Comparative Diversity of Litter and Ground Dwelling Spiders in an Urban, Semi Urban and Rural Gradient

Joicy James & Mathew M.J.
Dept. of Zoology, Sacred Heart College, Thevara, Kochi – 682013,Kerala, India
Email: *mathewmj@gmail.com*

ABSTRACT

A study was undertaken to compare the diversity and species richness of litter and ground dwelling spiders in an urban, semi urban and rural gradient and the effect of urbanization on the ground spiders. The present study was also proposed to make an in-depth study on the diversity and abundance of spiders in relation to different habitat types- Mangalavanam, Hill palace and Thevackal landscapes. The study was extended for a period of six months from February to July 2014. Spiders were collected from mainly three regions - Mangalavanam, Hill palace and Thevackal. Spider species were collected by hand picking method and pit fall trap method from the ground stratum and preserved in 70% alcohol. The study documented 24 species of spiders belonging to 10 genera and 14 families from Mangalavanam, Hill palace and Thevackal. Analysis of the faunal composition revealed that Lycosidae was the taxonomically dominant family. Analysis of the beta diversity revealed that Thevackal recorded the highest values for most of the diversity indices, as well as species richness. Analysis of the guild structure revealed that ground runners were the dominant feeding guild. The overall trends in abundance of spider community showed correlation with seasons. The study of spiders was conducted between three seasons, namely post-monsoon, pre-monsoon and monsoon (February to July). The highest species occurrence was recorded in the post-monsoon months followed by pre-monsoon months and the least occurrence was during the monsoon period. The effects of urbanization on ground-dwelling spiders (Araneae) were studied using pitfall traps along an urban-suburban–rural forest gradient in city Cochin. This study found that overall spider species richness was significantly higher in the rural site- Thevackal compared to the urban area- Mangalavanam and sub urban area- Hill palace. The ratio of forest species was significantly higher in the rural sites than in the suburban and urban ones, suggesting that forest species are indeed sensitive to the disturbance caused by urbanization. Analysis revealed that the species composition changed remarkably along the urbanization gradient.

Keywords: Urbanization, urban-semi urban-rural gradient, biodiversity, spiders

INTRODUCTION

Arthropods comprise of more than 900,000 described insect species and about 43,678 described spiders in the world belong to the order Araneae of class Arachnida. Spiders are one of the diverse and functionally important predators regulating the terrestrial arthropods and possess a unique ability to spin web.

Being highly diverse and abundant predators, spiders are important regulators of terrestrial arthropod populations (Coddigton and Levi, 1991) and may prove to be useful indicators of the overall species richness and health of terrestrial communities. Despite being one of the most diverse groups of organisms on earth, spiders have largely been ignored because of the human tendency to favour some organisms over others of equal importance because they lack a universal appeal. Spiders also play a very important role by being exclusively predatory (Wise, 1993) and thereby regulate insect populations.

Recent research has paid more attention to incorporate the requirements of invertebrates, including spiders, into forest management strategies. Spiders are abundant in most terrestrial ecosystems and are affected by change in vegetation structure (Uetz, 1991). They also have the advantage of being efficiently sampled and relatively easily identified compared to other invertebrate groups. Spiders occupy a strategic functional position in terrestrial food webs as they are important in the regulation of invertebrate populations and as a food source for higher organisms. Spider communities are ubiquitous in forest ecosystems as they are seen from the litter layers to the canopy and hence are ideal for study in forest environments.

Urban ecosystems are defined as areas under profound human influence, characterized by high density of human habitation and industrial development (Niemelä, 1999; McIntyre et al., 2001). Urbanization refers to the formation of urban ecosystems, which leads to the modification of the original landscape and habitats (McDonnell & Pickett, 1990) or even the loss of natural habitats (Miyashita et al., 1998; Gibbs & Stanton, 2001). Urban areas are also characterized by higher temperatures (~ 2–3°C) than surrounding areas and a higher abundance of non native, invasive and generalist species , which replace the native flora and fauna and are often absent in the centres of cities. The effect of urbanization generally is more marked in the core of a city, which is surrounded by areas of decreasing habitation and development with moderate or low disturbance levels (Dickinson, 1996). Urbanization is the primary cause of several forms of disturbance, such as the alteration and fragmentation of natural habitats, changes in temperature, moisture and edaphic conditions, as well as high levels of pollution . The study of the responses of ecosystem to anthropogenic disturbance in urban areas is important for the well-being of humans and nature.

