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A COMPARATIVE SURVEY OF CURSORIAL SPIDER  
COMMUNITIES IN INDIGENOUS AFROMONTANE FORESTS  
AND IN PINE PLANTATIONS

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**A comparative survey of cursorial spider  
communities in indigenous afro-montane  
forests and in pine plantations.**

by

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## **PART I: INTRODUCTION, MATERIALS AND METHODS**

### **CHAPTER 1**

#### **INTRODUCTION**

##### **1.1 Spiders in Africa**

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 only 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; Blandin & Célérier 1981; Malaisse & Benoit 1979). Russel-Smith, Ritchie & 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, Mopane woodland and floodplain grassland, in Botswana.

In South Africa van den Berg & Dippenaar-Schoeman (1988) published results of an eight month long survey of spiders in a pine plantation near Sabie. Van den Berg & Dippenaar-Schoeman (1991) reported on ground-living spiders in grass habitat in Pretoria while Lotz, Seaman & Kok (1991) conducted a one year study on spiders in grass in the Orange Free State.

Several surveys of natural areas in South Africa were undertaken using other collecting methods. Unfortunately these studies are not directly comparable to pitfall studies, due to differences in what is measured with different trapping techniques. Dippenaar-Schoeman, van den Berg & van den Berg (1989) collected spiders over a four year period with a sweepnet in savanna and

grass, while spiders from *Protea* spp. were collected by Coetzee, Dippenaar-Schoeman & van den Berg (1990). Collecting spiders in the Mountain Zebra National Park led to a checklist of spiders found there (Dippenaar-Schoeman 1988).

Surveys of South African agroecosystems include work on spiders in strawberry beds near Pretoria (Dippenaar-Schoeman 1977, 1979) and a survey in cotton fields near Brits (van den Berg, Dippenaar-Schoeman & Schoonbee 1990, van den Berg & Dippenaar-Schoeman 1991). Pitfall traps were not used.

Our 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 medical 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 has produced the situation where even the most basic distributional information is lacking for most species.

## **1.2 Forests in South Africa**

A fraction of South Africa's surface area (0.2% or less than 3000 km<sup>2</sup>) is covered by high evergreen forest (Lawrence 1953; Huntley 1984). Areas previously covered by undisturbed indigenous forests have been drastically altered. Pine plantations are one example where indigenous vegetation is being replaced by exotic vegetation. Other examples include clearing for agriculture, subsistence farming and veld burning practices (Geldenhuys & MacDevette 1989). In many localities only scattered remnants of the original forests have survived in inaccessible corners. Southern African forests are very fragmented and the large ratio of forest margin to forest area point to the important role

played by the ecotonal areas in understanding forest dynamics (Geldenhuis & MacDevette 1989). Fortunately, however, a few areas remain where concerned authorities have attempted to preserve the grandeur of continuous southern African forest.

Evergreen forests in South Africa show close affinities with the larger tracts of rain forests found in tropical Africa (Lawrence 1953; Geldenhuis & MacDevette 1989), though the largest trees are never as high as the trees closer to the equator and canopy stratification is less marked. However, all characteristics which have been described as typical for African rain forests are present in the temperate forests as well, though to a lesser degree. Lawrence (1953) speculated that "South African forests can thus be described as southern outliers of the Central African forest zone and have probably been derived from them by way of Natal and Zululand along a southwestward curve of migration parallel to the Southern coastline of South Africa and ending in the Cape Peninsula". Rivers and moist valleys along mountain ranges probably acted as lanes of dispersal for forest immigrants from the North (Lawrence 1953).

Though relatively large forested areas may give the impression of self-sufficiency, management to counter external threats is usually necessary to achieve the objectives of conservation. Ngome State Forest in northern Natal is but one of many examples of this situation. Bordered by the vast pine plantations of the escarpment, Ngome's ca 2500 ha of indigenous forest provide an island haven for its native fauna and flora. Contrasting with this are the pine plantations in the area that provide a profile of communities stressed by human intervention.

### **1.3 The community in ecology**

Some early efforts to group organisms can be found in



Theophrastus's (372-288 BC) description of plant distribution in relation to altitude and also in the natural histories book of Plinius (23-79 BC) (Anderson & Kikkawa 1986). Later on in biological history plant geographers were the first to discuss an underlying order in vegetation cover. An attempt was made to subdivide vegetation into different plant 'communities' (for a more extensive discussion see Anderson & Kikkawa 1986). At the turn of the century biologists had already distinguished between autecology and synecology when dealing with the social structures of animal and plant populations. In 1933 the Committee on Nomenclature of the Ecological Society of America accepted communities as "a general term to designate sociological units of every degree from the simplest (as an unrooted mat of algae) to the most complex biocoenosis (as a multistorey rain forest)." Using Tokeshi (1993) as an example, the modern definition of an ecological community may be given as "an assemblage of populations of animal and plant species living together in an area". Similar definitions are to be found in popular textbooks on the topic (e.g. Krebs 1985; Begon, Harper & Townsend 1990). However, Tokeshi (1993) also discusses various potential problems which can arise due to the vagueness of the concept. These difficulties have always plagued community studies and should always be born in mind, especially when the results of different studies using different collecting methods are compared.

A widely held view among modern ecologists can be summed up in the words of Robert Whittaker (1975) that "much ecological understanding can be integrated also around the concepts of communities as assemblages of different species which interact with one another, and ecosystems as functional systems formed by communities and their environments" (cited by Anderson & Kikkawa 1986). Usually groupings of species forming functional units (sharing general resources, reproducing and surviving interactively in a localised setting) form the basis for

community ecology. The community has become one of the most frequently used concepts in ecological literature.

#### **1.4 Objectives of community ecological studies**

Community ecological studies progress from being purely descriptive towards the understanding of community structure and ultimately providing predictive theories and management tools (Gauch 1982). The following list taken from Gauch (1982) reflects the full extent of this process:

##### **A. Description:**

- (1) Description of a given community.
- (2) Delimiting and naming of communities.
- (3) Mapping of communities within a region.
- (4) Identification of recurring species groups.
- (5) Assignment of new community samples to previously defined community types.

##### **B. Understanding:**

- (1) Structure of communities.
- (2) Regulation and maintenance of communities.
- (3) Distribution of species and communities along environmental gradients.
- (4) Competitive interactions among species.
- (5) Species niches and habitats.

##### **C. Prediction and management:**

- (1) Prediction of community from environment or environment from community.
- (2) Prediction of course of succession or response to disturbance.
- (3) Land use recommendations.
- (4) Management of grazing, forest, and recreational areas.
- (5) Relating community data to other data bases (fire, harvesting, weather).
- (6) Data reduction for inventory.

## 1.5 Objectives of the spider survey at Ngome State Forest

Based on Gauch's (1982) analysis of the objectives of community ecological studies, the following list of aims for this particular study shows the extent to which Gauch's aims were realised.

The aims set for this study can be divided into three sections. Following is a brief description of each and the ways in which they were accomplished:

A. Ecological survey of the cryptic, ground-living spider fauna at Ngome State Forest, northern Natal.

- (1) Compilation of species list.
- (2) Classification of spider communities in different habitat types (by performing a cluster analysis on the data set).
- (3) Ordination of spider communities in different habitat types (by performing principal components analysis and detrended correspondence analysis on the data set).

B. Comparison of communities from indigenous forest with those of commercial pine plantations.

- (1) Compare diversity indices.
- (2) Calculate distance coefficients (part of cluster analysis).
- (3) Test for disturbance by fitting rank-abundance curves to different communities.

C. Identification of community ecological patterns for the creation of relevant hypotheses

- (1) Phenological patterns.
- (2) Species rich vs. species poor habitat types.

From the above it can be seen that this survey provides most of the descriptive background of the investigated community (according to Gauch's list), in this case ground-active spiders. The identification of certain ecological patterns represents a step towards the understanding of community structure. Combining the results of this study with other databases and management plans will make a contribution to the third and final aim of community ecological studies: prediction and management.

## **CHAPTER 2**

### **STUDY AREA, MATERIALS AND METHODS**

#### **2.1 Study area**

Ngome State Forest is situated on the escarpment in northern Natal ( $27^{\circ}49'$  South,  $31^{\circ}26'$  East). The Ntendeka Wilderness Area includes the larger part of Ngome's indigenous tropical forest. The Wilderness Area covers 5230 ha of which 2636 ha is indigenous forest and the rest grassland. Outside the borders of the Wilderness Area large areas of exotic pine plantations make up the remainder of the State Forest.

The veld type of the area is classified as north-eastern mountain sourveld (Acocks 1988). The climax of this veld type is high forest, 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). The Ngome State Forest contains tree species typical of both 'inland tropical forest' and 'mist belt mixed podocarpus forest'. The forest was last intensively logged prior to 1903 and the canopy reaches heights of up to 30 m in some areas.

Rainfall averages 1470 mm/year (1973-1985) with January the wettest (232 mm) and June the driest (15,5 mm) months of the year. Maximum temperature averages  $26,6^{\circ}\text{C}$  in January/February and  $18,6^{\circ}\text{C}$  in June/July. Altitude varies between 405-1365 metres above sea level.

#### **2.2 Habitat types**

The structural richness of the entire forest habitat made the sampling of all plant layers ineffectual for one person.

Attention was therefore focused on one part of the community complex, namely the forest floor. All organisms contribute to the energy relationships of the ground and many animals which do not normally occur at ground level visit the forest floor as transients (Williams 1959).

For the purposes of this study 5 different habitat types were chosen. These were the following:

- (1) Grass
- (2) Open forest  
(indigenous)
- (3) Dense forest  
(indigenous)
- (4) Ecotone (pine)
- (5) Pine

Grass habitat consisted of glades surrounded by indigenous forest in order to maximize the possibility of successful invasion by forest animals. 'Open forest' was characterised by the absence of significant undergrowth while the 'dense forest' was chosen with undergrowth as thick as possible without making human movement impossible. In both these habitat types the canopy was closed. The 'ecotone' was a small pine plantation directly surrounded on three sides by indigenous forest. The pine habitat was not surrounded by indigenous forest, though still in the State Forest area to make comparisons with natural areas meaningful. No trapping sites were further than ca 8 km apart and no trapping sites were closer together than ca 100 metres.

A rough estimate of plant species composition, cover and social grouping of the low-growing plants in each grid was done in order to give a basic description of the five habitat types (Tables 1-5). Each plant species was classified in a cover class and a social grouping class during the summer of 1993. Cover of live plants in winter was lower due mainly to grasses dying off during this period. Only plants covering substantial areas close to

ground surface were considered in these descriptions as they were assumed to be most relevant to ground-living spiders. Six cover-classes and five grouping-classes were used. In order of least cover to most cover the six cover-classes were:

- 1) sparsely present
- 2) plentiful, but of small cover value
- 3) covering at least 5% of area
- 4) covering 25-50% of area
- 5) covering 50-75% of area
- 6) covering more than 75% of area.

In order of increasing sociability the five grouping-classes were:

- 1) isolated individuals
- 2) grouped or tufted
- 3) small patches
- 4) extensive patches
- 5) pure populations.

### **2.3 Pitfall trapping**

A total of 180 pitfall traps were used. A pitfall trap consisted of a plastic container (10 cm diameter) sunk to ground level with a funnel leading to a honey jar filled with Hood's solution (95% 70%-alcohol and 5% glycerol). Traps were spaced 5 m apart in a 3x3 grid pattern. Twenty grids containing 9 pitfall traps each were divided between the habitat types. This gave 4 grids placed in different areas to sample each habitat type. Grids within habitat types were coded as A, B, C, and D respectively. As an example, grid 2C refers to the third grid in the open forest habitat. At times throughout the rest of the thesis this coding system will be used when referring to different grids.

Sampling was done on a continuous basis starting in January 1992 and ending in January 1993. Traps were cleared on the same day

in the middle of each month. 'Jan', for example, stands for the period mid-December 1992 to mid-January 1993. Contents of traps in the same grid were pooled to give one independent sample or sampling unit.

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 done as accurately as possible by a spider taxonomist (A.S. Dippenaar-Schoeman). All voucher specimens are stored in the National Collection of Arachnology at the Plant Protection Research Institute in Pretoria.



**Table 1:** The dominant plant species, dominant plant species's cover and social grouping of dominant plants for the four sampling grids in grass habitat at Ngome State Forest.

GRID NO.	SPECIES	COVER	GROUPING
1A	1. <i>Cynodon dactylon</i> 2. <i>Rynchostria</i> sp. 3. <i>Pteridium aquilinum</i> 4. <i>Brachiaria</i> sp.	Covering more than 75% of area Covering at least 5% of area Plentiful, but small cover value Sparsely present	Extensive patches Small patches Isolated individuals Isolated individuals
1B	1. <i>Cynodon dactylon</i> 2. <i>Rynchostria</i> sp. 3. <i>Pteridium aquilinum</i> 4. <i>Brachiaria</i> sp.	Covering 50-75% of area Covering 25-50% of area Plentiful, but small cover value Sparsely present	Extensive patches Small patches Isolated individuals Isolated individuals
1C	1. <i>Panicum natalensis</i> 2. <i>Watsonia</i> sp. 3. Unidentified sp.	Covering 25-50% of area Covering 25-50% of area Covering 25-50% of area	Grouped or tufted Grouped or tufted Grouped
1D	1. <i>Panicum natalensis</i> 2. <i>Watsonia</i> sp. 3. Unidentified sp.	Covering 25-50% of area Covering 25-50% of area Covering 25-50% of area	Grouped Grouped Grouped

**Table 2:** The dominant plant species, dominant plant species's cover and social grouping of dominant plants for the four sampling grids in open forest habitat at Ngome State Forest.

GRID NO.	SPECIES	COVER	GROUPING
2A	1. <i>Cyperus</i> sp. 2. <i>Pseudo-brachiarta</i> sp. 3. Tree saplings (several species)	Sparsely present Sparsely present Sparsely present	Isolated individuals Isolated individuals Isolated individuals
2B	1. Tree saplings (several species)	Sparsely present	Isolated individuals
2C	1. <i>Oplusminus hirtellus</i> 2. <i>Cyperus</i> sp. 3. Tree saplings (several species)	Sparsely present Sparsely present Sparsely present	Isolated individuals Isolated individuals Isolated individuals
2D	1. <i>Oplusminus hirtellus</i> 2. Tree saplings (several species)	Sparsely present Sparsely present	Isolated individuals Isolated individuals

**Table 3:** The dominant plant species, dominant plant species's cover and social grouping of dominant plants for the four sampling grids in dense forest habitat at Ngome State Forest.

GRID NO.	SPECIES	COVER	GROUPING
3A	1. <i>Pseudobrachiartha</i> sp. 2. Tree saplings (several species)	Covering 25-50% of area Plentiful, but of small cover value	Small patches Isolated individuals
3B	1. <i>Pseudobrachiartha</i> sp. 2. Tree saplings (several species)	Covering 25-50% of area Plentiful, but of small cover value	Small patches Isolated individuals
3C	1. <i>Pseudobrachiartha</i> sp. 2. Tree saplings (several species)	Covering 25-50% of area Plentiful, but of small cover value	Small patches Isolated individuals
3D	1. <i>Pseudobrachiartha</i> sp. 2. Tree saplings (several species)	Covering 25-50% of area Plentiful, but of small cover value	Small patches Isolated individuals

**Table 4:** The dominant plant species, dominant plant species's cover and social grouping of dominant plants for the four sampling grids in ecotone habitat at Ngome State Forest.

GRID NO.	SPECIES	COVER	GROUPING
4A	1. <i>Oplusminus hirtellus</i>	Covering 25-50% of area	Extensive patches
4B	1. <i>Oplusminus hirtellus</i> 2. Tree saplings (several species)	Covering 50-75% of area Sparsely present	Extensive patches Isolated individuals
4C	1. <i>Oplusminus hirtellus</i> 2. <i>Cyperus</i> sp.  Tree saplings (several species)	Covering 50-75% of area Sparsely present Sparsely present	Extensive patches Isolated individuals Isolated individuals
4D	1. <i>Oplusminus hirtellus</i> 2. <i>Galium</i> sp.  3. Unidentified species	Covering 25-50% of area Covering at least 5% of area Covering at least 5% of area	Extensive patches Small patches Small patches

**Table 5:** The dominant plant species, dominant plant species's cover and social grouping of dominant plants for the four sampling grids in pine habitat at Ngome State Forest.

