1ha). A portion of these fragments includes areas with abandoned cardamom plantation. All fragments are highly disturbed, with Injipara being protected from disturbance since the year 2000 as part of a restoration programme (Mudappa & Raman, in press) while the other two sites continue to be disturbed by fuel wood collection, cattle grazing, and illegal felling.

The study was carried out from January to April 2004 using belt transects, vegetation beating, pitfall traps, and leaf litter extraction. The belt transects were of 25m length and 2m width, with sampling restricted to a maximum height of 1.6m. Ten transects were sampled in each fragment with at least 50m distance between transects in the smaller fragment (Injipara)

and at least 100m distance between transects in Puthuthottam and Korangumudi. Besides spiders detected on the vegetation, those on webs were also recorded. Webs were visually detected or by using a fine water spray to highlight the details of the web. Notes on the type of web (structure, size, construction, design) were also maintained for each web-building spider taxon. Sampling time was restricted to 45-60 minutes in each transect, depending on the density of understorey weeds and shrubs to be walked through, and this included time spent on field to identify unfamiliar taxa encountered. The time taken to describe web characteristics (useful in identifying the family, and in some instances, up to the genus level) was excluded from the calculation of sampling time for each transect. Attempts were made to carefully scan the leaf litter surface, tree bark, foliage (including the under-surface of leaves when traces of webs were found), twigs, and branches of the vegetation (up to 1.6m height) along the transect.

Vegetation beating was carried out with a stick at the beginning and end of each transect by sharply tapping ten times a clump of vegetation about 1m in diameter at a height of about 1m. The spiders dislodged from the vegetation were pooled as a single sample for analysis. The dislodged spiders were collected in a tray handheld beneath the plants and transferred into vials for identification.

Pitfall traps are a popular and useful method to capture terrestrial invertebrates (Curtis, 1980; Kitching *et al.*, 2000). The pitfall trap used in this study was a brown plastic bowl with an upper inner diameter of 15cm and a depth of 7.5cm. One pitfall trap was placed near each transect by clearing leaf litter from the area where the trap was placed within the soil with the lip of the bowl level with the ground. The bowl contained a detergent solution (2.5cm depth) with a small metal sheet placed on four stakes as a roof to prevent rainwater or litter from falling into the trap. The leaf-litter was then placed back around the container. The pitfall was kept for 24 hours before it was collected from the field and sorted.

Spiders were extracted from leaf litter using a modified Tullgren funnel (Kitching *et al.*, 2000) consisting of ten 40cm funnels in an insect-proof box, each with a 60W bulb over it and tight-fitting collection vials beneath. A 3-mm wire mesh was used in each funnel to prevent excessive amounts of litter fragments contaminating the samples of extracted spiders. About two

metres away from each transect, a 25 x 25cm metal frame was placed on the ground and the leaf litter within the frame was quickly scooped up and placed in a plastic cover, labelled, and tied tightly. In the field station, the leaf litter was placed in a tray and quickly sifted, to look for larger spiders and other arthropods too large to pass through the funnel mesh. The leaf litter was then placed in the funnel. Studies have recommended extraction from two days (Jansen, 1997) to 4-6 days (Kitching *et al.*, 2000). In this study 36hr of extraction were used for each sample.

Spiders were identified to the family and morphospecies levels using existing identification keys (Pocock, 1900; Levi & Levi, 1968; Kaston, 1978; Tikader, 1980; Tikader & Malhotra, 1980; Tikader, 1982; Tikader, 1987; Cushing, 2001). Details of body parts, such as pattern of eye arrangement, were examined using a dissection microscope (10-20X) or a binocular microscope (Leica, 100X), and identification features noted and sketched for each taxon. Using morphospecies richness has been found to be effective as a surrogate for true species richness for sampling diverse and poorly studied taxa such as spiders and ants (Oliver & Beattie, 1996; Krell, 2004). Spiders were also classified into seven functional groups based on hunting method and web type (Levi & Levi, 1968; Kaston, 1978).

The computer programme Estimate S (Colwell, 1997; Version 6.01b) was used to calculate morphospecies richness accumulation curves using species-abundance data from transect and vegetation beating samples. The number of observed species, individuals, and Coleman rarefaction curves (Coleman *et al.*, 1982) and their standard deviations were estimated from the data using 50 random permutations (sampling without replacement).

