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Diversity of ground-living spiders at Ngome State Forest, Kwazulu/Natal: a comparative survey in indigenous forest and pine plantations

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Summary

A survey of ground-living spiders was conducted over a one-year period at Ngome State Forest, Kwazula/Natal. Five different habitat types: grass, open forest, dense forest, ecotone and pine, were sampled with 180 pitfall traps. The grass, open forest and dense forest represented indigenous vegetation while the pine represented exotic vegetation. The ecotone consisted of a mixture of indigenous forest plants and pine trees. Pine had the lowest spider diversity while grass had the highest spider diversity. However, variation in spider diversity within habitat types was considerable and an analysis of variance found no significant difference in mean values of spider diversity between habitat types. Consequently, the results do not unambiguously support the hypothesis that exotic vegetation has lower ground-living spider diversity than indigenous vegetation.

Key words: spiders, Araneae, diversity, indigenous forest, pine

Résumé

On a mené pendant un an une étude sur les araignées vivant sur le sol de la Ngome State Forest, au Kwazulu/Natal. On a testé cinq types d'habitats différents avec des pièges: l'herbe, la forêt ouverte, la forêt dense, l'écotone et la pinède. L'herbe, la forêt ouverte et la forêt dense présentaient une végétation indigène tandis que la pinède représente une végétation exotique. L'écotone consiste en un mélange de plantes forestières indigènes et de pins. La pinède renferme la plus faible diversité d'araignées et l'herbe, la plus haute diversité. Cependant, la variation de diversité des araignées à l'intérieur des types d'habitat était considérable, et une analyse de la variance n'a pas montré de différence significative dans les valeurs moyennes de diversité des araignées entre les types d'habitat. Par conséquent, les résultats ne supportent pas sans ambiguïté l'hypothèse selon laquelle la végétation exotique présente une plus faible diversité d'araignées vivant au sol que la végétation indigène.

Introduction

Species abundance and the variation of this phenomenon in different ecological communities have fascinated ecologists over the years. The mathematical

description of these patterns has led to theories concerning community diversity, environmental stability, prey-predator ratios, species-area relationships, resource partitioning and evolutionary processes (e.g. Hutchinson, 1953; Whittaker, 1965, 1972; McNaughton & Wolf, 1970; Leigh, 1990; Lockwood, Christensen & Legg, 1990). In recent decades human-induced changes to the environment and the concomitant effects on species diversity have been a subject of growing concern. Examples of the effects of human disturbance on spider communities include studies of industrially polluted areas in Holland (Deeleman-Reinholdt, 1990), pesticide spraying in agroecosystems (van den Berg, Dippenaar-Schoeman & Schoonbee, 1990) and burning of heathland habitat (Merret, 1976). The results of these studies seem to suggest that spider communities are especially sensitive to chemical pollution (e.g. Deeleman-Reinholdt, 1990) as well as any alteration of plant structure in their habitats (e.g. Canard, 1990; Gibson, Hambler & Brown, 1992).

In many areas of Africa the planting of exotic trees has superseded indigenous forest. This has an effect on plant structure at ground level, which should have an effect on the community structure of the ground-living spider fauna. Since spiders were shown to be important components of forest floor ecosystems (Moulder & Reichle, 1972), this could have significant effects on other invertebrate groups and plants as well.

Compared with areas in the northern hemisphere, ecological surveys of the African spiders are particularly sparse. Studies employing pitfall traps and where data have been quantified, are a subset of the already meagre amount of information available on the topic. Surveys of spider communities of savanna in Ivory Coast and miombo woodland in Zaïre have been published (Blandin, 1971, 1972; Malaisse & Benoit, 1979; Blandin & Célérier, 1981). Russel-Smith, Richie & Collins (1987) reported on surface-active spiders of arid bushland in Kenya. Russell-Smith (1981) published the findings of a one year study on the surface-active spiders in two habitat types, namely mopane woodland and floodplain grassland, in Botswana.

Little is known about the ground fauna of South Africa. Van den Berg & Dippenaar-Schoeman (1988) published results of a survey of spiders in a pine plantation near Sabie that covered an eight-month period. Van den Berg & Dippenaar-Schoeman (1991) reported on ground-living spiders associated with termites in a grass habitat in Pretoria, while Lotz, Seaman & Kok (1991) conducted a one-year study on spiders in grass in the Free State Province.

Present knowledge of the African spider fauna is largely restricted to taxonomy, and even taxonomic studies have only scratched the surface of the rich fauna. Studies concerning ecological, agricultural and evolutionary issues are distressingly scarce. The number of qualified workers in the field of African arachnology is restricted to only a handful of workers, most of whom are based on other continents. This paper forms part of a series of papers on the ground-living invertebrate communities of Ngome State Forest and aims to make a contribution towards a better understanding of African spider ecology. This aim is achieved through comparing the diversity of ground-living spider communities in grass patches, indigenous forest and pine plantations.