GRID NO.	SPECIES	COVER	GROUPING
5A	1. <i>Oplusminus hirtellus</i>	Covering more than 75% of area	Pure populations
5B	1. <i>Oplusminus hirtellus</i>	Covering more than 75% of area	Pure populations
5C	1. <i>Pennisetum clandestinum</i>	Covering more than 75% of area	Pure populations
5D	1. <i>Pennisetum clandestinum</i>	Covering more than 75% of area	Pure populations

## 2.4 Classification and ordination

Pitfall traps give a measure of both the ground surface activity and density of trapped spider species (Uetz 1977). It is conceivable that spiders typical of other vegetation strata in the forest may occasionally be included in the samples. Certain spider species are known to exhibit vertical migration patterns (Le Sar & Unzicker 1978, cited in Cloudsley-Thompson 1987). This may leave the mistaken impression that these species are less abundant than they actually are. By including only the species of which relatively larger numbers were trapped, these incidental captives were largely eliminated from the data set. For both classification and ordination the data matrix (sampling grids vs species abundance) was reduced to include only those species for which more than 20 individuals were trapped. There were 50 species (out of the original 136 species) with more than 20 trapped individuals and together they represented 93,6% of all collected spiders.

A cluster analysis was performed to classify the grids into similar and dissimilar groups according to the distance coefficients calculated for species assemblages of ground-living spiders [as opposed to similarity coefficients: Ludwig & Reynolds (1988)]. A distance coefficient was calculated for each pairwise combination of grids. The distance coefficient chosen was relative absolute distance (RAD) (Whittaker 1952). When clusters were formed a group average strategy was used with different cluster strategies influencing the values of the parameters (Ludwig & Reynolds 1988).

The first method of ordination used was principal components analysis (PCA). PCA breaks down a resemblance matrix (a matrix consisting of variance-covariance correlations or Euclidean distances) into a set of perpendicular axes or components. Each

axis corresponds to an eigenvalue of the matrix (the eigenvalue being the variance accounted for by that axis). A full account of the steps involved can be found in Ludwig & Reynolds (1988).

The second method of ordination used was detrended correspondence analysis (DCA) (Hill & Gauch 1980). DCA attempts to "correct" for nonlinearities in the analysed dataset, linearity of data being an assumption of PCA. Correspondence analysis, as compared to principal components analysis, seems to perform better in situations where one broad and underlying gradient is to be found (Ludwig & Reynolds 1988). It is recommended that more than one ordination method be applied to an ecological data set in order to gain optimal insight into existing community patterns (Ludwig & Reynolds 1988).

## **2.5 Abundance and diversity**

The relative abundance of each spider species was plotted in order of its rank from most to least abundant. The data were then fitted to the lognormal distribution model. The lognormal distribution is given by:

$$S(R) = S_0 e^{-a^2 R^2}$$

where  $S(R)$  is the number of species in the  $R$ th octave from the mode,  $S_0$  is an estimate of the number of species in the modal octave (the octave with the most species), and parameter  $a$  is an inverse measure of the width of the distribution (Ludwig & Reynolds 1988).

To fit the observed data to the lognormal model the data were arranged in the form of a frequency distribution which gives the number of species in each abundance class or octave. Logarithms

to base two were used so that each class involved a doubling of the number of individuals trapped. This was done after Preston (1948) who was the first to suggest that the lognormal distribution would give the best description of species-abundance patterns.

The lognormal distribution is completely characterized by two parameters,  $S_0$  and  $a$  (Ludwig & Reynolds 1988). An estimation for parameter  $a$  is given by

$$a = \sqrt{\frac{\ln\left[\frac{S(0)}{S(R_{\max})}\right]}{R_{\max}^2}}$$

where  $S(0)$  is the observed number of species in the modal octave and  $S(R_{\max})$  is the observed number of species in the octave most distant from the modal (which is indicated by  $R_{\max}$ ).  $S_0$  can be estimated from

$$S_0 = e^{(\ln S(R) + a^2 R^2)}$$

where  $\ln S(R)$  is the mean of the log rhythms of the observed number of species per octave and  $R^2$  is the mean of the  $R^2$ 's.

The BASIC computer program LOGNORM.BAS (Ludwig & Reynolds 1988) was used for estimating the parameters with the above equations,



and iterating different parameter values ( $a$  and  $S_0$ ) to obtain the best fit to the model for each of the five habitat types. The best fit to the model was obtained by using estimated parameter values, computing the expected lognormal frequencies and then testing the goodness of fit to the model with a chi-square statistic. For this test LOGNORM.BAS (Ludwig & Reynolds 1988) was also used.

As the sample size is usually too small to detect the species in the rarer octaves, these species are supposed to be hidden behind the "veil" line on a lognormal plot (Preston 1948). In other words, the complete "bell" of the lognormal is absent and what is actually observed is a truncated lognormal distribution ending at its crest, which then represents the "veil" line. As the total area under the full lognormal curve represents the total theoretical number of species available for sampling, this number can be calculated from

$$S^* = 1.77 \left( \frac{S_0}{a} \right)$$

where  $S^*$  is the theoretical number of species available. This was calculated for each habitat and then compared with the actual number of species trapped.

Species abundance data for habitat types were plotted as a k-dominance curve. This involves plotting percentage cumulative abundances against the log of species rank. Rank abundance plots using the arithmetic rank and the log abundance were also plotted following the suggestion by Tokeshi (1993).

Shannon's diversity index and Simpson's diversity index are widely used and were calculated as well. Simpson (1949) gave the

first diversity index to be used in ecology. Simpson's index is given by

$$\lambda = \sum_{i=1}^S p_i^2$$

where  $p_i$  is the proportional abundance of the  $i$ th species, given by

$$p_i = \frac{n_i}{N}$$

$i = 1, 2, 3, \dots, S$  and  $n_i$  is the number of individuals of the  $i$ th species and  $N$  is the known total number of individuals for all  $S$  species in the population.

Shannon's index was first used in information theory (Shannon & Weaver 1949) and is now probably the most widely used diversity index in ecology. It is given by

$$H' = - \sum_{i=1}^{S^*} (p_i \ln p_i)$$

where  $H'$  is the average uncertainty per species in an infinite community made up of  $S^*$  species with known proportional abundances  $p_1, p_2, p_3, \dots, p_{S^*}$ . The evenness for the two diversity

indices was calculated and is defined as diversity divided by the log of the number of species. Diversity, richness and evenness were determined for all sampling grids and also for the different habitat types.

## **PART II: RESULTS AND DISCUSSIONS**

### **CHAPTER 3**

#### **CLASSIFICATION AND ORDINATION**

##### **3.1 Introduction**

###### **3.1.1 Multivariate analysis**

Classification and ordination techniques are multivariate methods developed for the analysis and comparison of complex communities. The classification of ecological communities represents one of the first descriptive aims in the progress of community ecological studies. These methods arose out of a need for useful management tools and also by the appeal and importance of undisturbed communities in their natural state (Gauch 1982).

Frequently referred to as 'pattern analysis' multivariate techniques provide a subjective method in the sense that revealed patterns are interactions between properties of data sets and the mind of the investigator (Gauch 1982; Whittaker 1956). The process of classifying entities, whether it is individuals, species, populations or communities, is therefore a human activity judged by its usefulness in understanding nature, rather than a necessary effect of an underlying order of reality.

###### **3.1.2 Difference between classification and ordination**

Classification techniques attempt to group similar entities (in this case sampling units or sampling grids) into groups. The aim of ordination is to reduce the information content of a large and unwieldy data set in order to identify patterns of relatedness among sampling units. It differs from classification mainly in

the sense that its aim is to emphasize possible continuous relationships rather than to classify units into similar groups (Barbour, Burk & Pitts 1987).

### **3.1.3 Pattern analysis**

Data sets are not treated as samples of undefined systems or universes, but rather as entities in their own right. Patterns are therefore never 'correct' or 'incorrect' but only profitable or unprofitable for its users (Williams 1976). Pattern analysis provides a tool for the generation of relevant hypotheses rather than to test hypotheses (Kikkawa 1986).

At the start of the survey the habitat types were identified in a subjective manner. Plant species, plant structure, plant cover, locality etc., made an overall impression on the human observer and grids were placed accordingly. It is obvious, however, that from a spider's vantage point it is possible that differences in habitat type may exist which will influence the assemblage of a spider community, but which will be indiscernible to the human eye. Classifying communities using multivariate analysis provides a tool which can be used to distinguish different communities of organisms in a more objective manner. The data used for clustering represent spider abundances in different sampling grids. Clusters therefore represent different spider communities and not necessarily different plant communities.

## **3.2 Results**

### **3.2.1 Classification**

For the multivariate analysis techniques used in this study (cluster analysis, principal components analysis and detrended correspondence analysis) the data set was reduced to all species

for which more than 20 individuals were trapped. Of the original 136 recorded species 50 species met this criterion. The 50 most abundant species represented 93.6% of all the trapped spiders (see also the chapter on Materials and Methods). An advantage of this approach is that the likelihood of including stray spiders from taller vegetation is minimized.

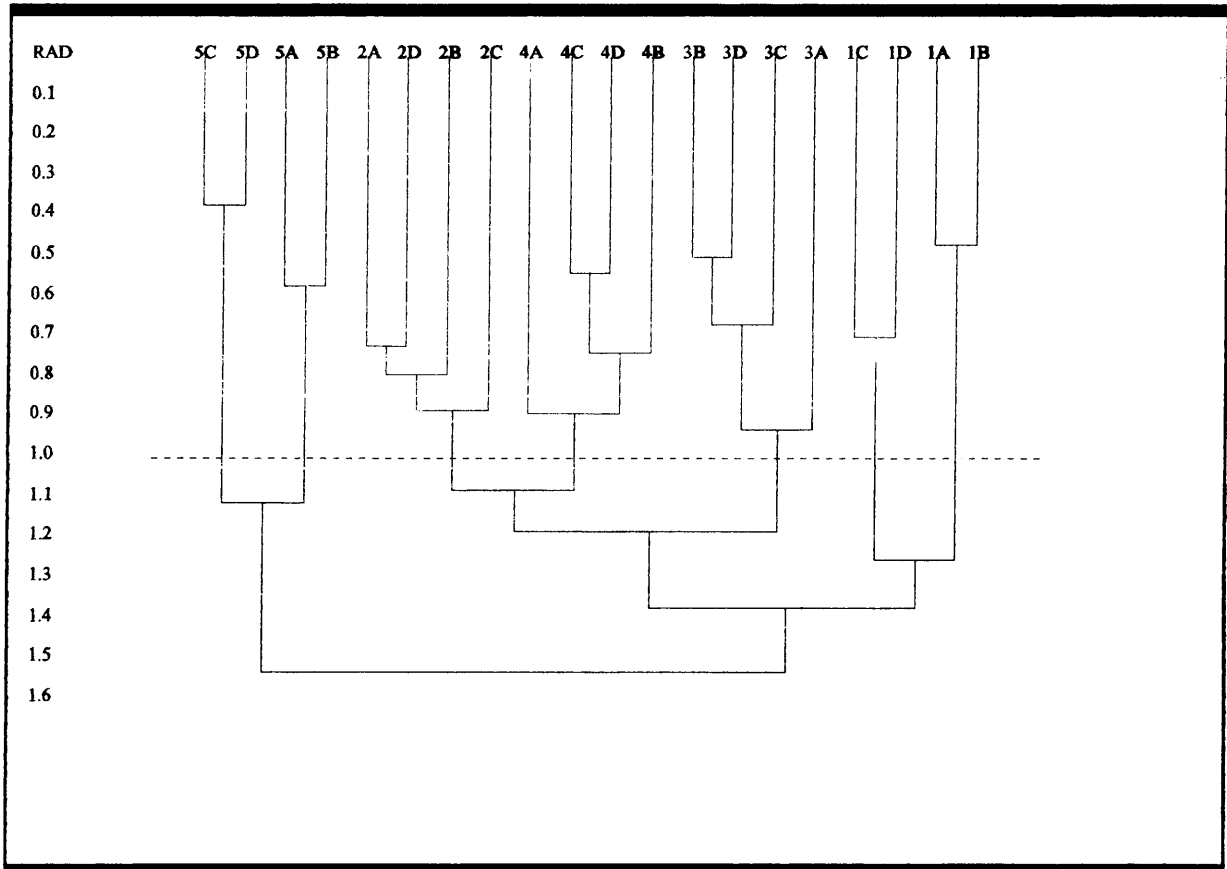
The results of the cluster analysis for sampling grids are given in Table 6. Clustering was done by the group average strategy. The index used was relative absolute distance (RAD) (see Materials and Methods). A graphic representation of the results in the form of a dendrogram is given in Figure 1.

### **3.2.2 Ordination**

The results of the principal component analysis (PCA) for sampling grids are given in Table 7 and are plotted in Figure 2. The first component represents 19.16%, the second component 10.36% and the third component 5.98% of the total variation in the data set. The results of the detrended correspondence analysis (DCA) for spider species are given in Table 8 and plotted in Figure 3. Spider species were coded for graphical presentation and the corresponding species names of code names are given in Appendix A. The corresponding results for sampling grids are given in Table 9 and plotted in Figure 4. The first component represents 22.51% of the variation, the second component 11.17% and the third component 7.21%.

**Table 6:** Cluster analysis for the 20 sampling grids [or sampling units (SU's)] based on spider abundance at Ngome State Forest (1992/1993) using RAD as index and the group average strategy.

Cluster cycle	Number of groups	Cluster level (RAD)	Reference SU	SU's in the group
1	19	0.37	5C	5D
2	18	0.50	3B	3D
3	17	0.54	4C	4D
4	16	0.57	5A	5B
5	15	0.57	1A	1B
6	14	0.67	3B	3C, 3D
7	13	0.70	1C	1D
8	12	0.72	2A	2D
9	11	0.74	4B	4C, 4D
10	10	0.79	2A	2B, 2D
11	9	0.88	2A	2B, 2C, 2D
12	8	0.89	4A	4B, 4C, 4D
13	7	0.93	3A	3B, 3C, 3D
14	6	1.08	2A	2B, 2C, 2D, 4A, 4B, 4C, 4D
15	5	1.11	5A	5B, 5C, 5D
16	4	1.18	2A	2B, 2C, 2D, 3A, 3B, 3C, 3D, 4A, 4B, 4C, 4D
17	3	1.25	1A	1B, 1C, 1D
18	2	1.37	1A	1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D, 4A, 4B, 4C, 4D
19	1	1.53	1A	All SU's form one group.

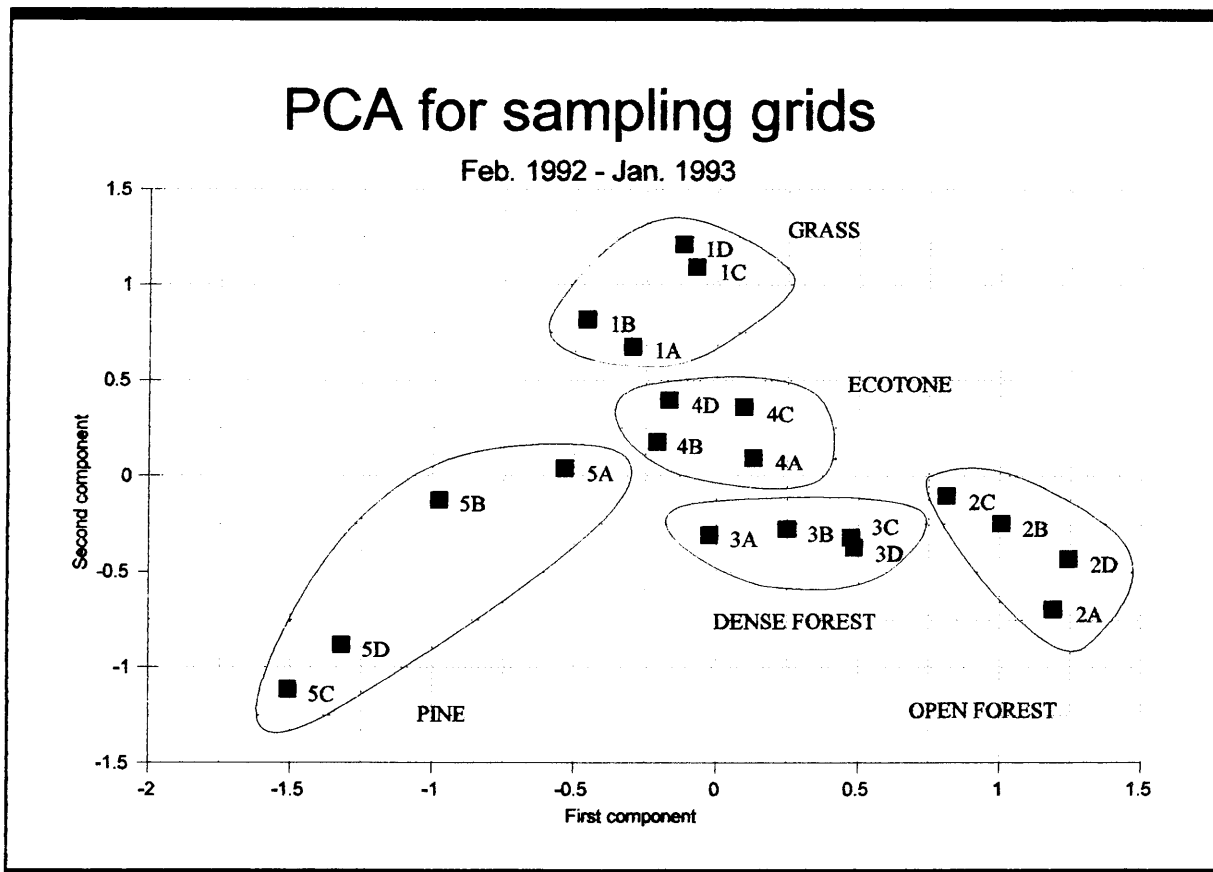


**Figure 1:** Clustering of sampling grids by the group average strategy based on spider abundance at Ngome State Forest (1992/1993). The index used is relative absolute abundance (RAD). The dotted line represents an arbitrary cut-off point for classifying different spider communities.