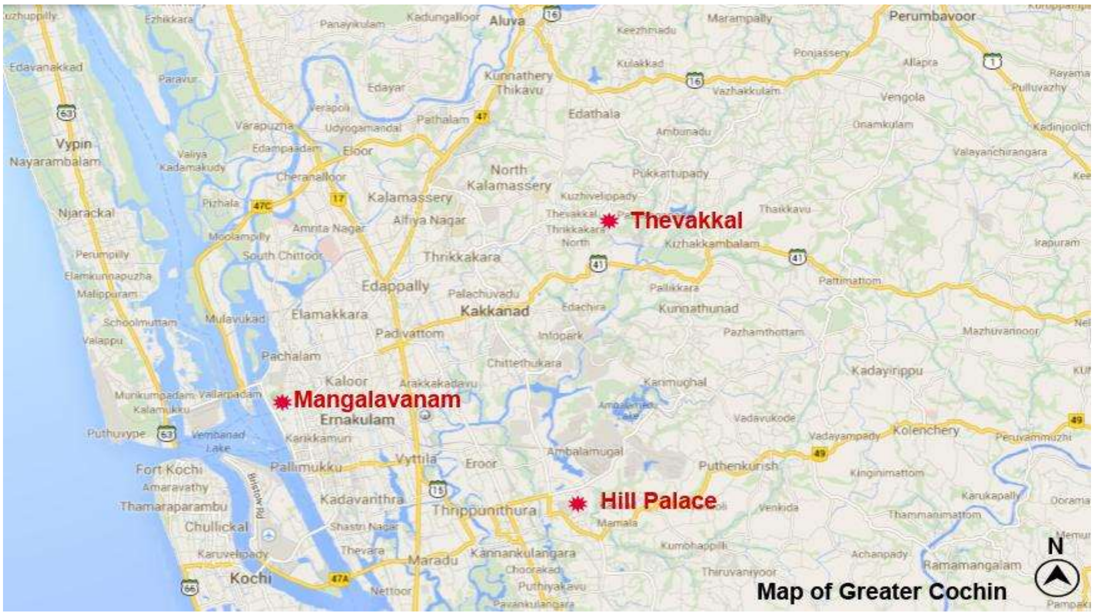
The highly affected city centre frequently maintains patches of natural habitats but these are usually more affected, managed, and fragmented than their suburban and rural complements. Such urban-rural gradients representing of diminishing intensities of human influence are characteristic of many cities around the world. Despite the prevalence and acceleration of urbanisation and the fact that urbanisation is considered one of the primary causes for the loss of biodiversity, little is known on whether or not changes caused by urbanisation affect biodiversity in similar ways across the globe.

Against this backdrop, the present study was undertaken to to identify the species diversity of ground and litter spiders in urban , semi-urban and rural landscapes (Mangalavanam, Hill Palace and Thevackal, respectively); to analyze the comparative diversity of spiders between the different study areas; to document the microhabitat associations and abundance of the spiders and to study the effect of urbanization on the ground dwelling spiders.

MATERIALS AND METHODS

The study area consisted of an urban forest - Mangalavanam, which lies in the heart of Kochi city; a semi urban forest – the forested premises of Hill Palace Museum, Thripunithura; and a rural forest – a privately owned forest in Thevakkal village (Fig.1). The sites comprise an approximately 21 km long urban-semi urban-rural gradient.