Materials and methods

Study site

Ngome State Forest (27° 49′ South, 31° 26′ East) is situated on the escarpment of northern Kwazulu/Natal, South Africa. The altitude of the area varies between 405 and 1365 m a.s.l. The Ntendeka Wilderness Area forms the larger part of Ngome's indigenous subtropical forest. This area covers 5230 ha of which 2636 ha is indigenous forest and the rest natural grassland. Outside the borders of the Wilderness Area, large areas of exotic pine plantations have replaced indigenous forest and grassland to make up the remainder of the State Forest.

The veld type of the area is northeastern mountain sourveld (Acocks, 1988). The climax of this veld type is high forest (heights of up to 30 m), and although extensive patches of forest still survive in Natal and the eastern Transvaal, most of it has been replaced by sour grassveld (Acocks, 1988). Ngome forest was intensively logged before 1903.

Rainfall averages 1507 mm/year (1959–1992) with January being the wettest (227 mm) and June the driest (26 mm) months of the year. During the study period (1992) the recorded rainfall (839 mm) was the lowest since 1959, when rainfall measurements were first recorded for this area. The mean maximum temperature is 26.6 °C in January/February and 18.6°C in June/July.

Pitfall traps

One-hundred-and-eighty pitfall traps consisting of a plastic container (10 cm-diameter) sunk to ground level with a funnel leading to a honey jar filled with 95% 70%-alcohol and 5% glycerol were used. Traps were spaced 5 m apart in a 3 × 3 grid pattern. Twenty grids containing nine pitfall traps each were divided between five habitat types giving four independent grids to sample each habitat type. Contents of traps in the same grid were pooled to give one sample. Traps were open continuously and were cleared in the middle of each month starting in January 1992 and ending in January 1993.

The contents of pitfall traps were sorted by hand under a dissection microscope. Spiders were first sorted into morphological species after which taxonomic identification was carried out as accurately as possible by the second author. Voucher specimens are sorted in the National Collection of Arachnology at the Plant Protection Research Institute in Pretoria.

Habitat types

Five apparently different habitat types were sampled. Cluster analysis showed the sampling grids to cluster according to habitat type and that the habitat types support different spider communities (van der Merwe 1994). The chosen grass patches (grids 1A, 1B, 1C and 1D) were glades surrounded by indigenous forest to maximize the possibility of successful invasion by forest animals. 'Open forest' (grids 2A, 2B, 2C and 2D) was characterised by the absence of significant undergrowth, while in 'dense forest' (grids 3A, 3B, 3C and 3D) undergrowth as dense as possible without making human movement impossible, was selected. In both these forest habitat types the canopy was closed. The 'ecotone' (grids 4A, 4B, 4C and 4D) was a mature pine plantation surrounded by indigenous forest. Indigenous forest vegetation has penetrated this plantation and created a habitat with elements of both exotic and indigenous vegetation. The 'pine' habitat (grids 5A, 5B, 5C and 5D) was not directly surrounded by indigenous forest. No trapping sites were closer than *c.* 30 m, and no sites were further than *c.* 8 km apart.

Statistical analysis

The widely used diversity indices of Shannon and Simpson were calculated for different sampling grids as well as for different habitat types. Diversity indices for different habitat types were calculated after data from different sampling grids within habitat types were pooled. Linear regressions were performed on Shannon's and Simpson's diversity and evenness indices. When Shannon's diversity index is calculated for a number of samples the values will be normally distributed (Taylor, 1978), which makes it possible to use analysis of variance (ANOVA) methods (Magurran, 1988). Values for Shannon's diversity indices of sampling grids were subjected to a single classification ANOVA.

Results

Numbers of trapped spiders

A total of 9360 spiders was trapped over the one year period. The number of spiders trapped per sample (where one sample is represented by the total catch of one sampling grid for a specific month) ranged from four spiders collected during January/February in grid 3C (dense forest) and four spiders during February/March in grids 1A (grass) and 1B (grass), to 141 spiders collected during December/January in grid 5C (pine). The mean number of spiders trapped in sampling grids was 39.00 (N=240, S=24.93). The number of spiders trapped in a habitat type and a specific month (the sum of four samples), ranged from 32 spiders trapped during July/August in dense forest to 412 spiders trapped during December/January in pine. The mean number of trapped spiders per month in habitat types was 156.00 (N=60, S=81.04). The total number of spiders trapped over the year sampled per habitat type ranged from 1225 individuals in dense forest to 2781 individuals in pine, with an average of 1859.40 in all habitat types (N=5, S=558.47).