**Table 7:** Principal components analysis (PCA) of sampling grids (or sampling units) based on spider abundance at Ngome State Forest (1992/1993). Given are the coordinates on the first three components (axes of maximum variation).

Sampling Unit	1 <sup>st</sup> component	2 <sup>nd</sup> component	3 <sup>rd</sup> component
1A	-0.298	0.677	0.104
1B	-0.458	0.819	-0.024
1C	-0.073	1.091	-0.784
1D	-0.119	1.211	-0.141
2A	1.190	-0.693	-0.293
2B	1.007	-0.246	-0.172
2C	0.813	-0.101	-0.106
2D	1.244	-0.432	-0.494
3A	-0.024	-0.307	0.117
3B	0.249	-0.276	0.122
3C	0.474	-0.320	0.144
3D	0.486	-0.373	0.160
4A	0.131	0.094	0.550
4B	-0.209	0.178	0.568
4C	0.096	0.360	0.769
4D	-0.167	0.396	0.736
5A	-0.535	0.041	0.417
5B	-0.978	-0.123	0.548
5C	-1.509	-1.114	-0.637
5D	-1.320	-0.881	-0.583

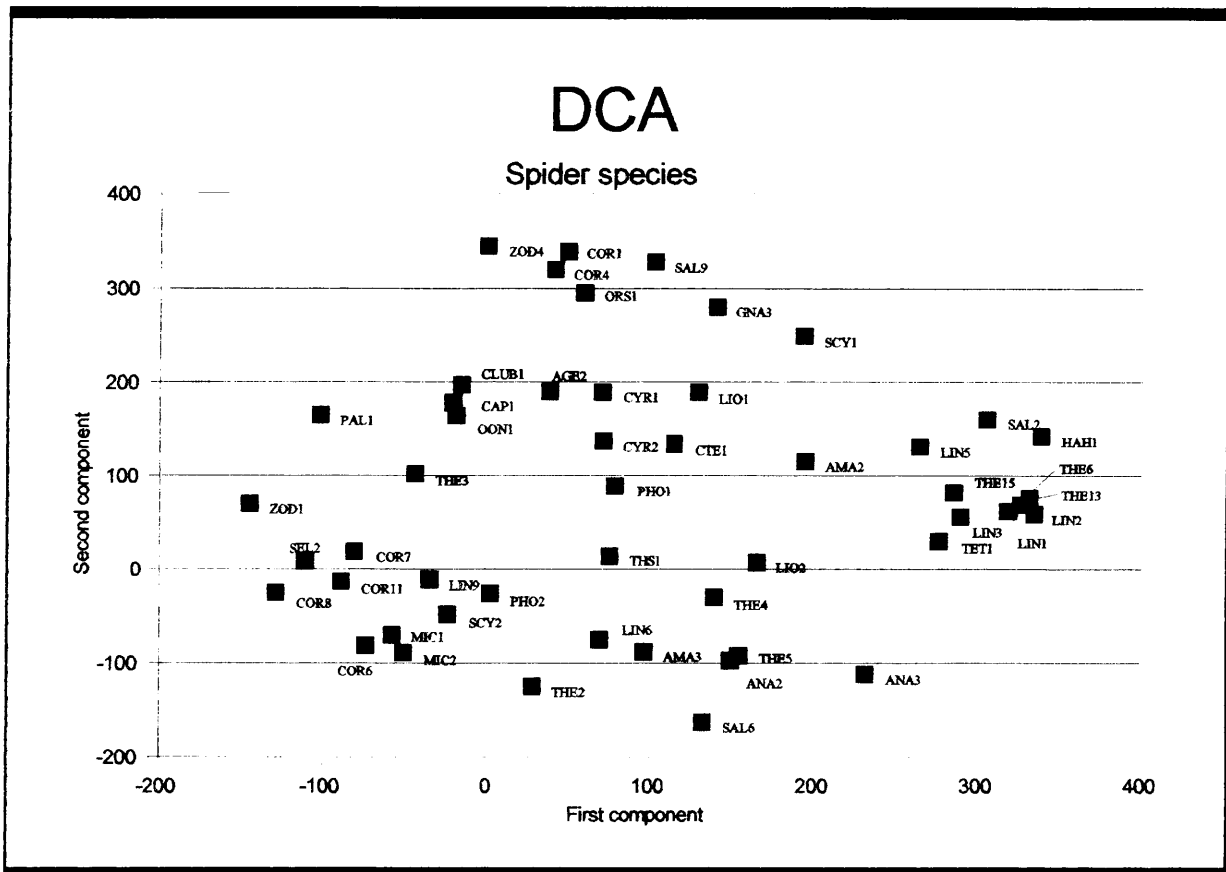


**Figure 2:** First two components of principal components analysis (PCA) of all sampling grids (or sampling units) based on abundance data for different spider species trapped at Ngome State Forest (1992/1993).

**Table 8:** Detrended correspondence analysis (DCA) for spider species in different sampling grids (or sampling units) at Ngome State Forest (1992/1993). Given are the species scores for the first three components. Codes for species names are given in Appendix A.

Species	Code used in plot	1 <sup>st</sup> component	2 <sup>nd</sup> component	3 <sup>rd</sup> component
	CTE1	103	133	30
	LIO1	129	189	-33
	LIN1	318	62	74
	LIN9	-35	-11	159
	HAH1	338	142	95
	LIO2	165	7	108
	LIN6	69	-75	129
	TET1	276	30	117
	AGE2	38	190	190
	ANA3	231	-112	-13
	CYR1	70	189	-33
	LIN3	289	56	139
	THS1	75	14	11
	COR4	41	320	166
	CYR2	71	137	7
	LIN2	334	59	71
	ZOD1	-145	70	-58
	MIC2	-51	-89	-76
	AMA3	96	-88	78
	THE6	331	76	60
	OON1	-19	164	154
	ANA2	149	-97	175
	SCYT1	193	249	-34
	MIC1	-58	-70	-9
	COR6	-74	-81	171
	SCYT2	-24	-48	2
	THE13	326	69	104
	SAL6	132	-163	183

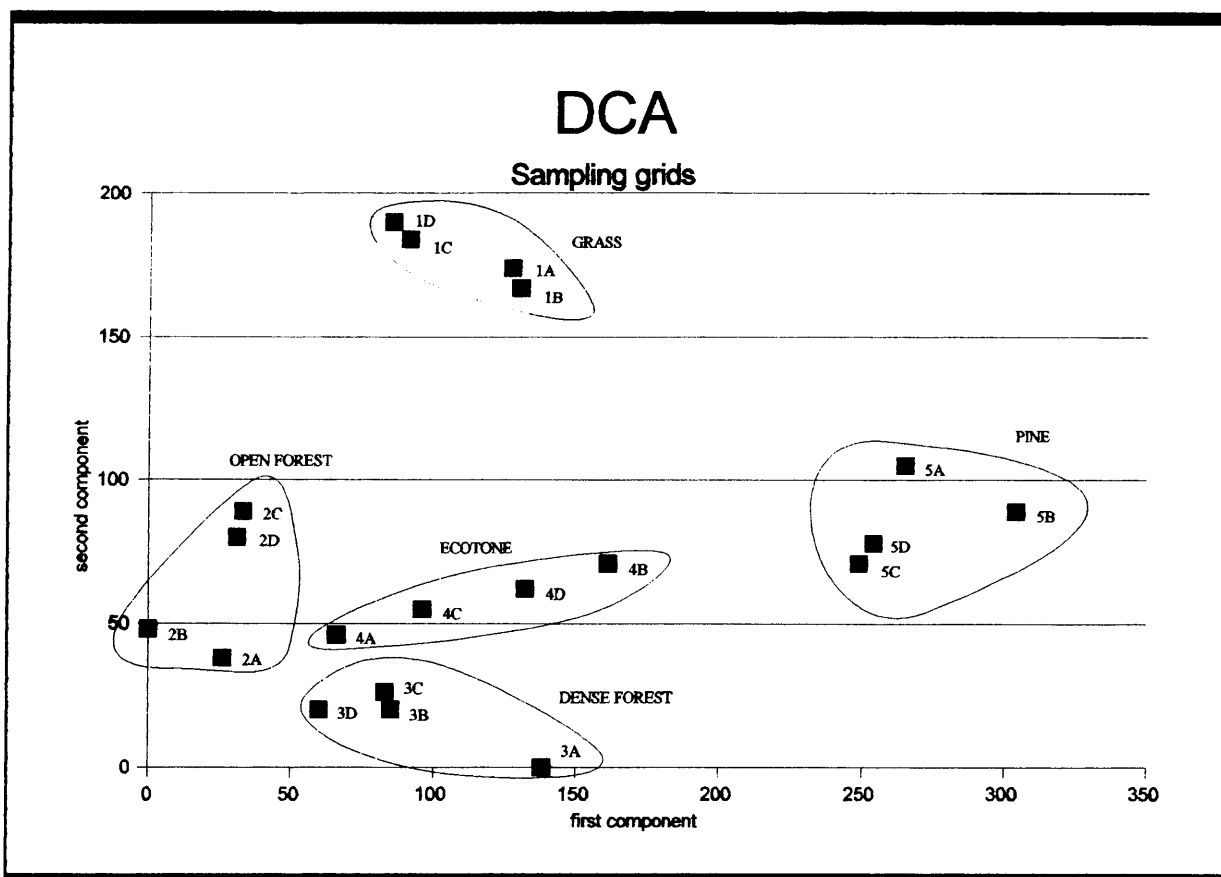
	SEL2	-111	9	67
	ZOD4	1.5E-39	345	425
	LIN5	264	131	-41
	GNA3	140	280	204
	SAL2	305	160	55
	THE3	-44	102	-181
	PAL1	-102	165	90
	PHO2	2	-26	199
	THE4	139	-30	87
	COR11	-89	-13	137
	ORS1	59	295	-185
	THE15	285	82	-45
	CAP1	-21	178	-357
	PHO1	78	89	178
	SAL9	102	328	-113
	COR7	-81	19	-47
	THE2	28	-125	-65
	COR8	-129	-25	189
	AMA2	194	115	210
	THE5	154	-92	142
	COR1	49	339	216
	CLUB1	-16	197	-111



**Figure 3:** Detrended correspondence analysis (DCA) for spider species trapped in different sampling grids (or sampling units) at Ngome State Forest (1992/1993). The positions of the spider species on the first two components are represented. Codes for spider species are given in Appendix A.

**Table 9:** Detrended correspondence analysis (DCA) of sampling grids (or sampling units) based on spider abundance at Ngome State Forest (1992/1993). Given are the sampling grid scores for the first three components.

Sampling grids	1 <sup>st</sup> component	2 <sup>nd</sup> component	3 <sup>rd</sup> component
1A	127	174	110
1B	130	167	99
1C	91	184	79
1D	85	190	154
2A	26	38	128
2B	1.5E-39	48	54
2C	33	89	149
2D	31	80	40
3A	138	1.5E-39	117
3B	85	20	125
3C	83	26	98
3D	60	20	130
4A	66	46	1.5E-39
4B	161	71	37
4C	96	55	68
4D	132	62	60
5A	265	105	65
5B	304	89	78
5C	249	71	116
5D	254	78	118



**Figure 4:** Detrended correspondence analysis (DCA) for sampling grids (or sampling units) based on spider abundance at Ngome State Forest (1992/1993). The positions of sampling grids on the first two components are represented in the graph.

### **3.3 Discussion**

#### **3.3.1 Classification**

The results of the cluster analysis confirm the differences between the habitats as they were identified originally. The horizontal dotted line in Figure 1 shows an arbitrary division for defining seven clusters. The cluster analysis therefore suggests two more habitat types than the number originally identified for the study (assuming that different habitat types give rise to different spider communities).

Of the four sampling grids placed in the grass habitat two were placed in one grass glade (sampling grids 1A and 1B) and the other two in another grass glade (sampling grids 1C and 1D). The two different glades contain two sufficiently different spider communities to be treated separately (Figure 1). As can be seen from Table 1, the dominant low growing plant species in the two glades are different. The two glades also have differences in plant structure which may also explain the different spider communities.

Sampling in the pine habitat also included two different plantations. Sampling grids 5A and 5B represent one plantation while grids 5C and 5D represent the second plantation. The dominant plant species covering the surface in the two plantations are different (Table 5). This had the result that different spider communities were found in the two different pine plantations.

The spider communities in the pine plantations are structurally the furthest removed from those of the other habitat types. The communities in the two grass glades are the next two clusters to be the most different from the remaining clusters. This result



is to be expected as the remaining three clusters represent the indigenous forest vegetation which should lead to similarities in spider community composition. The ecotone habitat (which is an old pine plantation bordering on indigenous forest) has been invaded by numerous elements typical of the indigenous forest. Saplings of indigenous forest trees and other pioneer plant species are to be found in this habitat type. The proximity of this habitat to indigenous forest and the indigenous elements to be found there are probable explanations for the similarities of ecotone spider communities with indigenous forest spider communities. The reason for the closer similarity of the spiders in the ecotone habitat with the spiders in the open forest, compared with the spiders in the dense forest, is not obvious and will need further investigation to be understood. It is also possible that these relationships change over time. The relationships discussed above are often referred to as  $\beta$ -diversity (in contrast with  $\alpha$ -diversity which is discussed in chapter 4).

### **3.3.2 Ordination**

The principal components analysis and the detrended correspondence analysis both give similar results. The positions of all grids on the first two components are such that grids belonging to the same habitat types form respective groupings. This is another confirmation (in concordance with the results of the cluster analysis) that the chosen habitat types represent real differences in spider communities. Since no additional data on microclimatic variation, plant structure and composition, soil composition etc. were quantified (due to the costs involved), the underlying causes and correlations with the major components can only be guessed at. From casual observations made during the trapping period it is likely that the first component will be correlated with plant structure. The 3-dimensional complexity of

the plant structure increases from left to right in Figure 4. The second component is less defined but could probably be correlated with variations in temperature and humidity. Grass, positioned at the top of the graph, should have the most variable temperature and humidity regime, while dense forest, positioned at the lower end of the second component, should have the least fluctuation in temperature and humidity. It must be stressed, however, that these arguments can only belong to the realm of conjecture until more data become available.

The corresponding ordination for spider species supplied by DCA points to another possible pattern (Figure 3). Species positioned on the right side of the first component (i.e. those that are dominant in pine) tend to have smaller body sizes. The converse is true for species on the left side of the graph. Though this pattern can also only be speculated about, it suggests that smaller species tend to dominate in vegetation with higher structural complexity and larger species of spiders dominate in the more open areas. This is clearly an area in need of further investigation.

It is concluded that multivariate analysis of the data showed the different habitat types to support different ground-living spider communities. The composition of spider communities in pine differed most from all other habitat types. This result supports the hypothesis that the planting of pine trees largely affects the composition of ground-living spider communities.

## CHAPTER 4

### ABUNDANCE AND DIVERSITY

#### 4.1 Introduction

##### 4.1.1 Abundance

Species abundance and the variation of this phenomenon in different ecological communities have fascinated ecologists for good reason. The mathematical description of these patterns has led to theories concerning community stability, species-area relationships, resource partitioning and evolutionary processes (e.g. Hutchinson 1953, Kolasa & Biesiadka 1984, McNaughton & Wolf 1970, Whittaker 1965, 1972).

When using community ecological data to construct species abundance distributions, it is usually fitted to several statistical distribution models each with its own theoretical and biological interpretation. Large samples of species abundance data can be summarized in different ways to show emerging patterns (Ludwig & Reynolds 1988). The abundance of each species in the community can be plotted from the most to the least abundant. Another way to summarize the same data is to use a frequency distribution showing the number of species represented by 1, 2, 3, ...  $n$  individuals or whatever measure of abundance is used. Plotting percentage cumulative abundances against species rank gives "k-dominance" plots which were originally devised to compare relatively similar communities with one another (Pielou 1975). Tokeshi (1993) discusses several different ways used in presenting abundance data and proposes that the arithmetic rank versus log abundance plot be used as a standard method of presenting this type of data.

Most of these plots show typical curves, The most common being the lognormal distribution (Sugihara 1980). In other words, the community consists of many species with intermediate abundances and a few species with very high or very low abundances.