Figure1. Map of the study area



The study was conducted for a period of 6 months from February to July 2014. Two methods viz. ground hand collection and pit fall trap method were used for collection of spiders from ground. Collecting by hand is one of the best methods to collect spiders. Ground collection involved searching mostly on hands and knees, exploring leaf litter, logs, rocks, and plant surfaces at the ground stratum. A soft paintbrush or cotton swab was used to gently knock the specimen into a collecting vial. The specimens were also carefully picked by hand. Turning over stones and logs exposed many spiders and hand collecting was the method of choice. The pitfall trap is the ideal method for catching ground-dwelling spiders. Pitfall traps usually consist of suitable pots or jars dug into the ground. At the bottom, the jar contains a small quantity of preserving fluid such as ethylene glycol with a drop of washing-up liquid (to reduce the surface tension). A lid is placed a little way above the trap so that crawling spiders can get by, but small vertebrates, rain, dirt, etc., are kept out of the trap. Plastic cups make suitable pitfall traps. The traps need to be cleared frequently since water can often find its way into the trap and damage the specimens. Sampling was conducted monthly in the selected study sites. The collected specimens were preserved in 70% alcohol in separate tubes with labels containing information regarding the collection.

The collected spiders were identified with the help of expertise available at the Division of Arachnology, Sacred Heart College, Thevara, Kochi, Kerala using diagnostic keys and other literature (Tikader, 1987; Barrion and Litsinger, 1995; Dippenaar-Shoeman and Jocque, 1997; Deeleman-Reinhold; 2000) using stereoscopic microscopes (Leica MS5, Olympus SZ112). Adult males and females collected from the fields were identified up to the species level whereas immature spiders were identified up to generic level.

The diversity, richness, and evenness indices of spider communities were computed using “Biotools”, an MS Excel add-in. The two main diversity indices used were the Shannon-Wiener index, which is sensitive to changes in the abundance of rare species in a community, and the Simpson index, which is sensitive to changes in the most abundant species in a community (Solow, 1993). Shannon –Wiener index, which increases with the number of species in the community, is an ordinal scale. Margalef index, a species richness index, was computed based on the relationship between species richness (S) and total number of individuals observed (N) which increases with increasing sample size. Evenness index is a measure of how evenly species are distributed in a sample. When all species in a sample are equally abundant, an evenness index will be at its maximum, decreasing towards zero as the relative abundance of the species diverge away from evenness.

In order to evaluate whether or not different habitats differed markedly in community composition, hierarchical cluster analysis was performed. The Bray-Curtis similarity index (Bray and Curtis, 1957) was used to construct similarity matrices between samples and formed the basis for cluster analysis. Bray-Curtis similarity index was computed using the software Primer6.

The ecological guild concept has been of great interest to arachnologists, and the different manner in which spiders forage for common resource, prey arthropods, has led to numerous attempts to classify them into guilds. Guild classification is based on the quantitative analysis of ecological characteristics of spider families. Pattern of similarity in guild composition suggests the possibility of plant habitat structure as an influence on the spider community.

The spider guild classification was done based on the families collected during the study. Designation of spider guild was based on the ecological characteristic known for the family (Young and Edwards, 1990). Ecological characteristics relating to foraging manner, nature of web, prey species, microhabitat use, site tenacity and daily activity were subjected to guild classification. Output of the analysis was organized into tabular form and subsequent guild designations were based on the relative similarity of spider foraging modes.

Monthly sampling data were prepared with detailed information on the occurrence of mature male, female and juvenile spiders. These data were used to deduce the population dynamics and seasonality of spiders across the study sites.

RESULTS AND DISCUSSION

A total of 11 species of spiders belonging to 10 genera and 8 families were sampled from Mangalavanam (Table 1), 17 species of spiders belonging to 14 genera and 8 families from Hill palace (Table 2), and a total of 24 species of spiders belonging to 19 genera and 14 families from Thevackal (Table 3)

Table 1. Total number of families, genera, species and individuals recorded from Mangalavanam, Cochin, Kerala.