The number of spiders collected monthly in all habitat types ranged from 292 in July/August to 1427 in December/January; the mean number of spiders trapped per month was 780.00 (N=12, S=297.20). Two peaks were observed, a lesser one in April/May and a larger one in December/January. Numbers were relatively low during the winter period with August yielding the lowest number of trapped spiders. The same seasonal pattern held for individual grids and for different habitat types.

Diversity

Results for species diversity of sampling grids are summarised in Table 1. Diversity indices for individual sampling grids gave variable results. Analysis of

Table 1. Shannon and Simpson's diversity and evenness indices and species richness for sampling grids based on spider abundance at Ngome State Forest (1992/1993)

Grids	Diversity indices Shannon	Diversity indices Simpson	Evenness indices Shannon	Evenness indices Simpson	Species richness
1A	1.135	0.911	0.770	0.533	51
1B	1.212	0.892	0.752	0.553	41
1C	1.112	0.857	0.669	0.516	46
1D	1.189	0.888	0.689	0.510	53
2A	1.157	0.889	0.700	0.538	45
2B	1.018	0.796	0.645	0.504	38
2C	1.237	0.897	0.777	0.564	39
2D	1.233	0.900	0.750	0.548	44
3A	1.112	0.882	0.739	0.586	32
3B	1.173	0.882	0.727	0.547	41
3C	1.256	0.914	0.827	0.602	33
3D	1.166	0.897	0.749	0.577	36
4A	1.022	0.849	0.679	0.564	32
4B	1.038	0.874	0.774	0.651	22
4C	1.089	0.873	0.695	0.557	37
4D	1.165	0.909	0.781	0.610	31
5A	0.773	0.749	0.553	0.536	25
5B	0.760	0.726	0.537	0.513	26
5C	1.211	0.915	0.737	0.557	44
5D	1.187	0.910	0.736	0.564	41

Table 2. Shannon and Simpson's diversity and evenness indices and species richness for habitat types based on spider abundance at Ngome State Forest (1992/1993)

Habitats	Diversity indices Shannon	Diversity indices Simpson	Evenness indices Shannon	Evenness indices Simpson	Species richness
Grass	1.353	0.912	0.694	0.468	89
Open forest	1.279	0.900	0.686	0.483	73
Dense forest	1.294	0.914	0.731	0.516	59
Ecotone	1.179	0.901	0.690	0.528	51
Pine	1.134	0.874	0.626	0.482	65

variance failed to detect any significant differences (at the 95% level) in the means of Shannon's diversity indices for grids between the habitat types (P=0.2190). The pine plantation represented by grids 5A and 5B had conspicuously low richness and diversity. Grid 5B had the lowest values for both Shannon's and Simpson's diversity indices. Grid 3C (dense forest) had the highest value for Shannon's index and grid 5C (pine) had the highest value for Simpson's index.

Results for species diversity of the various habitat types (where data from sampling grids within habitat types are pooled) are summarised in Table 2. When Shannon's index was used, grass showed the highest diversity, and pine the lowest. Simpson's index gave the highest value for dense forest and again the lowest value for pine.

Table 3. The families of spiders trapped at Ngome State Forest (1992/1993) and the number of species and individuals trapped for each family in all habitat types combined

Family	Number of species	Number of spiders	Family	Number of species	Number of spiders
Agelenidae	1	3	Microstigmatidae	2	184
Amaurobiidae	4	347	Mimetidae	1	3
Anapidae	4	312	Oonopidae	5	114
Araneidae	1	1	Orsolobidae	3	51
Archaeidae	1	20	Palpimanidae	1	38
Caponiidae	1	31	Philodromidae	2	11
Clubionidae	5	38	Pholcidae	5	74
Corinnidae	13	366	Pisauridae	1	3
Ctenidae	1	1318	Salticidae	12	197
Cyatholipidae	2	17	Scytodiae	5	175
Cyrtaucheniidae	2	339	Selenopidae	2	62
Gnaphosidae	5	83	Tetragnathidae	4	239
Hahniidae	1	688	Theridiidae	15	365
Heteropodidae	4	13	Theridiosomatidae	1	160
Linyphiidae	11	2528	Thomisidae	4	7
Liocranidae	2	1360	Zodariidae	5	176
Lycosidae	10	37	TOTAL	136	9360

Values for species richness and evenness for sampling grids are given in Table 1. Grid 1D (grass) had the highest richness (53 species), while grid 4B (ecotone) had the lowest richness (22 species). Shannon's evenness index was highest for grid 3C (dense forest) and lowest for grid 5B (pine). Simpson's evenness index was highest for grid 4B (ecotone) and lowest for grid 2B (open forest).