Workers have attempted to interpret different curves or models as having different underlying biological explanations. When many independent factors influence a species-rich assembly of individuals their species-abundance relations are quantitatively described by a lognormal distribution (May 1981). The geometric distribution and the 'broken stick' distribution represent communities which are relatively species-poor and homogenous (May 1975). The geometric and 'broken stick' models are special cases which are not considered in this study. All of these models has revealed that contradicting hypotheses can lead to the same model and that different models can be fitted to the same data (Ludwig & Reynolds 1988). Therefore, these models should be seen only as tools which may or may not be useful in the generation of hypotheses, depending on the type of community that is investigated. The many different available models and their biological interpretations can be confusing. A detailed investigation of the field lies beyond the scope of this study. It should be mentioned that species abundance data need not be linked to any model and it is valid to present species abundance data without the use of any models (Tokeshi 1993).

#### **4.1.2 Diversity**

Biological diversity has long been the subject of much debate in community ecology. It has been suggested that the concept of diversity is actually a "nonconcept" due to the many semantic, technical and conceptual problems involved with the term (Hurlbert 1971). In a recent review Tokeshi (1993) discussed the favoured use of diversity indices compared with species abundance

patterns as follows: "if diversity is accepted as a useful measure of communities, so should species abundance patterns be; there are no objective scientific grounds for regarding the latter with disfavour in comparison with the former. Indeed the latter may be preferable if a detailed analysis of a community is intended." Probably the majority of other workers in the field ascribes to the view as put by Magurran (1988): "Diversity lies at the root of some of the most fundamental and exciting questions in theoretical and applied ecology." At the same time it is generally accepted that care should be taken when diversity measures are interpreted, and to be aware of the limitations of diversity indices (Ludwig & Reynolds 1988).

Different diversity indices put emphasis on different components of the diversity concept (richness and evenness). Since both components get incorporated into one numerical value, confusion may result during the interpretation of different indices (Ludwig & Reynolds 1988, Magurran 1988) and different indices may even lead to conflicting conclusions. However, as examples in Magurran (1988) show, different diversity measures are often correlated. However, Kempton (1979) found that different indices often produced different orderings of communities, though he also concluded that this inconsistency is rarer in field data than the use of artificial data suggests (Magurran 1988). When diversity indices are used and interpreted it is necessary to understand the mathematical emphasis of the index. It is therefore advisable to include an evaluation of evenness and richness (in isolation) in any final analysis.

Diversity in the context of the above is often referred to as  $\alpha$ -diversity. A second variety of diversity measures consider the degree of overlap or change between sites or communities or along gradients (Magurran 1988). This is called  $\beta$ -diversity and is described by similarity indices, distance measures and also by

the multivariate techniques of classification and ordination (for more details see chapter 3).

## **4.2 Results**

### **4.2.1 Abundance**

The total number of spiders trapped in sampling grids, habitats and months are given in Table 10. 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 4 spiders collected during January/February in grid 3C (dense forest) and also 4 spiders during February/March in grids 1A and 1B, to 141 spiders collected during December/January in grid 5C (pine). The average number of spiders trapped in sampling grids was 39.00 ( $n=240$ ,  $\sigma=24.88$ ,  $s=24.93$ ). 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 average number of trapped spiders per month in habitat types was 156.00 ( $n=60$ ,  $\sigma=80.36$ ,  $s=81.04$ ). 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 ( $n=5$ ,  $\sigma=499.51$ ,  $s=558.47$ ).

The number of spiders collected monthly in all habitat types ranged from 292 in July/August to 1427 in December/January. The average number of spiders trapped per month was 780.00 ( $n=12$ ,  $\sigma=284.55$ ,  $s=297.20$ ). 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 as well as the different habitat types.

The lognormal model was fitted to the frequency distributions of the abundance data from different habitat types (see Materials and Methods for a full explanation of parameters and terminology). Assuming that the communities under study are adequately described by the lognormal distribution, it is then possible to predict the number of scarce species in the community not included in the sample. Frequency distributions for different habitat types are given in Tables 11-15. Estimated values for parameters  $a$  and  $S_0$  are given as well as the  $X^2$  statistic describing the goodness of fit to the lognormal distribution. Chi-square values fell between 1.89 and 13.12. Finally the observed number of species and the theoretical number of species available for sampling (as calculated from the lognormal distribution) are given in Table 16.

Rank-abundance plots for spiders in different habitats are given in Figure 5. A k-dominance plot for spiders in different habitat types is given in Figure 6. All habitat types show more or less similar curves for the rank-abundance plots. This makes unambiguous statements concerning differences between habitat types impossible. The same is true for the crossing lines on the k-dominance plot.

#### **4.2.2 Diversity**

Results for species diversity of sampling grids are summarised in Table 17. Diversity indices for individual sampling grids give variable results. The pine plantation represented by grids 5A and 5B has 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 habitat types are summarised in Table 18. When Shannon's index was used, grass showed the highest diversity (1.353), and pine the lowest (1.134). Simpson's index gave the highest value for dense forest (0.914) and again the lowest value for pine (0.874). Graphic representations of diversity indices are given in Figures 7-10.

Values for species richness and evenness for sampling grids are given in Table 17. 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 indices for sampling grids again show high variability which makes interpretation difficult.

Species richness and evenness for habitat types are given in Table 18. Grass had the highest richness (89 species) and Ecotone the lowest (51 species). Forest and Pine habitats had intermediate values. Shannon evenness was highest for dense forest (0.731) and lowest for pine (0.626). Simpson evenness was highest for ecotone and lowest for grass.

A regression for the values of the two indices calculated for sampling grids (Figure 11) shows that they are closely correlated ( $r^2 = 0.881506$ ). A regression for the values of the two evenness indices for sampling grids (Fig. 12) shows a poor correlation ( $r^2 = 0.410104$ ).

Table 19 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 (15 species), while nine families were represented by only one species. The family Linyphiidae was numerically the dominant family with 2528 individuals (27% of the total number of trapped spiders). The only other families represented by more than 1000 individuals were the families Liocranidae (1360 individuals) and Ctenidae (1318 individuals). Table 20 gives the number of spider families trapped in each habitat type. The highest number of families was trapped in grass habitat (28 families) and the lowest number of families in dense forest and ecotone habitats, each with 24 families.

**Table 10:** Total number of ground-living spiders collected at Ngome State Forest for sampling grids, habitat types and months from February 1992 to January 1993.

grids	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	TOT
1A	18	4	16	15	12	20	17	58	29	46	25	20	280
1B	11	4	24	17	11	18	15	61	30	28	44	18	281
1C	35	36	43	75	41	28	17	34	17	33	79	92	530
1D	21	53	37	45	14	22	14	26	36	43	69	84	464
SUB	85	97	120	152	78	88	63	179	112	150	217	214	1555
2A	58	40	19	42	15	19	16	33	71	56	52	108	529
2B	23	18	32	22	20	24	15	76	55	57	57	81	480
2C	28	36	42	22	16	21	10	40	53	39	49	64	420
2D	35	38	35	82	27	27	21	48	41	41	61	92	548
SUB	144	132	128	168	78	91	62	197	220	193	219	345	1977
3A	29	19	17	23	11	6	10	27	39	50	37	36	304
3B	38	31	37	24	17	14	8	21	31	22	28	35	306
3C	4	8	8	23	32	11	6	29	19	30	16	43	229
3D	37	27	19	37	15	13	8	43	43	51	37	56	386
SUB	108	85	81	107	75	44	32	120	132	153	118	170	1225
4A	21	21	17	44	30	14	12	23	42	41	64	120	449
4B	12	24	25	32	34	17	17	10	24	25	18	39	277
4C	38	54	64	75	38	21	24	83	58	55	56	74	640
4D	30	56	48	47	40	23	18	13	44	51	33	53	456
SUB	101	155	154	198	142	75	71	129	168	172	171	286	1822
5A	61	57	46	69	51	42	9	28	23	34	46	91	557
5B	54	40	46	82	45	27	6	15	32	77	133	95	652
5C	87	80	79	116	42	62	35	29	50	75	83	141	879
5D	44	71	90	77	35	41	14	26	40	85	85	85	693
SUB	246	248	261	344	173	172	64	98	246	248	261	412	2781
TOT	684	717	744	969	546	470	292	723	777	939	1079	1427	9360

**Table 11:** Fit of lognormal to frequency distribution of spiders for grass habitat at Ngome State Forest (1992/1993). Estimated values for parameters  $a$  and  $S_0$  are given which give the best fit to the model.  $\chi^2$  statistic indicates goodness of fit.

OCTAVE	INDIVIDUALS PER SPECIES	R	OBSERVED S(R)
1.	0-1	-1	13
2.	1-2	0	20.5
3.	2-4	+1	16
4.	4-8	+2	13
5.	8-16	+3	10.5
6.	16-32	+4	6
7.	32-64	+5	5
8.	64-128	+6	2
9.	128-512	+7	1
10	256-512	+8	2
$a=0.21$ $S_0=15.5$ $\chi^2=4.33$			

**Table 12:** Fit of lognormal to frequency distribution of spiders for open forest habitat at Ngome State Forest (1992/1993). Estimated values for parameters  $a$  and  $S_0$  are given which give the best fit to the model.  $X^2$  statistic indicates goodness of fit.

OCTAVE	INDIVIDUALS PER SPECIES	R	OBSERVED S(R)
1.	0-1	-1	10.5
2.	1-2	0	14.5
3.	2-4	+1	10
4.	4-8	+2	4
5.	8-16	+3	13.5
6.	16-32	+4	9
7.	32-64	+5	5.5
8.	64-128	+6	3
9.	128-512	+7	1
10	256-512	+8	2
$a=0.18$ $S_0=12.3$ $X^2=8.78$			

**Table 13:** Fit of lognormal to frequency distribution of spiders for dense forest habitat at Ngome State Forest (1992/1993). Estimated values for parameters  $a$  and  $S_0$  are given which give the best fit to the model.  $X^2$  statistic indicates goodness of fit.

OCTAVE	INDIVIDUALS PER SPECIES	R	OBSERVED S (R)
1.	0-1	-1	7.5
2.	1-2	0	10.5
3.	2-4	+1	8
4.	4-8	+2	10
5.	8-16	+3	7.5
6.	16-32	+4	6.5
7.	32-64	+5	4
8.	64-128	+6	2
9.	128-256	+7	3
$a=0.16$ $S_0=9.0$ $X^2=1.89$			

**Table 14:** Fit of lognormal to frequency distribution of spiders for ecotone habitat at Ngome State Forest (1992/1993). Estimated values for parameters  $a$  and  $S_0$  are given which give the best fit to the model.  $X^2$  statistic indicates goodness of fit.

OCTAVE	INDIVIDUALS PER SPECIES	R	OBSERVED S(R)
1.	0-1	-1	7
2.	1-2	0	9.5
3.	2-4	+1	8
4.	4-8	+2	6
5.	8-16	+3	3.5
6.	16-32	+4	5
7.	32-64	+5	5
8.	64-128	+6	2
9.	128-512	+7	3
10	256-512	+8	2
$a=0.156$ $S_0=7.6$ $X^2=2.69$			

**Table 15:** Fit of lognormal to frequency distribution of spiders for pine habitat at Ngome State Forest (1992/1993). Estimated values for parameters  $a$  and  $S_0$  are given which give the best fit to the model.  $X^2$  statistic indicates goodness of fit.

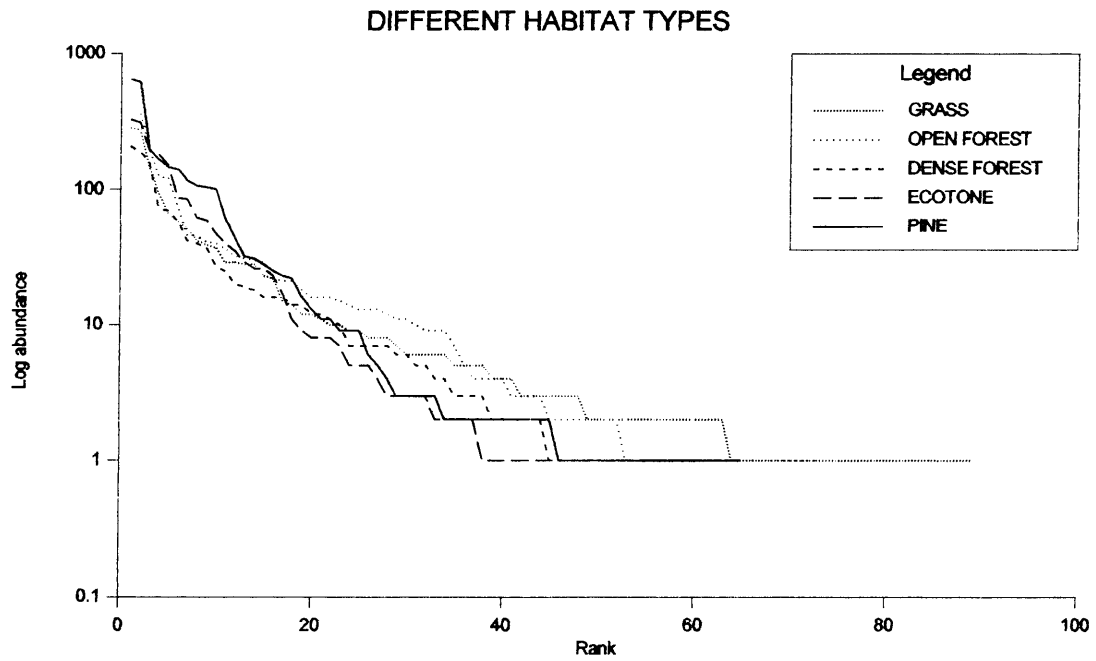
OCTAVE	INDIVIDUALS PER SPECIES	R	OBSERVED S(R)
1.	0-1	-1	10
2.	1-2	0	16
3.	2-4	+1	11.5
4.	4-8	+2	2.5
5.	8-16	+3	6.5
6.	16-32	+4	6
7.	32-64	+5	2.5
8.	64-128	+6	4
9.	128-256	+7	4
10.	256-512	+8	0
11.	512-1024	+9	2
$a=0.160$ $S_0=10.5$ $X^2=13.12$			

**Table 16:** The observed and the expected number of spider species in each sampled habitat type (assuming a lognormal distribution) at Ngome State Forest (1992/1993).

Habitat	Observed no. of species (S)	Expected no. of species (S*)
Grass	89	130.6
Open forest	73	121.0
Dense forest	59	99.6
Ecotone	51	86.2
Pine	65	116.2



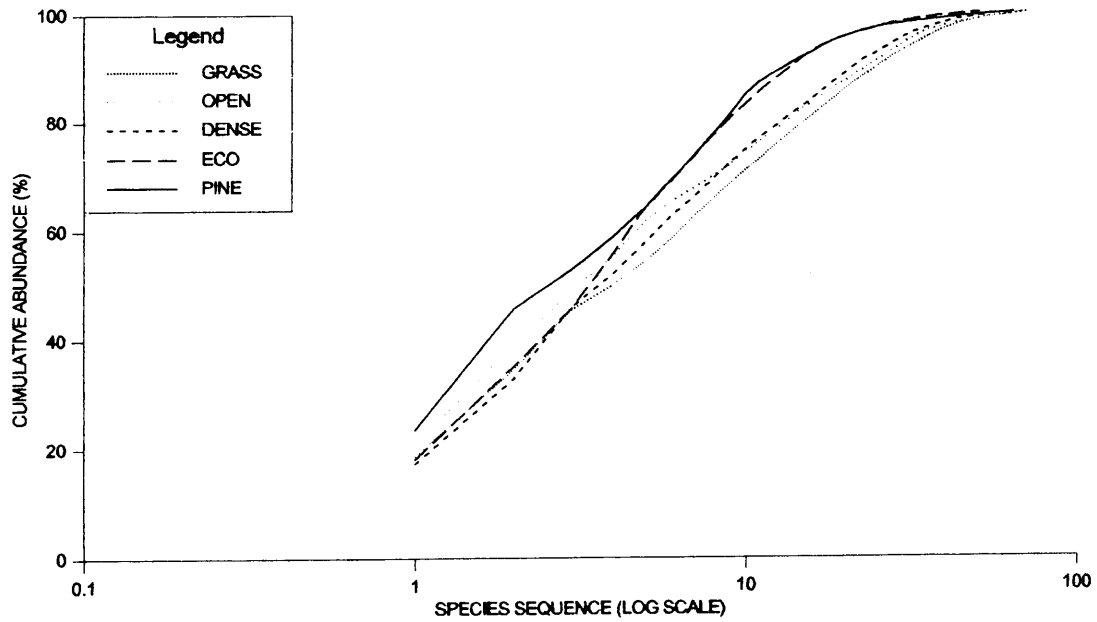
# RANK-ABUNDANCE PLOTS



**Figure 5:** Rank-abundance plots for spiders in different habitat types at Ngome State Forest (1992/1993).

# K-DOMINANCE PLOT

DIFFERENT HABITAT TYPES



**Figure 6:** K-dominance plot for spider communities in different habitat types at Ngome State Forest (1992/1993).

**Table 17:** Shannon and Simpson's diversity and evenness indices and species richness for sampling grids based on spider abundance at Ngome State Forest (1992/1993).