RESULTS

In total, there were 577 individual spiders belonging to 27 families in 382 detections (single individuals and groups) across all the sampling methods. Twenty-two individuals belonging to five families could not be identified but were taxonomically unique. These individuals were all obtained from pitfall trap and leaf litter extraction methods. Overall, 103 morphospecies were detected during the study (Table 3).

To compare morphospecies richness and abundance across sites, only data collected from transects and vegetation beating

Table 1. The mean values of the species richness and abundance of spiders across the three sites using transects and vegetation beating. The number in parentheses is the standard error.

	Injipara	Korangumudi	Puthuthottam	Kruskal-Wallis ANOVA χ^2	P
Species Richness (number of species/sample)					
Transects	8.8 (1.01)	6.7 (0.42)	6.0 (0.67)	5.95	0.051
Vegetation beating	3.0 (0.51)	3.1 (0.64)	2.5 (0.70)	0.475	0.789
Abundance (individuals/sample)					
Transects	15.5 (2.26)	11.8 (0.68)	8.8 (1.60)	7.069	0.029
Vegetation beating	5.3 (1.35)	4.7 (1.13)	3.4 (0.95)	0.844	0.656

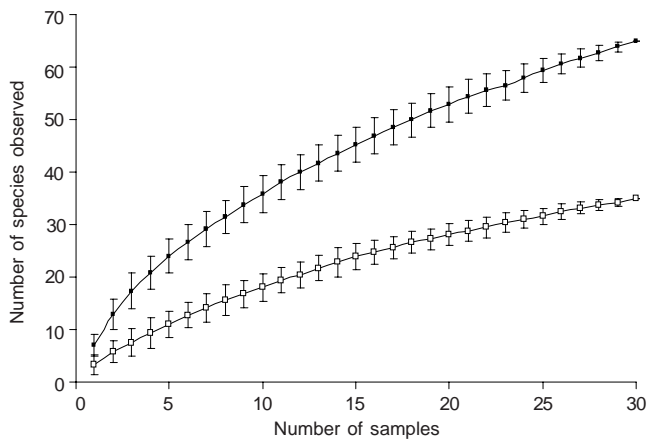


Figure 1. Sample-based spider species accumulation curves for the three study fragments for transects (filled squares) and vegetation beating (open squares). Vertical error bars represent 1 standard deviation.

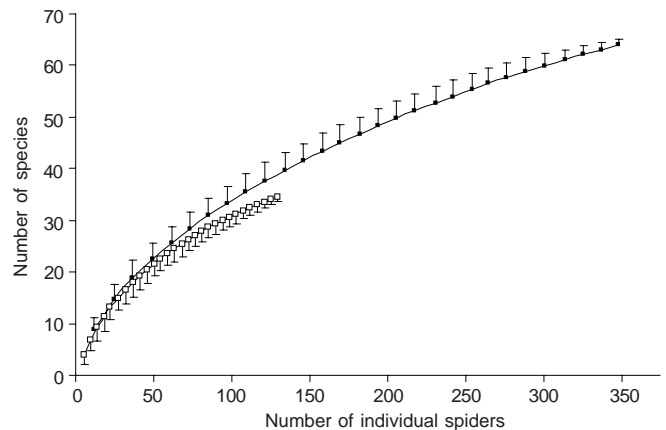


Figure 2. Species-individual accumulation curves (Coleman curves) for spiders from the three study fragments for transects (filled squares) and vegetation beating (open squares). Vertical error bars represent 1 standard deviation.

was used because of the low sample size from the other two methods. More species were detected along the 30 line transects than from the vegetation beating samples (Figure 1). The average number of species and individuals was higher in transect samples than vegetation beating samples in all three sites (Table 1). Comparisons among sites showed a significant difference in average species richness and abundance recorded using the transect method, with Injipara having higher values than the other two sites (Kruskal-Wallis ANOVA, $P \leq 0.05$, Table 1) possibly because of the site's protection status and higher tree and shrub densities. There was no significant difference observed among sites in spider species richness and abundance estimated with the vegetation beating method (Table 1).

A comparison of the number of species detected for standardised numbers of individuals is presented in the species-individuals curve (Figure 2). This shows that species richness from transect samples was only marginally higher than from vegetation beating.