SI.No	Family	No. of Genera	No. of Species	No. of individuals sampled
1	Araneidae	1	1	21
2	Tetragnathidae	2	2	44
3	Lycosidae	2	3	67
4	Corinnidae	1	1	20
5	Gnaphosidae	1	1	22
6	Salticidae	1	1	21
7	Sparassidae	1	1	19
8	Oonopidae	1	1	19
Total	8	10	11	233

Table 2. Total number of families, genera, species and individuals recorded from Hill palace, Cochin, Kerala

SI.No	Family	No.of Genera	No.of Species	No.of individuals sampled
1	Ctenidae	1	1	24
2	Corinnidae	1	1	9
3	Lycosidae	3	6	104
4	Salticidae	4	4	75
5	Sparassidae	1	1	35
6	Oxyopidae	2	2	48
7	Oonopidae	1	1	22
8	Tetragnathidae	1	1	15
Total	8	14	17	332

Table 3. Total number of families, genera, species and individuals recorded from Thevackal, Cochin, Kerala

SI.No	Family	No.of Genera	No.of Species	No. of individuals sampled
1	Araneidae	1	1	20
2	Ctenidae	1	1	21
3	Corinnidae	1	1	16
4	Cryptothelidae	1	1	35
5	Gnaphosidae	1	1	15
6	Linyphidae	1	1	19
7	Liocranidae	1	1	22
8	Lycosidae	3	7	120
9	Salticidae	3	3	44
10	Sparassidae	1	1	27
11	Oxyopidae	1	2	29
12	Oonopidae	1	1	12
13	Tetragnathidae	2	2	19
14	Theraphosidae	1	1	17
Total	14	19	24	416

A total of 233 individuals belonging to 11 species 10 genera and 8 families were sampled from the Urban area- Mangalavanam, 332 individuals belonging to 17 species 14 genera and 8 families were sampled from the semi- urban area- Hill palace, and a total of 416 individuals belonging to 24 species 19 genera and 14 families were sampled from the rural area- Thevakkal during the study period. Family Salticidae was represented by 4 species belonging to 4 genera. Monotypic families included Corinnidae, Ctenidae, Araeneidae, Gnaphosidae, Oonopidae, Sparassidae, Cryptothelidae, Linyphidae etc.

Numerically dominant family was Lycosidae with a collection of 67 individuals belonging to 3 species, 2 genera from Mangalavanam,104 individuals belonging to 6 species and 3 genera from Hill palace and 120 individuals belonging to 7 species and 3 genera from Thevackal. Family Tetragnathidae was represented by 44 individuals belonging to 2 species, 2 genera from Mangalavanam. Family Salticidae was represented by 75 individuals belonging to 4 species, 4 genera from Hill palace. The other important families recorded during the investigation were Oxyopidae and Sparassidae. In the rural area Thevackal, Family Saltcidae was represented by 44 individuals belonging to 3 species, 3 genera. Family Cryptothelidae was represented by 35 individuals, and Family Oxyopidae was also represented by 29 individuals belonging to 2 species.

At the species level, Lycosa mackenziei (Family Lycosidae) was the most abundant species with a total collection of 47 individuals (Table1.1) from Mangalavanam, followed by Dysciriognatha dentata (Family Tetragnathidae) with a total collection of 23 individuals, and Zelotes sp. (Family Gnaphosidae) with a total collection of 22 individuals.

In the Hill palace, at the species level, Heteropoda sp. (Family Sparasidae) was the most abundant species with a total collection of 35 individuals, followed by Lycosa mackenzie (Family Lycosidae) with a total collection of 33 individuals, and Stenaelurillus sp. (Family Salticidae) with a total collection of 29 individuals. In Thevackal , at the species level Cryptothela sundaica (Family Cryptothelidae) was the most abundant species with a total collection of 35 individuals, followed by Lycosa mackenzie (Family Lycosidae) with a total collection of 30 individual, Pardosa birmanica (Family Lycosidae) with a total collection of 29 individuals and Heteropoda sp. (Family Sparasidae) with a total collection of 27 individuals.