Species richness and evenness for habitat types are given in Table 2. Grass had the highest richness and ecotone the lowest. Forest and pine habitats had intermediate values. Shannon evenness was highest for dense forest and lowest for pine. Simpson evenness was highest for ecotone and lowest for grass.

A linear regression for the values of the two diversity indices calculated for sampling grids showed that they are closely correlated ($r^2=0.881506$). A linear regression for the values of the two evenness indices for sampling grids showed a poor correlation ($r^2=0.410104$).

Table 3 provides names of all the families, the number of species representing each family and the number of individual spiders representing each family for all habitat types combined. The combined pitfall catch of spiders for all habitat types represented 33 families and 136 species. The family Theridiidae was represented by the most species, while nine families were represented by only one species. The family Linyphiidae was numerically the dominant family (27% of the total number of trapped spiders). The only other families represented by more than one thousand individuals were the families Liocranidae and Ctenidae. Table 4 gives the number of spider families trapped in each habitat type. The highest number of families was trapped in grass habitat and the lowest number of families in dense forest and ecotone habitats.

Habitat type	Number of families trapped
Grass	28
Open forest	26
Dense forest	24
Ecotone	24
Pine	26

Table 4. The number of Spider families trapped in each habitat type at Ngome State Forest (1992/1993)

Discussion

Diversity measures can be divided into Type I and Type II indices. Type I indices are more sensitive to species richness and Type II indices are more sensitive to dominance (changes in the abundance of the most common species). The most widely used Type I and Type II indices are Shannon's and Simpson's indices, respectively (Magurran, 1988). There is suspicion about the usefulness of diversity indices, since there is a possibility for confusion arising out of the fact that diversity consists of two separate concepts; richness and evenness. It is therefore advisable to look at the components of diversity separately, and to be aware of conflicting results when using different diversity and evenness indices. However, regression analysis for the diversity indices used in this study shows a good correlation ($r^2=0.88$) which implies that these indices give relatively unambiguous results. The same cannot be said for the evenness indices which show a weak correlation ($r^2=0.41$). Species richness is a straightforward measurement when sample sizes are equivalent (as in this study).

Since grass shows the highest species richness (89 species) it is not surprising that it has the highest value for Shannon's diversity index. Evenness for grass is not particularly high and the dense forest habitat, which has high evenness, scores the highest value for Simpson's diversity index. At the other end of the scale pine habitat has the lowest value for both diversity indices. However, results of analysis of variance show these differences not to be significant. Therefore, the variability in diversity for individual sampling grids within habitat types caused the failure of this study to demonstrate the negative effect of exotic pine plantations on ground-living spider diversity. The results suggest that diversity varies considerably on a spatial (and possibly temporal) scale within habitat types.

When Simpson's index is used, both the least diverse (5B) and most diverse (5C) sampling grids are found to represent pine habitat. The conspicuously low diversity in grids 5A and 5B may be due to successional changes in diversity in pine habitats of different size and age. Sampling grids 5A and 5B represent a slightly older pine plantation, with taller trees, than sampling grids 5C and 5D, which have relatively high species richness and diversity. There is a suggestion in the results that older pine habitats with larger trees, may become progressively inhospitable for some spider species. However, not enough successional stages were sampled to make unambiguous statements concerning succession. A study on these aspects should be a productive line of future research.

Though not significant, the tendency for the grass habitat to have the highest diversity (and species richness) may be explained by the fact that this habitat type covers a much larger surface area than the forested habitats in the study region. Large areas can support larger population sizes, which in turn are less prone to extinction due to stochastic processes (Franklin, 1980; Gilpin & Soulé, 1986). Though the grass patches chosen for sampling are surrounded by indigenous forest, the exceptional dispersal ability of many spiders (Wise, 1993) may counter the effect of small-scale local extinctions, so that diversity is maintained. Another possibility may be that pronounced edge effects found in patchy habitats may lead to greater arthropod diversity (Nentwig, 1988). However (as mentioned before), differences in diversity between habitat types were not statistically significant, and the above arguments should be considered accordingly.

Using family number as a measure of diversity has limited value, since the resolution of this measure is much lower than that of species diversity or richness indices. However, the different habitat types do not show large differences in the number of trapped spider families which agree with the results from the species diversity indices. Also, in concordance with results from species diversity, the highest number of families was recorded for grass habitat.

Due to the large variation in spider diversity within habitat types, the results from this study do not unambiguously support the notion that exotic habitats (e.g. pine) have lower ground-living spider diversity than indigenous habitats (e.g. indigenous forest and grass). Cluster analysis of the sampling grids have shown that different habitat types support different spider assemblages (van der Merwe 1994). Although the lowering of plant species diversity and the introduction of exotic plants due to human influence affect the community structure of ground-living spiders, these factors seem to play a lesser role in determining the diversity of their communities in southern African forests.

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