The composition of the functional groups varied significantly across the four methods (Table 2, $X^2 = 349.6$, $df = 15$, $P < 0.001$; commensal Theridiids were combined with orb web spiders and platform web spiders were combined with sheet web spiders for X^2 analysis). Families like Araneidae, Uloboridae, Linyphiidae, and the non-commensal Theridiidae were more often captured during transects and vegetation beating. Except for the family Pholcidae which build irregular webs and were captured most often (22.4% of individuals) in the vegetation beating method, most other functional groups were frequently recorded on transects (Table 2). The families which fall under the guild of hunters were detected in all the sampling methods, less frequently in transects (19.4%) and vegetation beating (23.1%) than in pitfall traps (69.8%). Families that were unique to the transect method were the commensal Theridiidae, Hersiliidae, Palpimanidae, and Agelenidae. Families unique to the pitfall trap method were mainly hunters: Dysderidae-type, Gnaphosidae, Oecobidae, Prodidomidae, and two unidentified

families. The litter extraction method captured three unique families that were unidentified. No family was unique to the vegetation beating method.

DISCUSSION

Many methods have been used to sample spiders that occupy various niches in different vegetation strata including leaf litter, bark, tree hollows, on and under leaves, and tree canopies (Coddington *et al.*, 1991). The complexity of the vegetation in the study area disallowed the use of certain sampling methods such as the sweep net (Toti *et al.*, 2000), a method often used to sample spiders in open single-stratum vegetation.

Among the methods used, mean species richness per transect was almost three times that per vegetation beating (Table 1). A major reason was that more individuals were detected in transects. When standardised by individuals sampled, richness was only marginally higher possibly because of larger area or wider strata sampled. However, given that transects and vegetation beating samples took approximately equal time (30hr for 30 samples, including time for collection and identification of spiders in the vegetation beating method), transects sampled almost three times the number of individuals compared to vegetation beating (Table 1). Other factors in favour of using transects is that it samples more strata and also allows the collection of natural history information (such as web type, niche preference, and hunting behaviour), of which little is known for Indian spiders. The morphospecies of spiders captured by the two methods were however very different. This could be because the vegetation beating method of sampling is intensive, concentrates on a specific strata, and manages to dislodge even cryptic species likely to be missed in transects.

At the functional group level, there were differences between the four methods (including litter extraction and pitfalls) with three of the four methods capturing families that appeared to be unique to each of them. Although this could partly be a result of small sample sizes and needs to be confirmed with

Table 2. The number of individuals and percentages (within parentheses) of different families and functional groups captured in the four sampling methods.

Functional group/ Family	Methods				Total
	Vegetation beating	Litter extraction	Pitfall traps	Transect	
Commensals				5	5
Theridiidae ^a				5	5
Hunters	31 (23.1)	8 (27.6)	37 (69.8)	70 (19.4)	146
Amaurobiidae		1	4		5
Clubionidae	8		3	18	29
Ctenidae		1	6		7
Dysderidae type			2		2
Gnaphosidae			1		1
Hersiliidae				1	1
Lycosidae		2	3	19	24
Lyssomanidae	2			7	9
Oecobiidae			2		2
Oonopidae		4	11		15
Oxyopidae	1		1	6	8
Palpimanidae				1	1
Prodidomidae			2		2
Salticidae	14		2	13	29
Thomisidae	6			5	11
Irregular webs	30 (22.4)	9 (31)	3 (5.7)	3 (0.8)	45
Pholcidae	30	9	3	3	45
Orb webs	33 (24.6)	1 (3.4)	1 (1.9)	135 (37.4)	170
Araneidae	28	1		121	150
Uloboridae	5		1	14	20
Platform webs	13 (9.7)			90 (24.9)	103
Linyphiidae	13			90	103
Sheet webs				4 (1.1)	4
Agelenidae				4	4
Scaffolding webs	27 (20.1)		1 (1.9)	54 (15.0)	82
Theridiidae	27		1	54	82
Unidentified (5 families)		11 (37.9)	11 (20.8)		22
Total	134	29	53	361	577

^a Commensal theridiids were found on the webs of other species, whereas all other theridiids built scaffolding webs.

more effort, it is likely that a combination of the methods will help in obtaining a complete inventory of spiders found in an area.