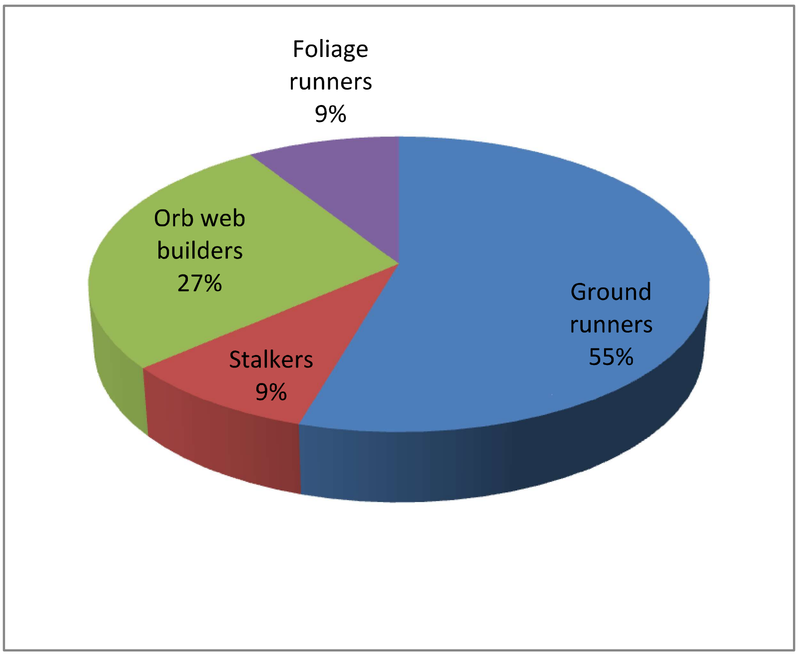
The various ecological indices (Shannon- Weiner index, Simpson's index, Margale' index, Evenness index), as well as species richness for the three different study sites were computed and the results are given in Table 2.1. Among the study sites, Thevackal recorded the highest Shannon-Weiner and Margalef's richness indices of 4.23 and 3.814 respectively. In the Hill palace, recorded the highest Simpson's index of 0.191.Mangalavanam recorded the highest Evenness index of 0.0078, and lowest Evenness index is 0.0013 in Thevackal.

Table 4. Species diversity measures of spiders recorded from Mangalavanam, Hill palace and Thevackal.

SI NO	Diversity Indices	Mangalavanam	Hill palace	Thevackal
1	Total no. of individuals (N)	233	332	416
2	Total no. of species (S)	11	17	24
3	Margalef's index $\{d = (S - 1)\vert lnN\}$.	1.834	2.756	3.814
4	Shannon Wiener Index, $H' = -\sum p_i \log p_i$	3.234	3.366	4.996
5	Simpson index, $D = [\sum n_i (n_i- 1)]/ [N (N-1)]$	0.161	0.191	0.126
6	Evenness index, $e = \{H' \vert \log S\}$	0.0078	0.0014	0.0013

The spiders collected during the study can be classified into 4 ecological guilds based on the foraging mode of the spiders viz., orb web weavers, stalkers, ground runners and foliage runners. Graphical representation of the guild analysis is provided in Fig. 4 and 5. Ground runners, comprised of families Lycosidae, Corinnidae, Gnaphosidae, Oonopidae, Ctenidae, Cryptothelidae, Linyphidae, Liocranidae, were the most dominant guild contributing 55% of the total individuals sampled during this investigation. This was followed by Orb web weavers (27% of the total sample) represented by families Araneidae and Tetragnathidae. Minor guilds included stalkers (9% of the total sample) represented by families Salticidae and Oxyopidae, and Foliage runners (9% of the total sample) represented by family Sparassidae.

Figure 1. Overall guild structure of litter and ground dwelling spiders recorded from three sites.



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 the relative distribution and predatory methods. Describing the spider diversity in terms of these groups allows greater insights into how habitat differences may be reflected in life history strategies. Guilds are ecological groupings of organisms which exploit a single or similar resource in a similar manner (Root, 1967). Recently, spiders have been subdivided into increasingly finer guild systems (Uetz, 1991). Unfortunately, the present paucity of knowledge of foraging methods of some families of spiders makes the development of highly resolved guild systems difficult.