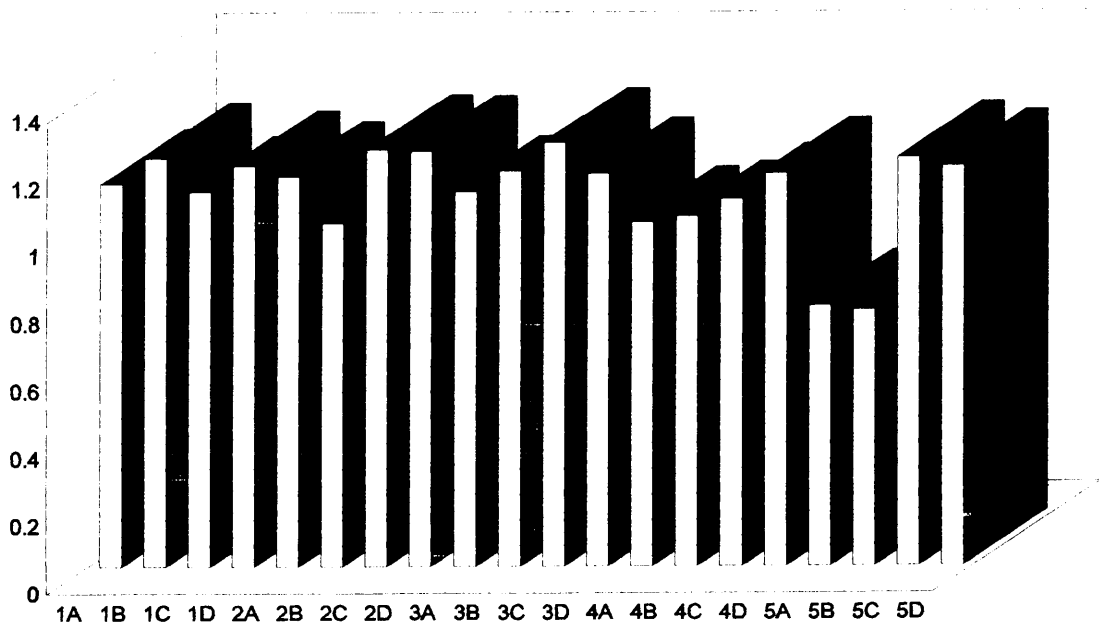
Grids	Diversity indices		Evenness indices		Species richness
	Shannon	Simpson	Shannon	Simpson	
1A	1.135	0.911	0.770	0.533	51
1B	1.212	0.892	0.752	0.553	41
1C	1.112	0.857	0.669	0.516	46
1D	1.189	0.888	0.689	0.510	53
2A	1.157	0.889	0.700	0.538	45
2B	1.018	0.796	0.645	0.504	38
2C	1.237	0.897	0.777	0.564	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 18:** 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		Evenness indices		Species richness
	Shannon	Simpson	Shannon	Simpson	
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

# DIVERSITY FOR SAMPLING GRIDS

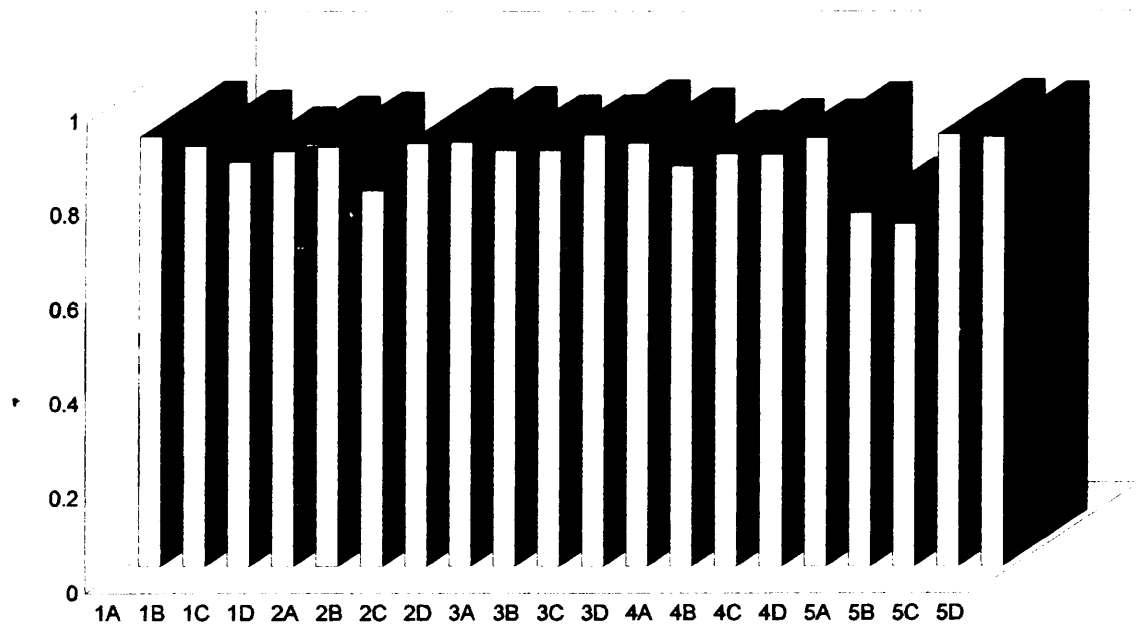
## SHANNON DIVERSITY INDEX



**Figure 7:** Shannon's diversity indices for sampling grids based on spider abundance data at Ngome State Forest (1992/1993).

# DIVERSITY FOR SAMPLING GRIDS

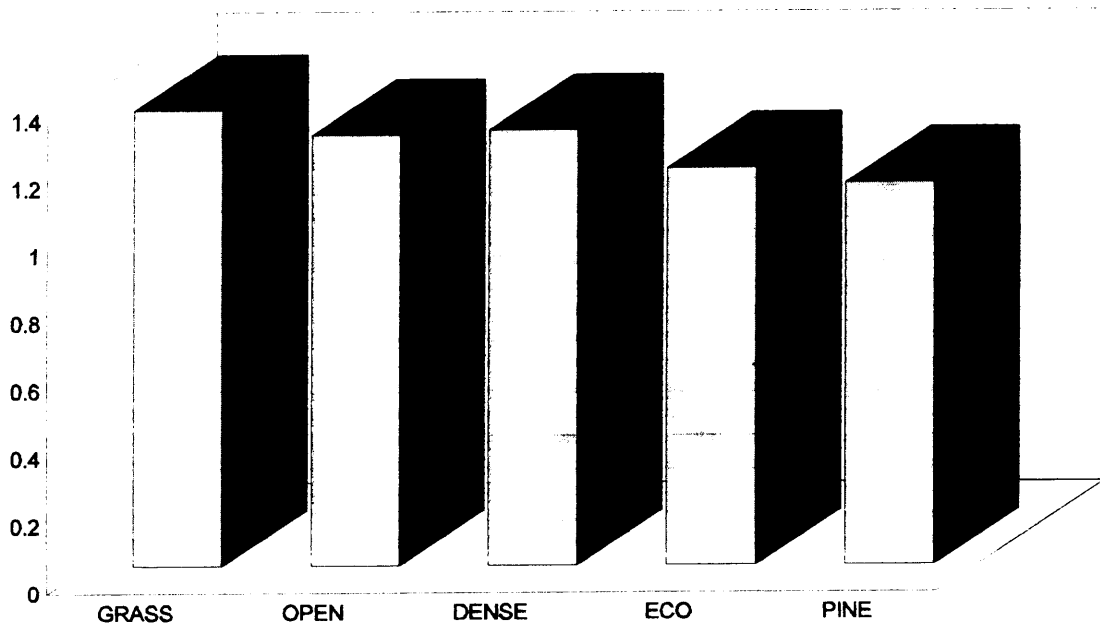
## SIMPSON DIVERSITY INDEX



**Figure 8:** Simpson's diversity indices for sampling grids based on spider abundance data at Ngome State Forest (1992/1993).

# DIVERSITY FOR HABITATS

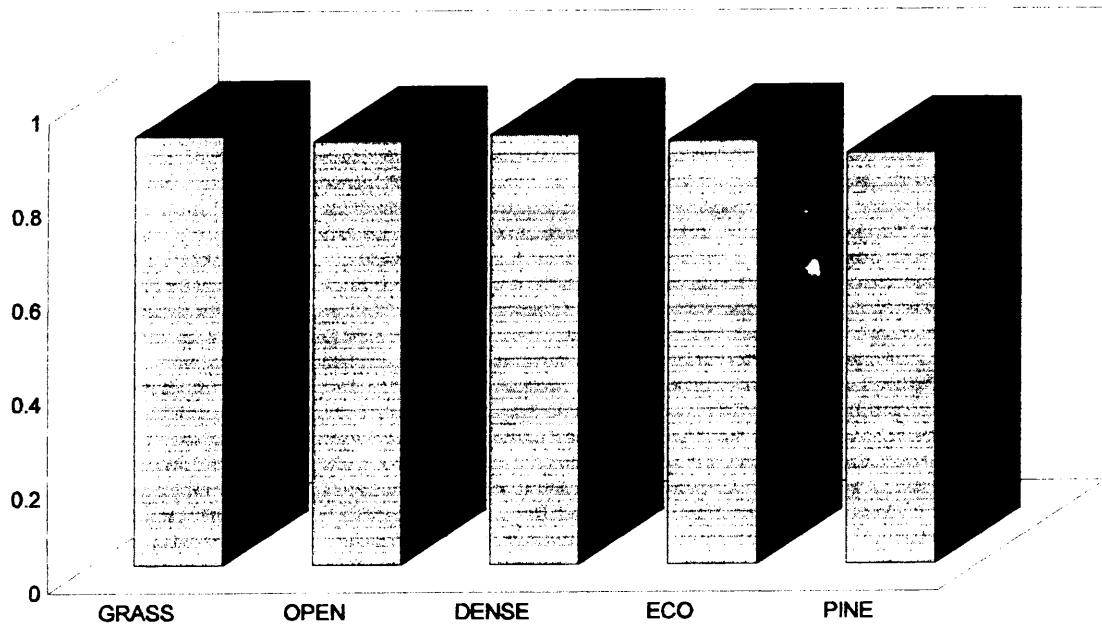
## SHANNON DIVERSITY INDEX



**Figure 9:** Shannon's diversity indices for habitat types based on spider abundance at Ngome State Forest (1992/1993).

# DIVERSITY FOR HABITATS

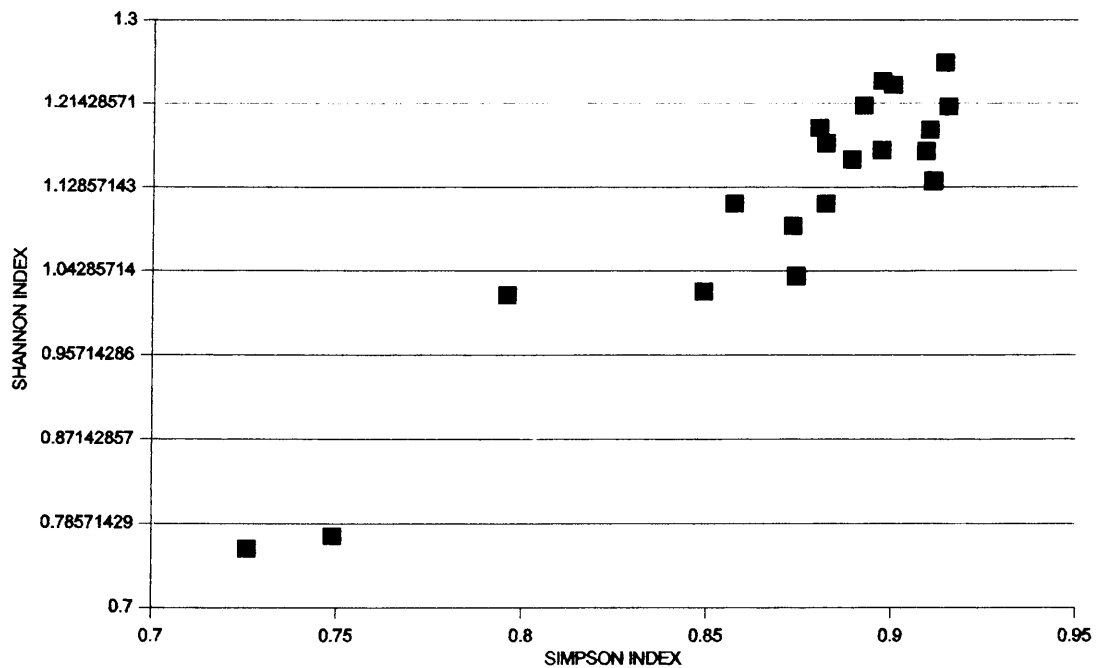
## SIMPSON DIVERSITY INDEX



**Figure 10:** Simpson's diversity indices for habitat types based on spider abundance at Ngome State Forest (1992/1993).



## DIVERSITY FOR GRIDS



**Figure 11:** Regression analysis for Shannon and Simpson's diversity indices of sampling grids based on spider abundance at Ngome State Forest (1992/1993).

Regression output:

Constant = -0.98873

Standard error of Y estimate = 0.048418

R squared = 0.881506

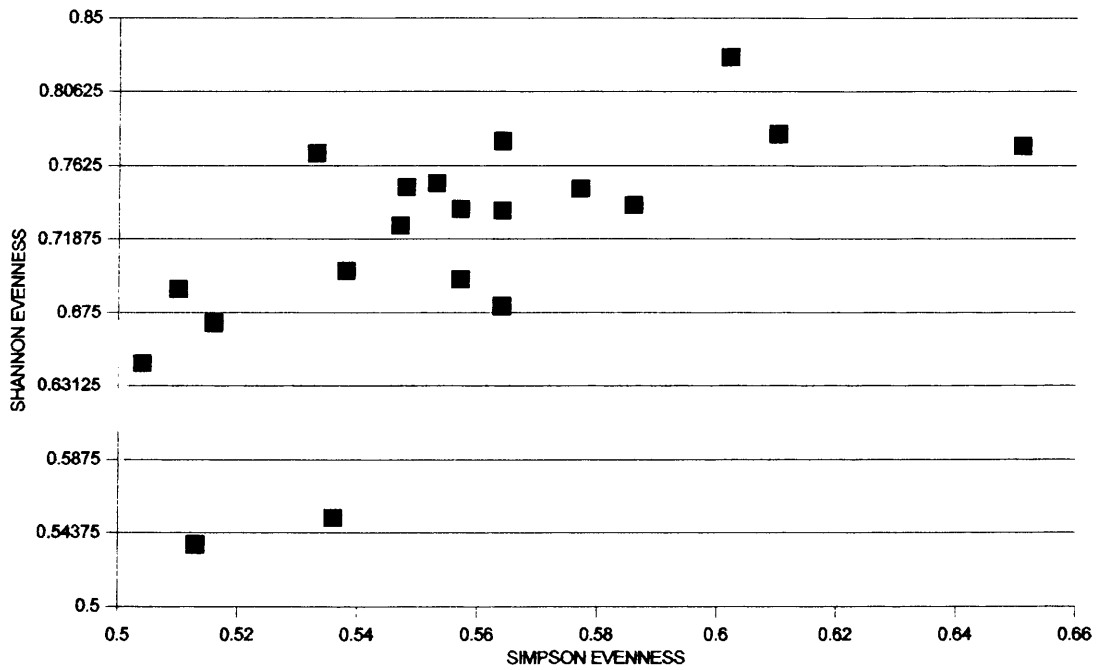
No. of observations = 20

Degrees of freedom = 18

X coefficient = 2.414639

Standard error of coefficient = 0.208666

# EVENNESS FOR GRIDS



**Figure 12:** Regression analysis of Shannon and Simpson's evenness indices for sampling grids based on spider abundance at Ngome State Forest (1992/1993).

Regression output:

Constant = 0.004637

Standard error of Y estimate = 0.057297

R squared = 0.410104

No. of observations = 20

Degrees of freedom = 18

X coefficient = 1.275225

Standard error of coefficient = 0.360488

**Table 19:** 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	Scytodidae	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

**Table 20:** The number of spider families trapped in each habitat type at Ngome State Forest (1992/1993).

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

## 4.3 Discussion

### 4.3.1 Abundance

In very large samples (tens of thousands of individuals rather than hundreds or thousands) one may find that the number of species represented by one individual may not be the highest. One would rather find that most species are represented by an intermediate number of individuals (assuming a lognormal distribution for the community). Unfortunately it is usually not possible to sample to such an extent and sampling tends to underestimate the number of species in the area under investigation (Kikkawa 1986). This means that the rare species would be absent from the sample and that the intermediate abundant species would be represented by only one or two individuals in the sample. Therefore, in the place of a lognormal distribution (when data are arranged in a frequency distribution), a truncated lognormal distribution will be the result. In a rank-abundance diagram this will mean that the right-hand portion of the graph will be absent. In this study sample sizes were usually only hundreds of individuals strong and we would therefore expect a truncated lognormal to be displayed. Rank-abundance plots of all five habitat types showed the same basic pattern described above. This result supported the decision to fit the data to the truncated lognormal model, and to test for goodness of fit with a chi-square statistic.