The pitfall trap (Image 1^w) and leaf litter extraction (Image 2^w) methods were useful to capture species not easily detectable visually at the ground level and the leaf litter stratum. Identification to morphospecies was, however, difficult due to the poor condition of the specimens. If the goal is to identify specimens to a morphospecies level, then the pitfall trap and

^w See Images 1 & 2 in the web supplement at www.zoosprint.org

leaf litter extraction methods will not be desirable methods to use because colours, patterns, and condition of the specimens generally deteriorates in stored conditions.

REFERENCES

- Ausden, M. (1996).** Invertebrates, pp.139-176. In: Sutherland, W.J. (ed.). *Ecological Census Techniques*. Cambridge University Press.
- Churchill, T.B. and J.M. Arthur (1999).** Measuring spider richness: effects of different sampling methods and spatial and temporal scales. *Journal of Insect Conservation* 3: 287-295.
- Coddington, J.A., C. Griswold, D. Davila, E. Penaranda and S. Larcher (1991).** Designing and testing protocols to estimate biodiversity in tropical systems, pp.44-60. In: Dudley, E. (ed.). *The Unity of*

Table 3. Number of individuals of spider morphospecies obtained across the four methods in rainforest fragments in the Anamalai Hills.

Family	Species	VB	LE	PT	Tr	Family	Species	VB	LE	PT	Tr	
Agelenidae	Agelenidae Un.i.d 1				2	Oecobiidae	Oecobiidae Un.i.d 1			2		
	Agelenidae Un.i.d 2				2	Oonopidae	Oonopidae Un.i.d 1		4	11		
Amaurobidae	Amaurobidae Un.i.d		1	4		Oxyopidae	<i>Oxyopes birmanicus</i>				1	
Araneidae	Araneidae Un.i.d 1		1				<i>Oxyopes</i> sp.1	1			5	
	<i>Araneus (pahalgaonensis?)</i>	1					Oxyopidae Un.i.d 1			1		
	<i>Araneus mitificus</i>	2				Palpimanidae	Palpimanidae Un.i.d 1				1	
	<i>Araneus</i> sp.1	8				Pholcidae	Pholcidae Un.i.d 1				1	
	<i>Araneus</i> sp.2	4					Pholcidae Un.i.d 2		9	3		
	<i>Araneus</i> sp.3				29		Pholcidae Un.i.d 3				1	
	<i>Araneus</i> sp.4				1		<i>Pholcus</i> sp.1				1	
	<i>Araneus</i> sp.5				1		<i>Pholcus</i> sp.2	30				
	<i>Araneus</i> sp.6				2	Prodidomidae	Prodidomidae Un.i.d 1				2	
	<i>Araneus</i> sp.6	1				Salticidae	<i>Myrmarachne</i> sp.					1
	<i>Araneus</i> sp.7				3		<i>Phidippus</i> sp.	10				6