The present system delineates four guilds, based upon gross differences in foraging behavior within the resident spider community. “Ground runners” are those spiders, which mainly feed on ground layer of the field and rarely come to the foliage or canopy of the plant for prey capture. Spiders of the family Lycosidae, Corinnidae, Ctenidae, Gnaphosidae, Salticidae, Sparassidae, Oonopidae, Cryptothelidae, Linyphidae,and Liocranidae constitute this guild. Spiders of the guild “Orb web builders” construct perfect orb webs for prey capture. Spiders of the family Araneidae, Tetragnathidae come under this category. Spiders coming under the category “Stalkers” actively jump over the prey for feeding. Spiders of the family Salticidae, Oxyopidae exhibit this type of feeding behavior.

Analysis of the guild structure of spiders in Mangalavanam, Hill palace and Thevackal revealed that ground runners, represented by families Lycosidae, Corinnidae,Ctenidae,Gnaphosidae, Salticidae, Sparassidae, Oonopidae ,Cryptothelidae, Linyphidae,and Liocranidae were the dominant feeding guild. The structure of the vegetation is expected to influence the diversity of spiders found in the habitat. Vegetation structure seems to influence the spider composition at the family level because similar families cluster within a similar habitat type. Species responses to particular features of the habitat, or complex community interactions, may also indicate the resulting assortment of species (Moran and Southwood, 1982).

The overall trends in abundance of spider community showed correlation with seasons. The highest species occurrence was recorded in the pre-monsoon months (February to May) and the least occurrence was during the monsoon period (June to August). Thus it is clearly evident that seasonality of spiders is directly related to season. This might be attributed to prevailing environmental conditions such as temperature, rainfall, and wind, which affect the availability of prey and occurrence of natural enemies of spiders like parasitic wasps.

It might be expected that climatic changes through seasons would influence the abundance of spiders (Kato et al, 1995). Most spiders are limited to a certain extent by environmental conditions. In general, different species have varying humidity and temperature preferences and are limited to those parts of the habitat which offer a microclimate within the range of their physiological tolerances.

The least spider abundance observed in the monsoon period in the present investigation could be attributed to the unavailability of insects during this season due to incessant rains. Furthermore, inclement weather conditions could have limited the foraging opportunities of themselves forcing them to undergo a period of inactivation.

Studies have demonstrated that a correlation exists between the structural complexity of habitat and population density (Uetz, 1979). Diversity generally increases when a greater variety of habitat types are present which lead to high population density (Hawksworth and Kalil- Arryo, 1995). It has been demonstrated that spiders are extremely sensitive to small changes in habitat structure; including habitat complexity, litter depth and microclimate characteristics. Thus the physical structure of the environments has an important influence on the habitat preferences of spider species.

Urban areas in India are faced with excessive population along with the pressure of unplanned economic development, industrialization, and vehicular emissions. In this paper, present the results of a faunistic survey conducted to document the spider diversity in Mangalavanam, an ecologically threatened urban forest located in the heart of Cochin City in Kerala state, India. Effects of urbanization on ground-dwelling spiders were studied using pitfall traps and hand picking method along an urban-suburban–rural forest gradient in Cochin. The ratio of spider species was significantly higher in the rural sites than in the suburban and urban ones, suggesting that spider species are indeed sensitive to the disturbance caused by urbanization. Canonical correspondence analysis revealed that the species composition changed remarkably along the urbanization gradient.