There are opposing views among ecologists as to whether a close fit of data to the lognormal model indicates a stable community (e.g. Whittaker 1975; Gray 1979, 1981; Stenseth 1979; Preston 1980, cited in Tokeshi 1993), or an unstable community (Dennis & Patil 1979; Hughes 1984, 1985, cited in Tokeshi 1993) and Tokeshi (1993) concludes as follows: "whilst there are semantic as well as some conceptual differences between the dichotomies

of equilibrium/non-equilibrium versus disturbed/undisturbed communities, the argument that equilibrium or undisturbed communities are always described by the log-normal model may not have as strong a logical basis as has been thought. Heterogeneous assemblies of species where a multitude of factors operate quasi-randomly and independently of each other in a multiplicative manner can relate to both equilibrium/undisturbed and non-equilibrium/disturbed environments, the latter being dependent on the nature, magnitude and frequency of disturbance." This discussion will view the lognormal (or truncated lognormal when dealing with samples) as a sufficiently good description of the manner in which species abundances are distributed in the communities under investigation. Because of the current uncertainty concerning the interpretation of the lognormal model as applied to the above mentioned dichotomies, this discussion will not attempt any such analysis of the results.

Species abundance in dense forest and ecotone habitats showed the closest fit to the lognormal model. This result could probably be explained by the relatively high values for the evenness indices in these habitat types (see discussion on evenness). As no single species tends to dominate in these communities, the underlying biological interpretation of the lognormal model (many factors simultaneously affecting species abundance patterns, in contrast to the geometric series model) also seems to be more plausible in these communities. Pine and open forest habitats showed the highest chi-square values and therefore showed the least fit to the lognormal model.

A problem with fitting data to the lognormal distribution exists in the fact that only a small number of classes are used (usually less than 10) (Magurran 1988). This can mean that the way species are distributed in only 2 or 3 classes can have a significant influence on the result. Octave 4 in the pine data and octaves

3 and 4 in the open forest data show an unexpected observed number of species. These octaves cause the chi-square values to increase. Considered together all the habitat types have relatively low chi-square values and the data therefore seem to be adequately described by the truncated lognormal model. Assuming that the communities are lognormally distributed (i.e. if all the scarce species which have not been trapped are included as well), valuable estimates of real species numbers can be made (as illustrated by the results). This has obvious implications for managing species diversity.

#### **4.3.2 Diversity**

Diversity measures can be divided into Type I and Type II indices (Peet 1974). 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. The 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.

The variability in diversity for individual sampling grids casts doubt on the legitimacy of the conclusions drawn for habitat types. The results suggest that diversity varies significantly on a spatial (and possibly temporal) scale within habitat types. The conspicuously low diversity in grids 5A and 5B (mentioned in the results section) may be due to successional changes in diversity in pine habitats of different age. Sampling grids 5A and 5B represent an older pine plantation than sampling grids 5C and 5D, which have relatively high species richness and diversity. The aim of this study was not to investigate successional stages in spider communities, and not enough successional stages were sampled to make unambiguous statements concerning succession. However, there is a suggestion in the results that older pine habitats may become progressively inhospitable for some spider species. A study on these aspects should be a productive line of future research.

The crossing lines on the k-dominance plot suggest that the diversity of the different habitat types cannot be unambiguously assessed. There is a tendency for the lines representing the indigenous areas to lie higher on the graph, and these lines could therefore be interpreted to suggest higher diversity. From the rank-abundance plots (which give the same information as the k-dominance plot) a similar trend is observed: lines representing pine and ecotone habitats generally have steeper slopes than the natural habitat types; the line representing grass having the most gentle slope. When results from the k-dominance and rank-abundance plots are viewed in combination with the results of the



diversity indices it would seem that slight differences in diversity do exist between habitats, though these differences are not as clearly defined as might have been expected.

The tendency for the grass habitat to have the highest diversity as determined by the various different techniques, 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. Though the grass patches chosen for sampling are surrounded by indigenous forest, the exceptional dispersal ability of most spiders may counter the effect of small scale local extinctions and a high diversity can be maintained.

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 agrees 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.

The results from this study support the notion that disturbed habitats (e.g. pine) have lower diversity than undisturbed habitats (e.g. indigenous forest and grass). However, the differences in diversity are smaller than might have been expected. An unexpected result concerns species richness which reached relatively high values in one of the two sampled pine plantations. From the results discussed above viewed together with the results from the previous chapter it is concluded that this study provides support for the hypothesis that human disturbance on spider habitat has a larger influence on species

composition than on diversity and richness of spider communities.

#### **4.3.3 Comparisons with other southern African studies**

Russell-Smith (1981) studied ground-living spider communities over a year employing 20 pitfall traps in two habitat types, Mopane woodland and floodplain grassland, bordering the Okavango swamps in Botswana. Results for species richness in the two habitat types were 87 spider species trapped in grassland and 84 spider species trapped in Mopane woodland. The number of species trapped in Okavango grassland compares well with the 89 species recorded for grass habitat at Ngome. Again it would seem probable that savanna and grass type vegetation support a higher faunal diversity in southern Africa than forested habitat types.

A spider survey in grass habitat at the Rietondale Research Station in Pretoria yielded a total of 55 ground-living spider species (van den Berg & Dippenaar-Schoeman 1991). The study covered three five-month periods over three successive years using 50 pitfall traps. The recorded number of species is considerably less than the number recorded for grass at Ngome and Okavango. A possible explanation for the relative paucity of spider species in Pretoria may be the higher pressure of human disturbance on their communities in this area.

A spider survey of a pine plantation near Sabie (eastern Transvaal) recorded 35 species from pitfall trapping (van den Berg & Dippenaar-Schoeman 1988). This is considerably less than the 65 species recorded in the pine plantations of Ngome. A total of 16 spider families was recorded from pitfall traps at Sabie compared to the 26 families recorded in pine from Ngome. The total number of pitfall trapped spiders at Sabie was 717, which is also considerably lower than the 2781 spiders trapped in the pine habitat of Ngome (Table 10). The Sabie study employed a

total of 100 pitfall traps compared to the 36 pitfall traps used in pine habitat at Ngome. The Sabie study did, however, only cover an eight month period. When the same eight month period (June to January) is considered for the Ngome study, the result is a total of 1682 trapped spiders, which is still significantly higher than the number of spiders trapped at Sabie. These results seem to suggest that the pine plantations at Ngome have more diverse and abundant spider communities than the plantations at Sabie. The results therefore imply that southern African pine plantations in different areas may differ considerably in their faunal diversity.

Results from other southern African spider studies are available (e.g. Dippenaar-Schoeman 1977, 1979, 1988; Dippenaar-Schoeman, van den Berg & van den Berg 1989; Coetzee, Dippenaar-Schoeman & van den Berg 1990; van den Berg, Dippenaar-Schoeman & Schoonbee 1990; van den Berg & Dippenaar-Schoeman 1991; Lotz, Seaman & Kok 1991). However, differences in collecting technique, extent of collection or level of taxa identification, make comparisons with the Ngome study difficult. For the identification of spider diversity patterns on a broader ecological scale, there is a need for more surveys to be done.

## CHAPTER 5

### HABITAT PREFERENCES AND PHENOLOGY OF ACTIVITY OF ABUNDANT SPIDERS

#### 5.1 Introduction

##### 5.1.1 Spider habitats

Spiders have colonised an extremely wide range of habitat types on earth. They are established in habitats ranging from Arctic and subantarctic islands through to deserts. The majority spiders's characteristic use of silk to ensnare prey has evolved into numerous intricate techniques for trapping their main diet of smaller invertebrates. Spiders specialising at preying on specific prey are the exception rather than the rule (Wise 1993), but are common among the families Mimetidae (spiders which exclusively prey on other spiders) and Zodariidae (specialised to prey on ants) (Foelix 1982).

The diversity, numbers and omnipresence of spiders in terrestrial habitats indicate their possible importance as key species in structuring invertebrate communities. Autecology (at the species level) in conjunction with synecology (at the community level) provide insights into which species are most influential. When attempting to elucidate autecological relationships in ecological systems, the description of the natural history of the organisms involved is an obvious starting point. Very basic to this approach is the gathering of information on the habitat preferences and phenology of the animals. Apart from autecology's importance in conservation, it has the potential to reveal species important as controlling agents in agroecosystems (e.g. Dippenaar-Schoeman 1977, 1979; McCaffrey & Horsburg 1980; Thornhill 1983; Agnew & Smith 1989; Riechert 1990) and other renewable resource crops of which

commercial forestry is an obvious example (e.g. Moulder & Reichle 1972; Jennings & Dimond 1988).

Species occupying narrow multidimensional niches are referred to as specialists, whereas species occupying wide niches are referred to as generalists (Holm 1985). In practice these terms are most frequently used when discussing a species occurring in limited types of habitat versus a species occurring in widely different types of habitat. This use of the terminology is an oversimplification (see Holm 1985 for a more extensive account of the identifying traits of specialists versus generalists), but can be useful when its limitations are kept in mind. Identifying species which only occur in specific habitat types is important in identifying potentially sensitive species to changes in the environment. Changes in habitat occur temporally as well as spatially, and both temporal and spatial distributions of species are important aspects to be considered.

### **5.1.2 Phenology and seasonality**

In the description of temporal patterns in population ecology the two terms phenology and seasonality are frequently used. Wolda (1988) uses the following definitions to distinguish between phenology and seasonality: (1) A phenomenon is seasonal if it, or its maximum expression, predictably occurs at roughly the same time of the year, each year that it does occur. (2) The phenology of a phenomenon is the temporal distribution of that phenomenon and (3) the seasonality of a phenomenon is the phenology of that phenomenon and the degree to which it is seasonal.

Used in the above context season refers to the relevant phenomenon under study (e.g. mating season) and should not be confused with conventional seasons such as 'summer' or 'dry

season' (Wolda 1988). It should also be clear that the concept of seasonality is more restricted in its meaning than the concept of phenology, and should therefore be used with greater care.

The data collected for this study cover only a one year period. In a strict sense one has only identified a pattern when support for its recurring nature has been provided. Seasonal patterns cannot be identified for studies which only cover one year. However, describing the temporal distribution of the phenomenon under study, even though its recurring nature has not been verified, still provides valuable information which may point to areas of possible interest for future studies, and this information should never be discarded as irrelevant. The results given in this chapter should be viewed in this context.

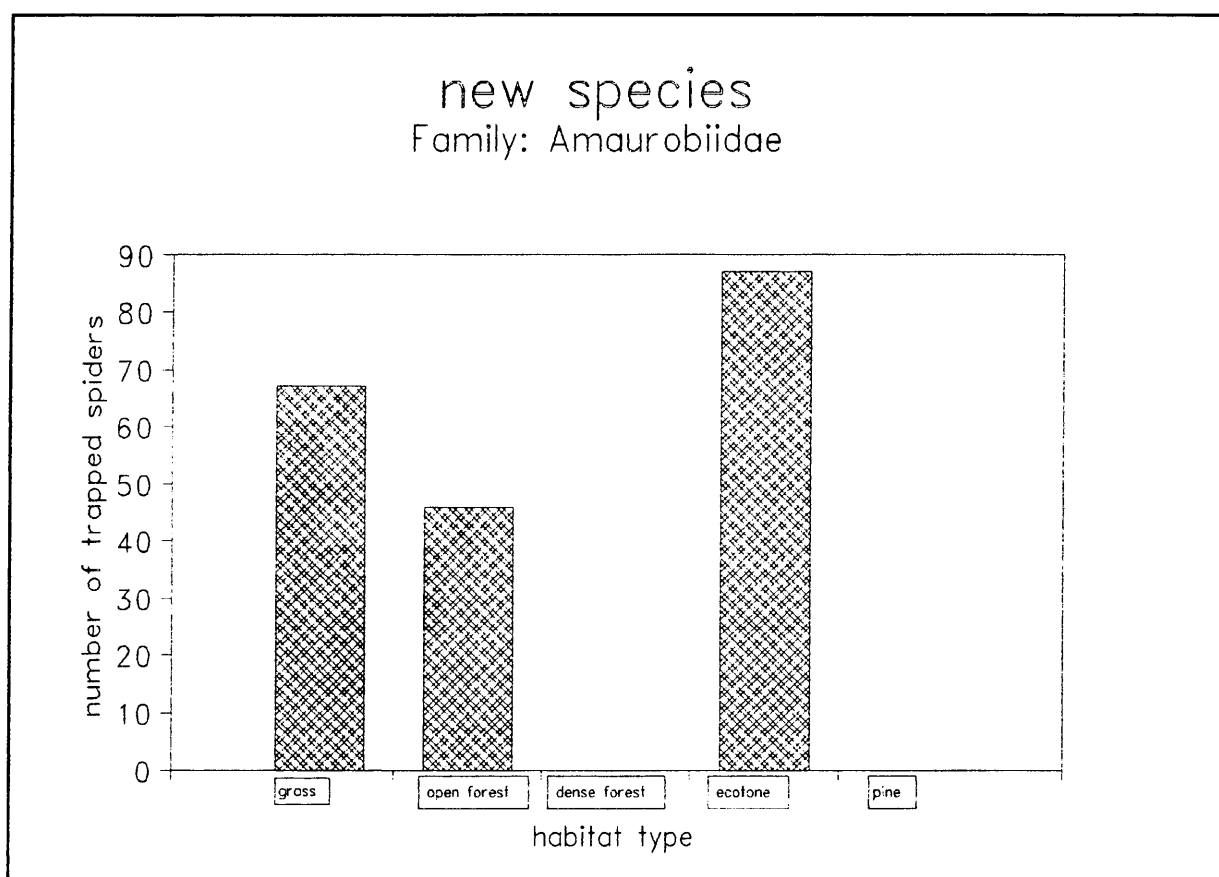
Pitfall trapping measures a combination of activity and density. Some authors have referred to the phenomenon measured by pitfall trapping as 'active density' (Uetz 1977) as it samples the number of cursorial spiders moving in an area for a given time (Bultman & Uetz 1982). It is the phenology of the active density of the spiders which is discussed in the following sections.

## **5.2 Results and discussion**

Ten spider species were represented by at least 200 trapped individuals. Data in the form of bar plots are given for these ten most abundantly trapped species in different habitat types in Figures 13, 15, 17, 19, 21, 23, 25, 27, 29 and 31. The monthly numbers of female, male and juvenile spiders (for the same ten species) are plotted in Figures 14, 16, 18, 20, 22, 24, 26, 28, 30 and 32.

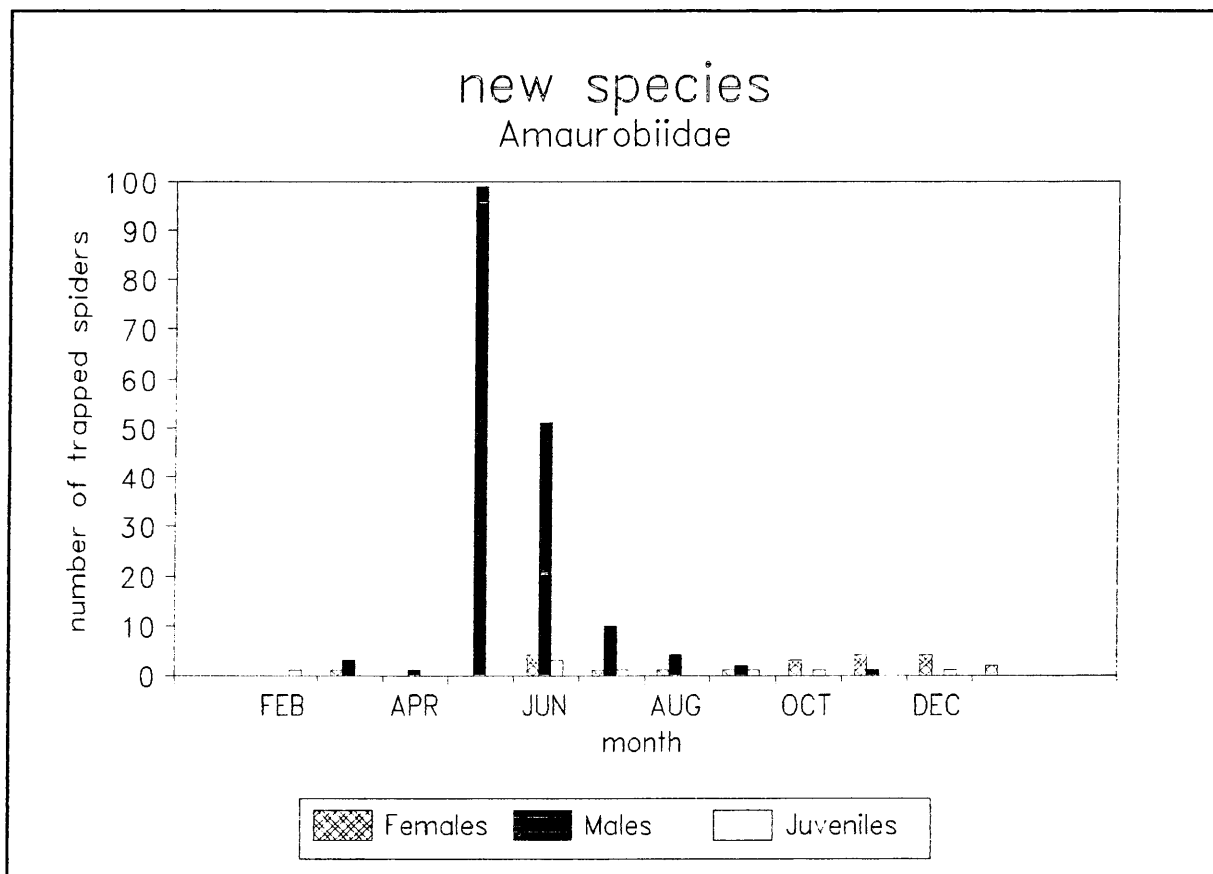
Due to the lack of revisionary work and keys many African spider taxa could not be identified to genus or species level. Several

of the spider taxa collected here represent new species and even new genera (A.S. Dippenaar-Schoeman, pers. comm.). All specimens collected are stored in the National Collection of Arachnology at the Plant Protection Research Institute in Pretoria and are available for further study.