	<i>Argiope anasuja</i>				1		Salticidae Un.i.d 1	3				2
	<i>Cyclosa</i> sp.1				5		Salticidae Un.i.d 2				2	
	<i>Cyclosa bifida</i>	2					<i>Telamonia</i> sp.	1				4
	<i>Cyclosa elongata</i>				4	Theridiidae	<i>Achaearana</i> sp.					3
	<i>Cyclosa</i> sp.2				1		<i>Argyrodes</i> sp.2					3
<i>Cyclosa</i> sp.3				14		<i>Argyrodes</i> sp.1					1	
<i>Cyrtophora</i> sp.1				1		<i>Argyrodes</i> sp.3	3					
<i>Gasteracantha hasseltii</i>	3			1		<i>Argyrodes</i> sp.4					1	
						<i>Argyrodes</i> sp.5	1					
						<i>Chryso</i> sp.	1				1	
Tetragnathidae	<i>Leucauge celebesiana</i>	1			3	Theridiidae Un.i.d 1					3	
	<i>Leucauge</i> sp.1	3			1	Theridiidae Un.i.d 2					2	
	<i>Neoscona</i> sp.1	1			1	Theridiidae Un.i.d 3	14					
	<i>Opadometa fastigata</i>				1	Theridiidae Un.i.d 4					2	
	<i>Parawixia dehanii</i>				1	Theridiidae Un.i.d 5				1		
	<i>Poltys</i> sp.				1	Theridiidae Un.i.d 6					1	
	<i>Tylorida culta</i>	2			38	Theridion sp.1					1	
	<i>Zygeilla</i> sp.1				13	Theridion sp.2	5				22	
	<i>Zygeilla</i> sp.2				1	Theridion sp.3	3				16	
	<i>Zygeilla</i> sp.3				1	Theridion sp.4					1	
Clubionidae	Clubionidae Un.i.d 1	1			2	Theridion sp.4					2	
	Clubionidae Un.i.d 2				1	Thomisidae	<i>Pistius</i> sp.	1				
	Clubionidae Un.i.d 3	7			9		<i>Runcia</i> sp.				1	
	Clubionidae Un.i.d 4				1		<i>Thomisus</i> sp.1	2			4	
	Clubionidae Un.i.d 5				2		<i>Thomisus</i> sp.2	2				
	Clubionidae Un.i.d 6				3		<i>Tibellus</i> sp.	1				
	Clubionidae Un.i.d 7				3	Uloboridae	<i>Miagrammopes</i> sp.	1			1	
Ctenidae	Ctenidae Un.i.d 1		1	6			Uloboridae Un.i.d 1				2	
Dysderidae	Dysderidae Un.i.d 1				2		<i>Uloborus</i> sp.1				1	
Gnaphosidae	Gnaphosidae Un.i.d 1				1		<i>Uloborus</i> sp.2	3			7	
Hersiliidae	<i>Hersilia</i> sp.				1		<i>Uloborus</i> sp.3				2	
Linyphiidae	<i>Linyphia</i> sp.1				47		<i>Uloborus</i> sp.4				2	
	<i>Linyphia</i> sp.2	4			1		<i>Uloborus</i> sp.5	1				
	<i>Linyphia urbasae</i>				1	Unidentified	Unidentified sp. 1				9	
	Linyphiidae Un.i.d 1	9			42		Unidentified sp. 2		8			
Lycosidae	<i>Hipassa</i> sp.				17		Unidentified sp. 3				2	
	<i>Lycosa</i> sp.				2		Unidentified sp. 4		1			
	Lycosidae Un.i.d 1		2	3			Unidentified sp. 5		2			
Lyssomanidae	<i>Lyssomanes</i> sp.	2			7							