CONCLUSION

There are many environmental factors that affect species diversity. Some of these factors include seasonality, spatial heterogeneity, competition, predation, habitat type, environmental stability and productivity (Rosenzweig, 1995). Additionally, there are many factors that determine the species composition. This may be related to the changes in the vegetational structure of the habitat. Spider density and diversity is directly related to the structural complexity of the environment. This study has demonstrated that a correlation between the structural complexity of habitat and species diversity. Diversity generally increases when a greater variety of habitat types are present. This study has also shown that wandering spiders such as lycosids respond to depth and complexity of the litter layer. The structure and depth of the litter have shown to be very important factors affecting the density and diversity of litter arthropods. Spider density and diversity increase with higher litter depth and complexity. Litter depth proved to be more important, in the short term, for spiders than nutrient content of the litter. This study shows that the positive correlation between litter depth, litter microclimate stability, and ground spider species richness. This study shows that the number of spider species associated with forest was significantly higher in the rural area than in the sub-urban and urban ones. This is because urbanization has affected the diversity of ground spider. The cause of urbanization is habitat alteration, pollution from vehicles, industries etc, temperature increases, etc. This leads to the decreasing spider diversity in urban area than semi-urban and rural areas.

REFERENCES

Barrion A. T, Litsinger JA (1995) Riceland spiders of South andSouth-East Asia. CA B International UK andIRRI Philippines.

Bray, J.R., Curtis, J.T. 1957. An ordination of the upland forest communities of Southern Wisconsin. *Ecol. Mon.*, 27:325-349.

Coddington, J.A., Young, L.H. and Coyle, F.A. 1996. Estimating spider species richness in a southern Appalachian cove hardwood forest. The Journal of Arachnology, 24: 111-128.

Deeleman-Reinhold, C.L. 2000. Forest Spiders of South East Asia: With a Revision of the Sac and Ground Spiders (Araneae: Clubionidae, Corinnidae, Liocranidae, Gnaphosidae, Prodidomidae, and Trochanterriidae. Brill Academic Publishers. 591 pp.

Dippenaar-Schoeman, A.S. and R. Jocqué. 1997. African Spiders. An Identification Manual. Plant Protection Institute Handbook No. 9. ARC, Plant Protection Research Institute, Pretoria. 392 pp.

Foelix, R. F. 1996. *Biology of spiders*. 2nd ed. Oxford University Press, New York. 330pp.

Hawksworth DL, Kalin-Arroyo MT. 1995. Magnitude and distribution of biodiversity. In: Heywood VH (ed). Global biodiversity assessment. Cambridge UK: Cambridge Univ Pr. p 107–91.

Kato, M., T. Inoue, A.A. Hamid, T. Nagamitsu, M.B. Merdek, A.R. Nona, T. Hino, S. Yamane and T. Yumoto. 1995. Seasonality and vertical structure of light attracted insect communities in a dipterocarp forest in Sarawak. *Res. Pop. Ecol.*, 37: 59-79.

Mcdonnell M.J. & Pickett S.T.A. 1990: Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. — Ecology 71: 1232–1237.

Mcintyre N.E., Rango J., Fagan W.F. & Faeth S.H. 2001: Ground arthropod community structure in a heterogeneous urban environment. Landsc. Urban Plan. 52: 257–274.

Moran, V. C. and Southwood, T. R. E., 1982. The guild composition of arthropod communities in trees. J. Anim. Ecol., 51:289 -306.

Niemela J. 1999: Is there a need for a theory of urban ecology? Urban Ecosyst. 3: 57–65.

Root, R.B. 1967. The exploitation pattern of the blue-grey gnatcatcher. *Ecol. Monog.*, 37: 317-350.

Solow, A.R. 1993. A simple test for change in community structure. *J. Animal. Ecol.*, 62: 191-193.

Tikader BK (1987).Handbook of Indian Spiders.Zoological Survey of India.Calcutta

Uetz, G.W. 1991. Habitat structure and spider foraging. In: McCoy, E,D., S.A. Bell, H.R. Mushinsky (eds). *Habitat structure; the physical arrangement of objects in space*. Chapman and Hall, London. Pp. 325-348.

Wise DH (1993) Spiders in Ecological Webs. Cambridge University Press, Cambridge.

Young, O.P. and G.B. Edwards. 1990. Spiders in United States field crops and their potential effect on crop pests. *J. Arachnol.,* 18: 1-27.