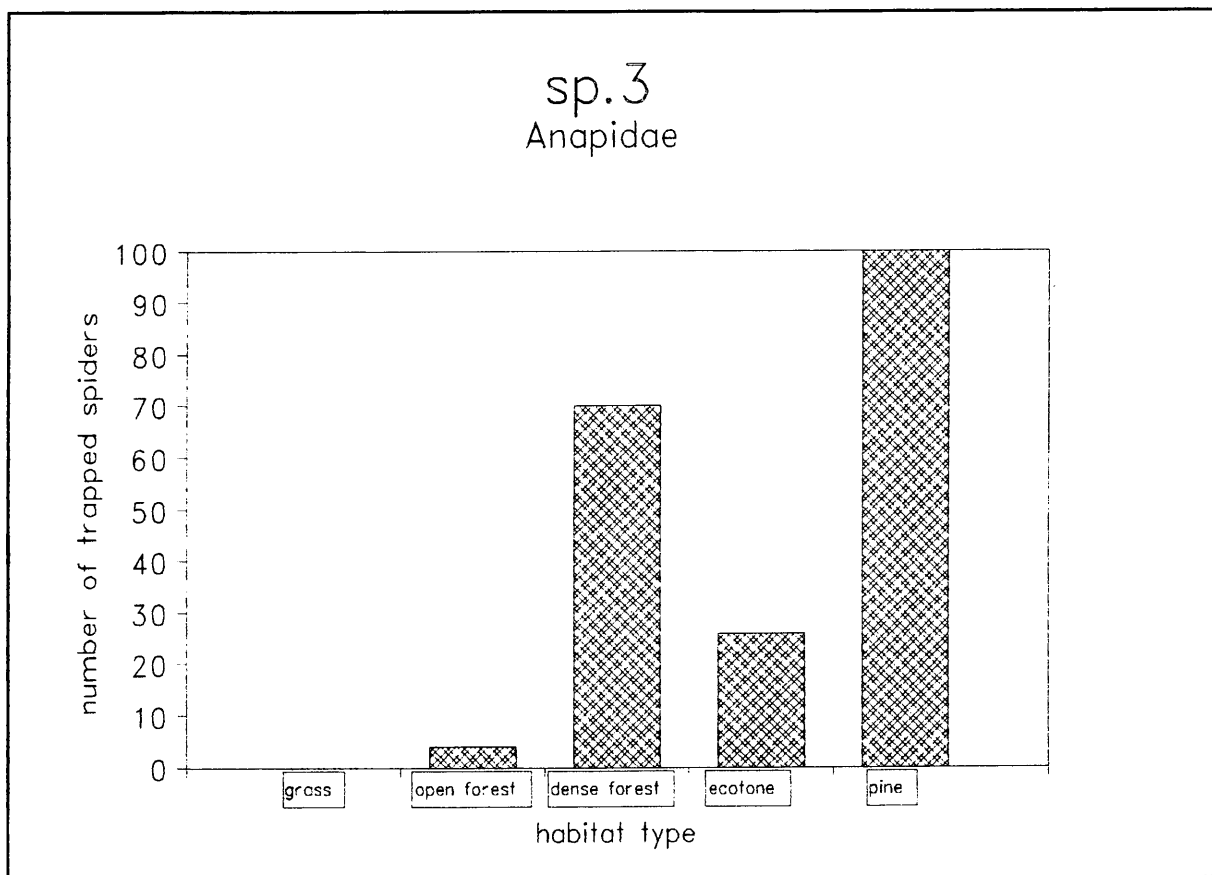


**Figure 13:** The total number of individuals of an undescribed species (Amaurobiidae) trapped in pitfall traps for each of the five habitat types during 1992/1993 at Ngome State Forest.

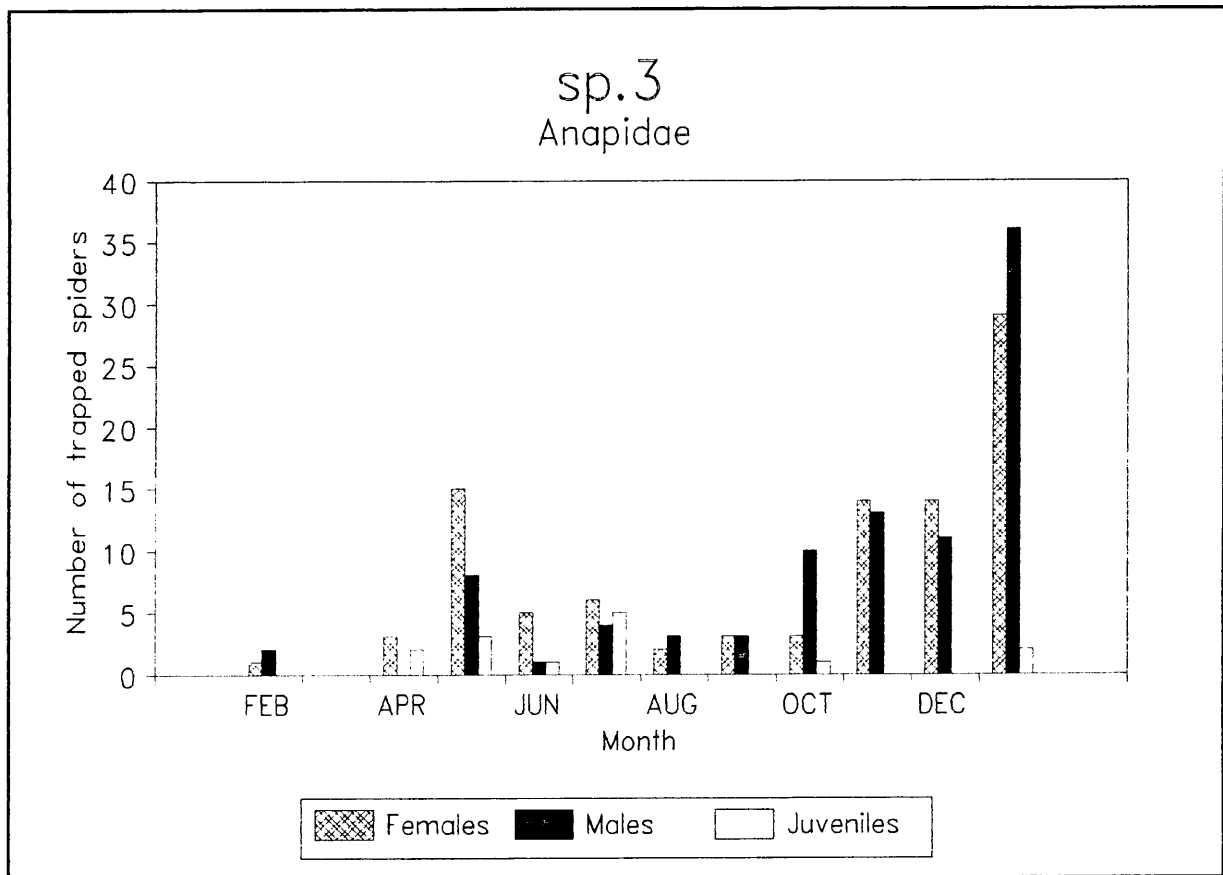




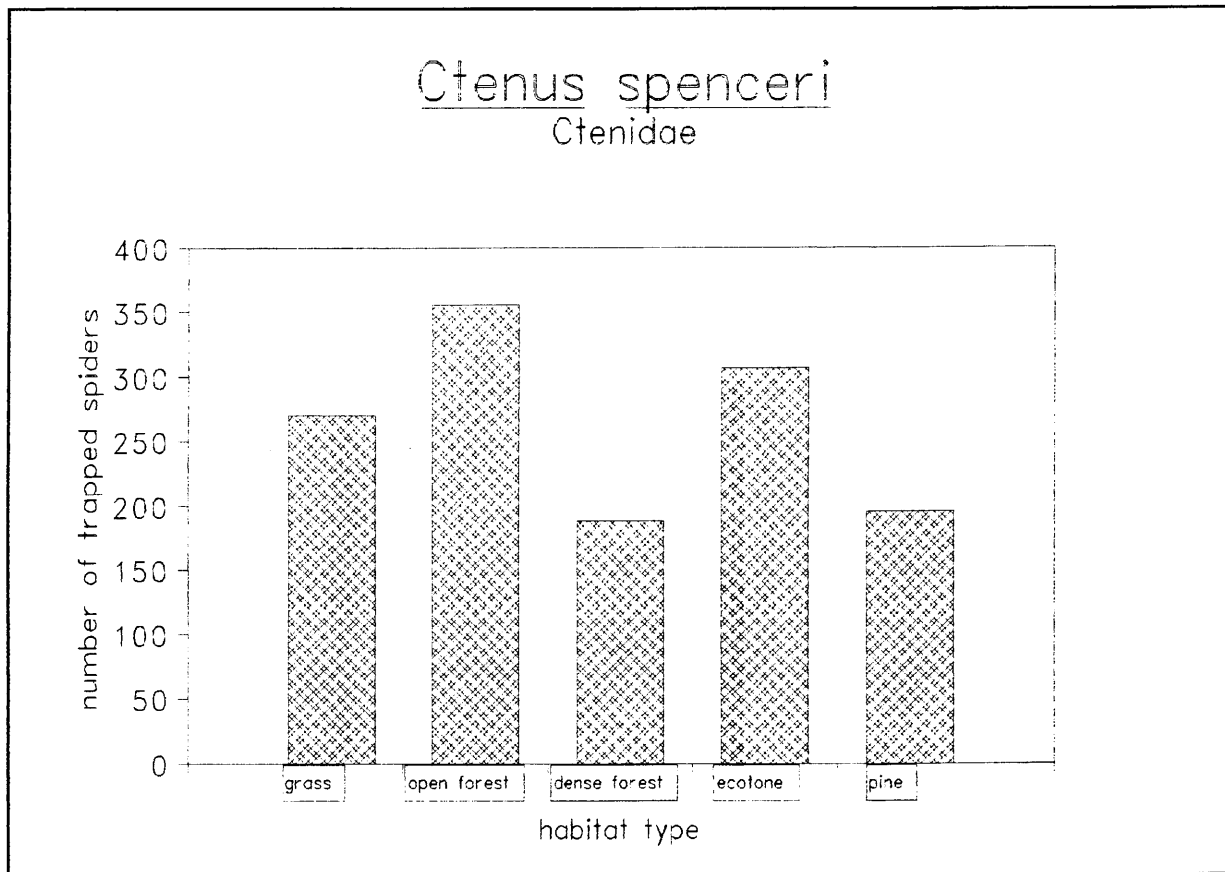
**Figure 14:** The monthly pitfall catch in all habitat types for female, male and juvenile spiders of an undescribed species (Amaurobiidae), during 1992/1993 at Ngome State Forest.



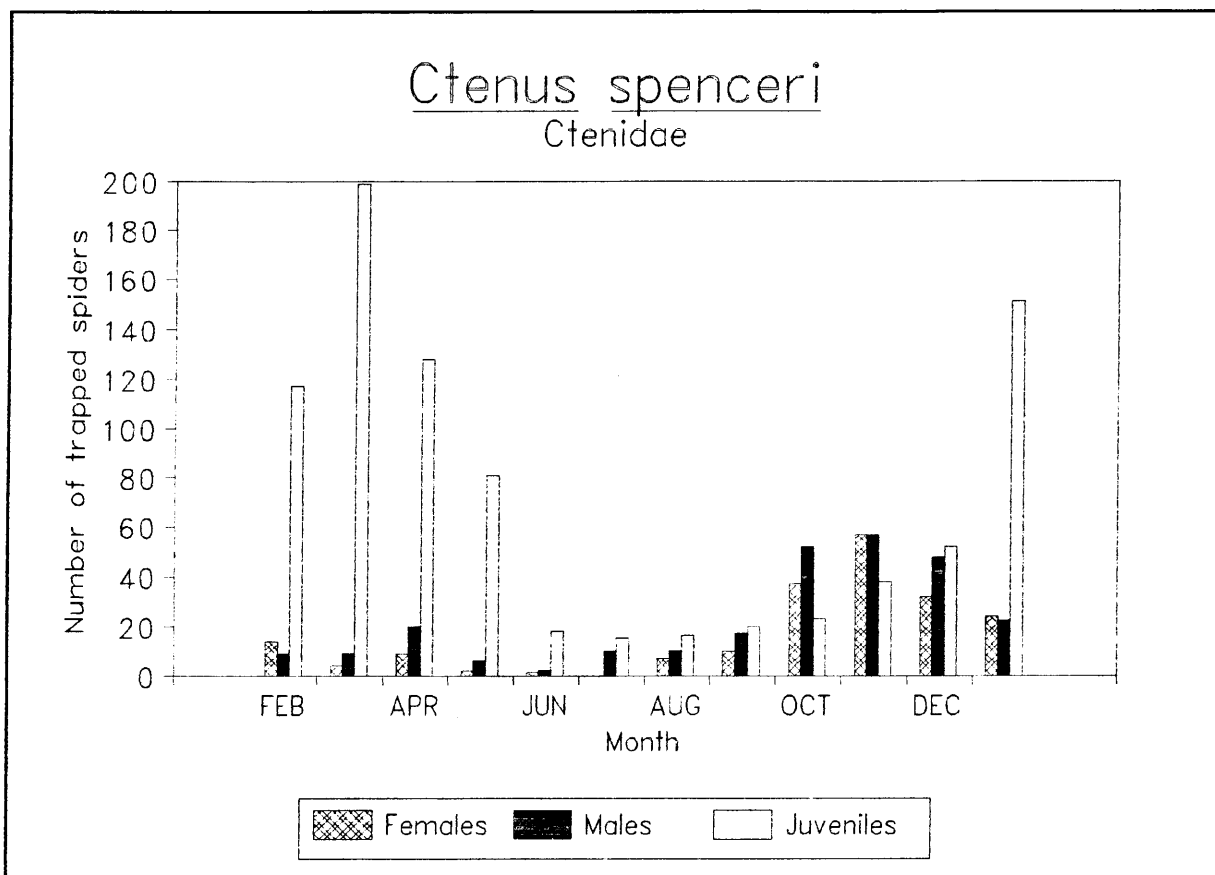
**Figure 15:** The total number of individuals of sp.3 (Anapidae) trapped in pitfall traps for each of the five habitat types during 1992/1993 at Ngome State Forest.