VB - Vegetation beating; LE - Litter extraction; PT - Pitfall traps; Tr - Transects

Evolutionary Biology. Proceedings of the IV International Congress in Systematics and Evolutionary Biology. Discorides Press, Portland, Oregon.

Coleman, B.D., M.A. Mares, M.R. Willig and Y.H. Hsieh (1982). Randomness, area, and species richness. *Ecology* 63: 1121-1133.

Colwell, R.K. (1997). Estimate S: Statistical estimation of species richness and shared species from samples. Version 6.01b. <http://viceroy.eeb.uconn.edu/EstimateS>.

Curtis, D.J. (1980). Pitfalls in spider community studies (Arachnida,

Araneae). *Journal of Arachnology* 8: 271-280.

Cushing, P.E. (2001). Colorado spider survey. Denver Museum of Nature and Science, Denver.

Edwards, R.L. (1993). Can the species richness of spiders be determined? *Psyche* 100: 185-208.

Gadagkar, R., K. Chandrashekhara and P. Nair (1990). Insect species diversity in the tropics; sampling methods and a case study. *Journal of the Bombay Natural History Society* 3: 337-353.

Green, J. (1999). Sampling method and time determines composition

- of spider collections. *The Journal of Arachnology* 27: 176-182.
- Hodge, S. and C.K. Vink (2000).** An evaluation of *Lycosa hiliaris* as a bioindicator of organophosphate insecticide contamination. *New Zealand Plant Protection* 53: 226-229.
- Jansen, A. (1997).** Terrestrial invertebrate community structure as an indicator of the success of a tropical rainforest restoration project. *Restoration Ecology* 2: 115-124.
- Kaston, B.J. (1978).** *How to know the spiders*. Pictured Key Nature Series. 289pp.
- Kitching, R.L., G. Vickerman, M. Laidlaw and K. Hurley (2000).** *The comparative assessment of arthropod and tree bio-diversity in old world rainforests: The rainforest CRC/ Earthwatch protocol manual*. Cooperative Research Centre for Tropical Rainforest Ecology and Management. Technical Report Rainforest CRC, Cairns.
- Krell, F. (2004).** Parataxonomy vs. taxonomy in biodiversity studies-pitfalls and applicability of 'morphospecies' sorting. *Biodiversity and Conservation*. 13: 795-812.
- Kumar, A., R. Chellam, B.C. Choudhury, D. Mudappa, K. Vasudevan, N.M. Ishwar and B.R. Noon (2002).** *Impact of Rainforest Fragmentation on Small Mammals and Herpetofauna in the Western Ghats, South India*, WII-USFWS Collaborative Project, Final report, Wildlife Institute of India, Dehradun.
- Levi, H.W. and L.R. Levi (1968).** *A guide to spiders and their kin*. Golden Press, New York.
- Menon, S. and K.S. Bawa (1997).** Applications of geographical information systems, remote sensing and a landscape ecology approach to biodiversity conservation in the Western Ghats. *Current Science* 73: 134-145.
- Mudappa, D. (2001).** Ecology of the brown palm civet *Paradoxurus jerdoni* in the tropical rainforests of the Western Ghats, India. Ph.D. thesis submitted to Bharathiar University, Coimbatore, India.
- Mudappa, D. and T.R.S. Raman (in press).** Rainforest restoration and wildlife conservation on private lands in the Valparai plateau, Western Ghats, India. In: Shahabuddin, G. and M. Rangarajan (eds). *Making Conservation Work*. Permanent Black, New Delhi.
- Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca and J. Kent (2000).** Biodiversity hotspots for conservation priorities. *Nature* 403: 853-858.
- Nair, S.C. (1991).** *The Southern Western Ghats: a biodiversity conservation plan*. INTACH, New Delhi.
- New, T.R. (1999).** Untangling the web: spiders and the challenges of invertebrate conservation. *Journal of Insect Conservation* 3: 251-256.
- Norris, K.C. (1999).** Quantifying change through time in spider assemblages: sampling methods, indices and sources of error. *Journal of Insect Conservation* 3: 309-325.
- Oliver, I. and A.J. Beattie (1996).** Invertebrate morphospecies as surrogates for species: a case study. *Conservation Biology* 1: 99-109.
- Pascal, J.P. (1988).** *Wet Evergreen Forests of the Western Ghats of India: Ecology, Structure, Floristic Composition and Succession*. Institut Français de Pondichéry, Pondicherry, India.
- Patil, R.K. and N. Raghavendra (2003).** An overview of spider diversity in India, pp.121-128. In: Gupta, A.K., A. Kumar and V. Ramakantha (eds.). *ENVIS Bulletin: Wildlife and Protected Areas, Conservation of Rainforests in India*. Wildlife Institute of India, Dehradun.
- Pik, A.J., J.M. Dangerfield, R.A. Bramble, C. Angus and D.A. Nipperess (2002).** The use of invertebrates to detect small-scale habitat heterogeneity and its application. *Environmental Monitoring and Assessment* 75: 179-199.
- Pocock, R.I. (1900).** *Fauna of British India, including Ceylon and Burma - Arachnida*. Taylor and Francis, London.
- Raman, T.R.S. and D. Mudappa (2003).** Bridging the gap: Sharing responsibility for ecological restoration and wildlife conservation on private lands in the Western Ghats. *Social Change* 33: 129-141.
- Siliwal, M., S. Molur and B.K. Biswas (2005).** Indian Spiders (Arachnida: Araneae): Updated checklist 2005. *Zoos' Print Journal* 20(10): 1999-2049.
- Tikader, B.K. (1980).** *Fauna of India: Spider (Thomisidae)*. 1: 1-248.
- Tikader, B.K. (1982).** *Fauna of India: Spider (Araneidae and Gnaphosidae)* 2: 1-533.
- Tikader, B.K. (1987).** *Handbook Indian Spiders*. Zoological Survey of India, Calcutta.
- Tikader, B.K. and M.S. Malhotra (1980).** *Fauna of India: Spider (Lycosidae)*. 1: 249-448.
- Toti, D.S., F.A. Coyle and J.A. Miller (2000).** A structured inventory of Appalachian grass bald and heath bald spider assemblages and a test of species richness estimator performance. *Journal of Arachnology* 28:329-345.

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