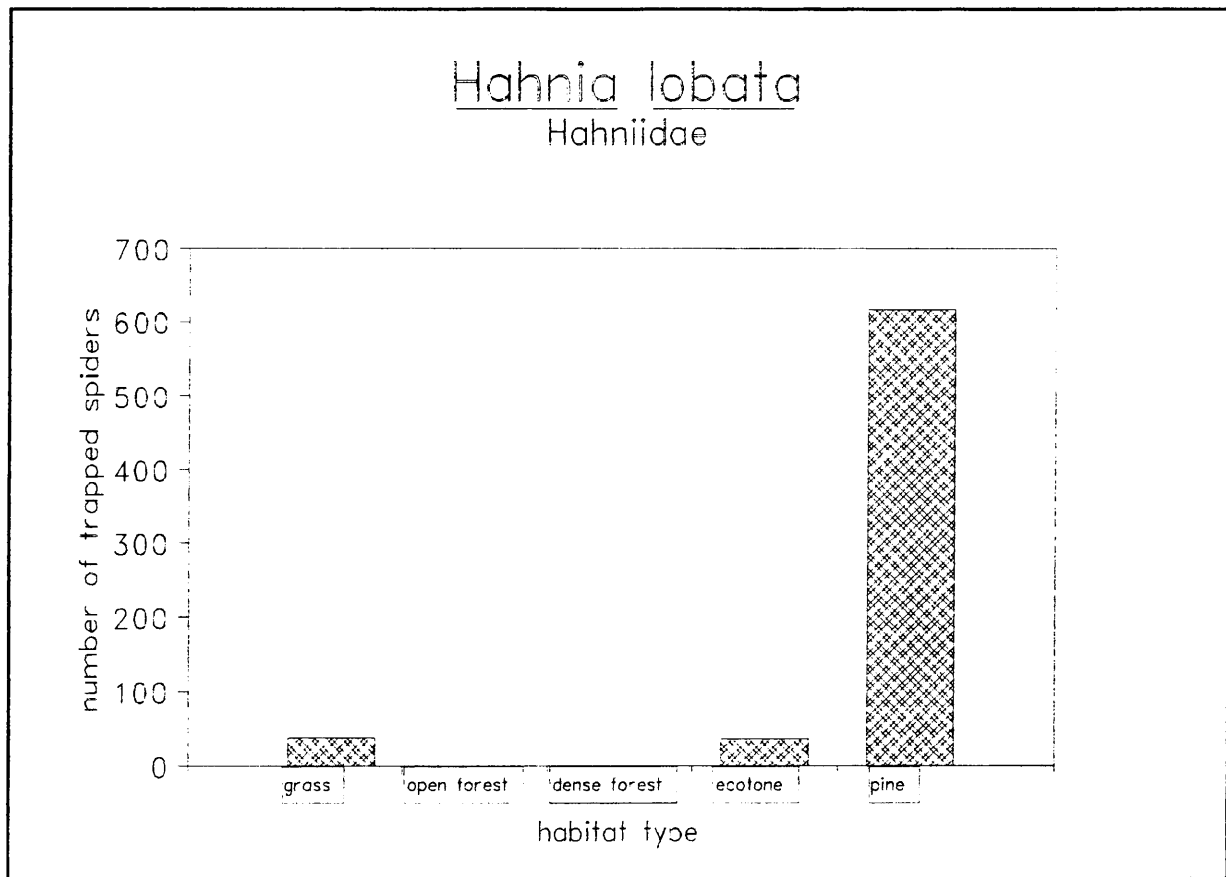
**Figure 16:** The monthly pitfall catch in all habitat types for female, male and juvenile spiders of sp.3 (Anapidae), during 1992/1993 at Ngome State Forest.



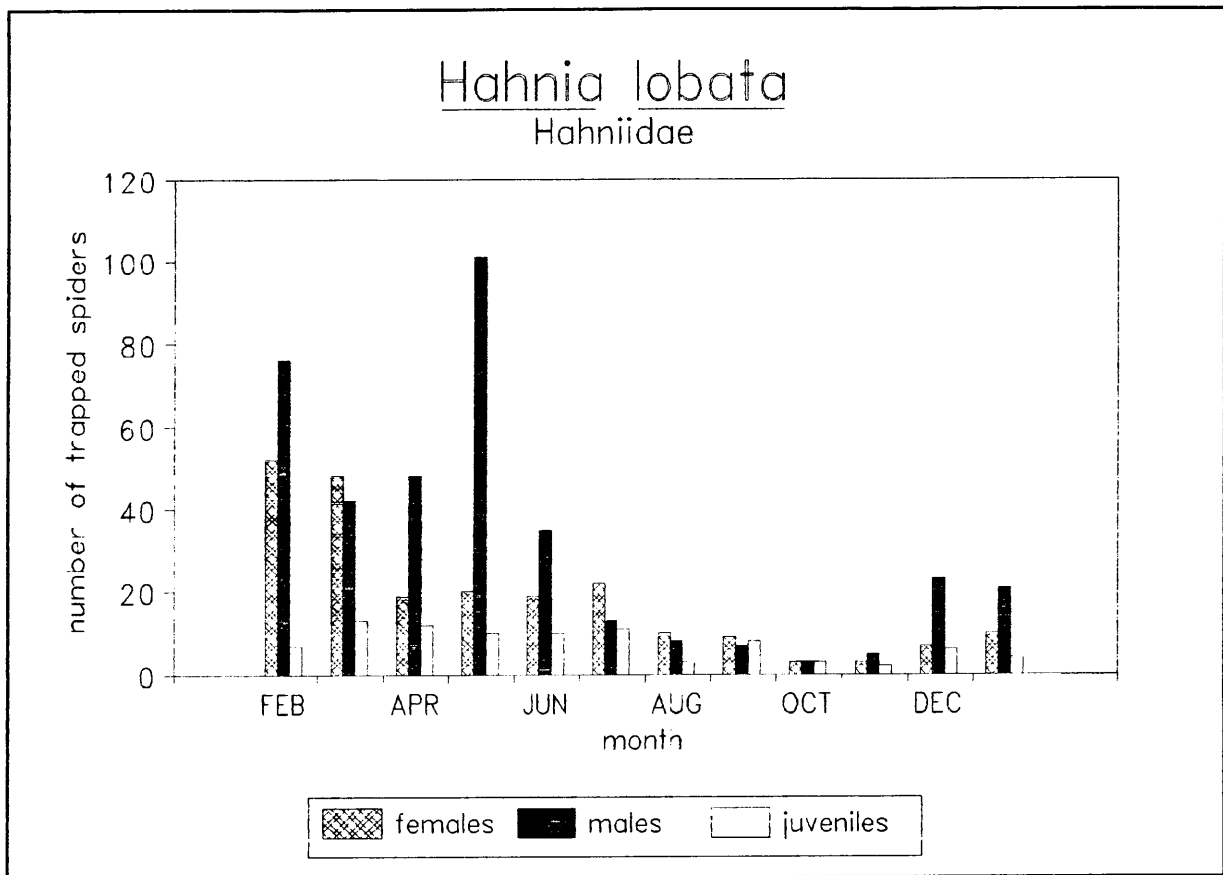
**Figure 17:** The total number of individuals of *Ctenus spenceri* (Ctenidae) trapped in pitfall traps for each of the five habitat types during 1992/1993 at Ngome State Forest.



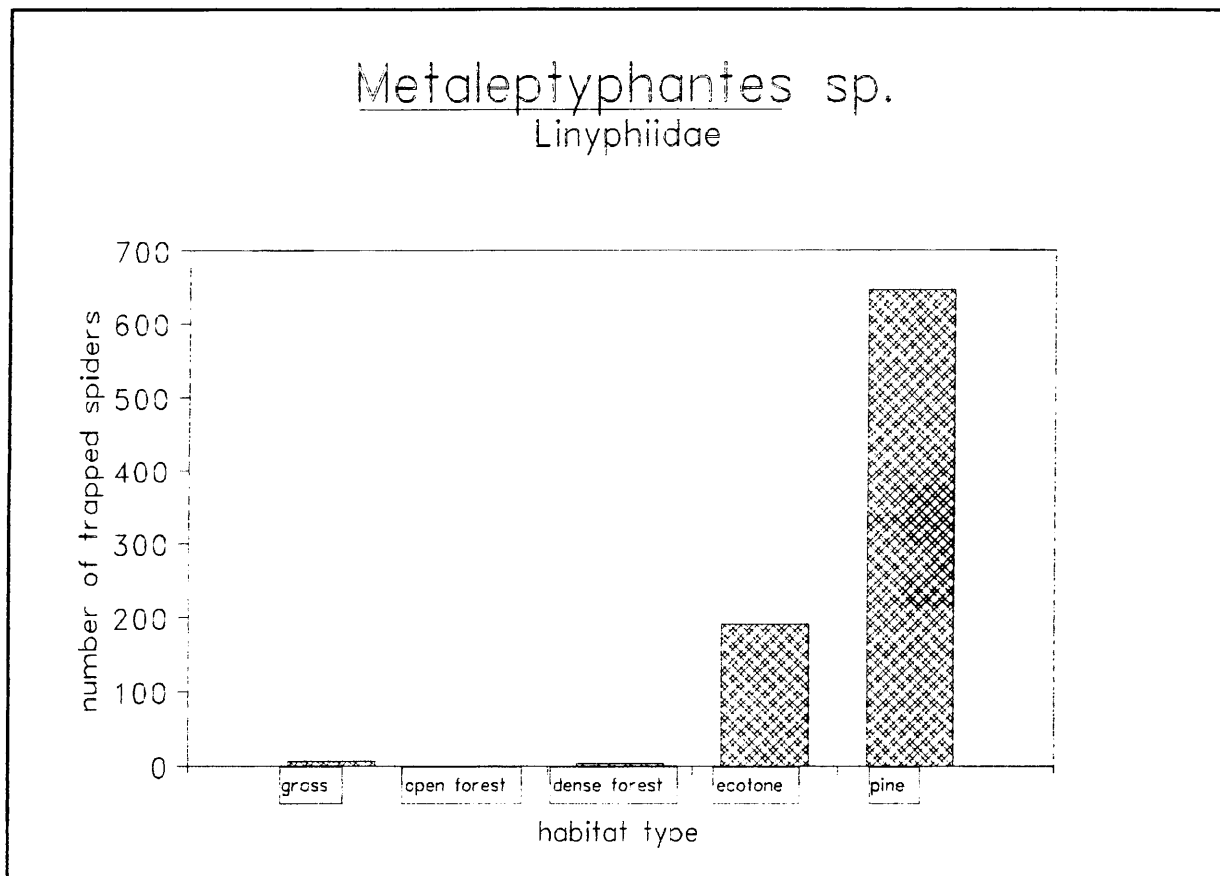
**Figure 18:** The monthly pitfall catch in all habitat types for female, male and juvenile spiders of *Ctenus spenceri* (Ctenidae), during 1992/1993 at Ngome State Forest.



**Figure 19:** The total number of individuals of *Hahnia lobata* (Hahniidae) trapped in pitfall traps for each of the five habitat types during 1992/1993 at Ngome State Forest.



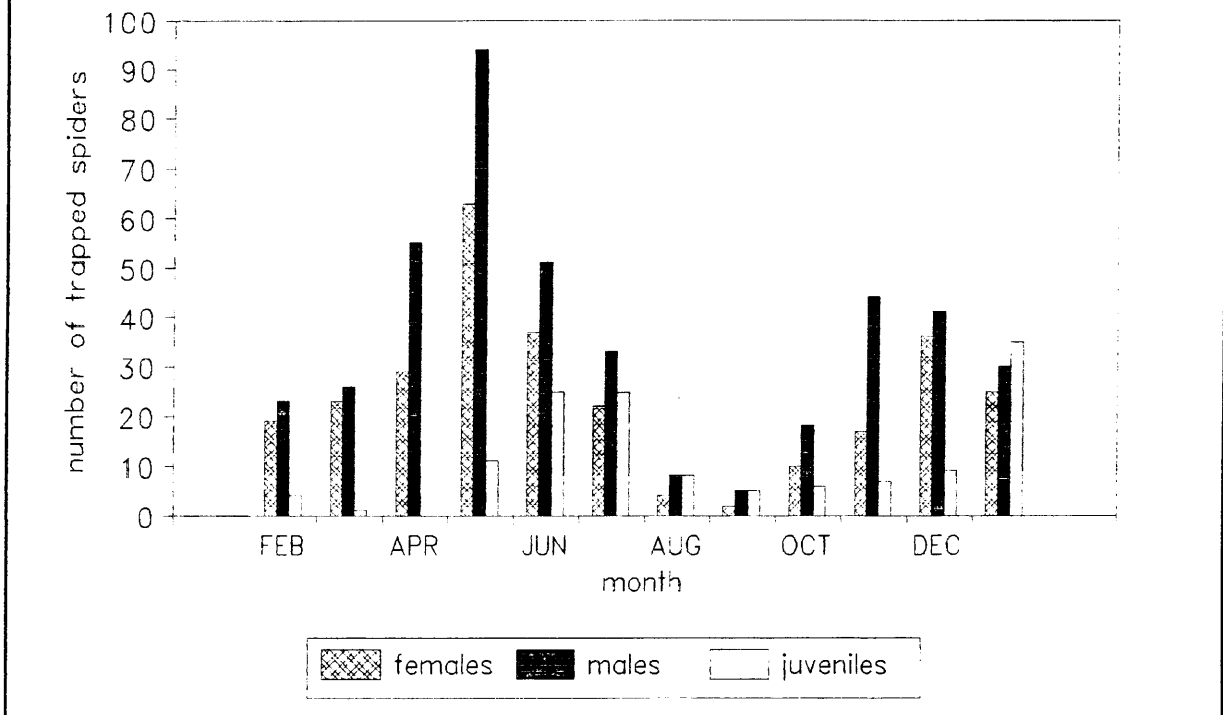
**Figure 20:** The monthly pitfall catch in all habitat types for female, male and juvenile spiders of *Hahnia lobata* (Hahniidae), during 1992/1993 at Ngome State Forest.



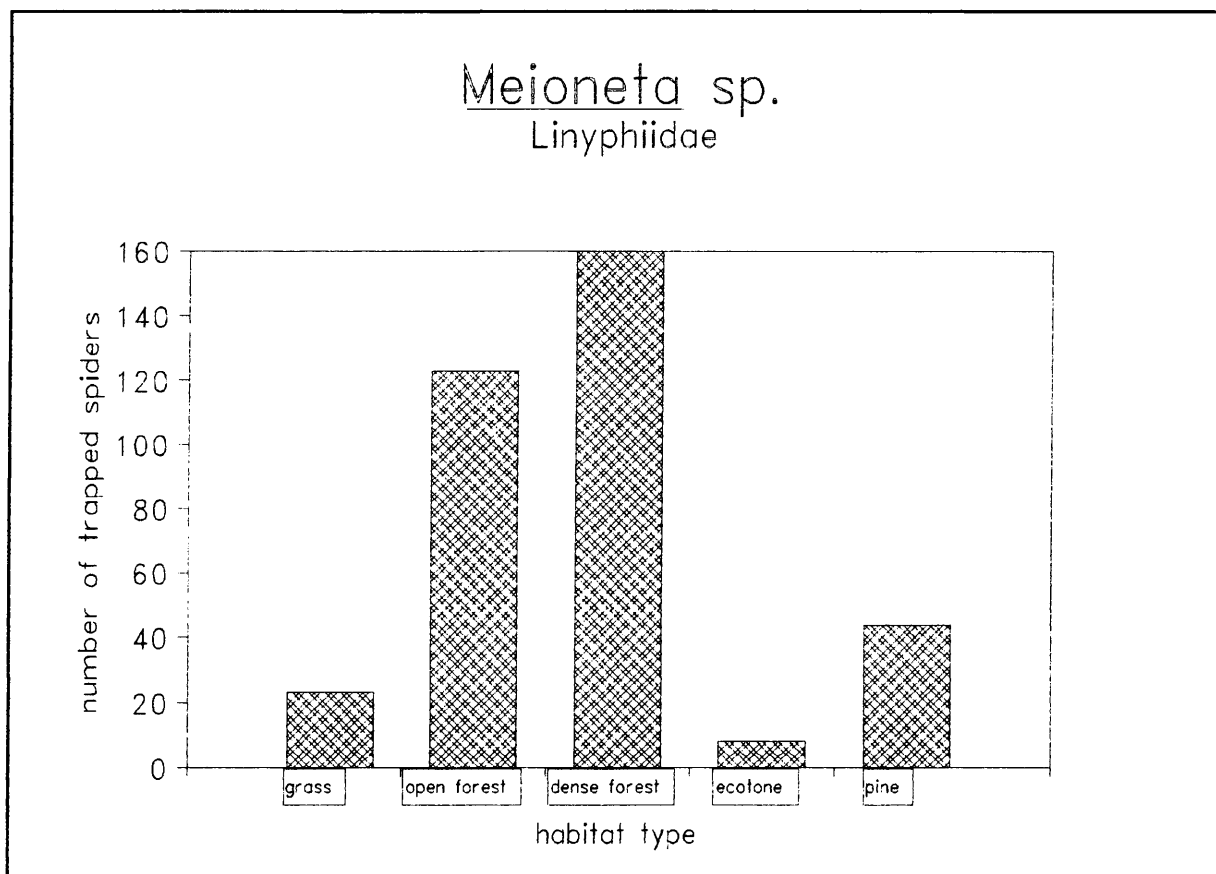
**Figure 21:** The total number of individuals of *Metaleptyphantes* sp. (Linyphiidae) trapped in pitfall traps for each of the five habitat types during 1992/1993 at Ngome State Forest.



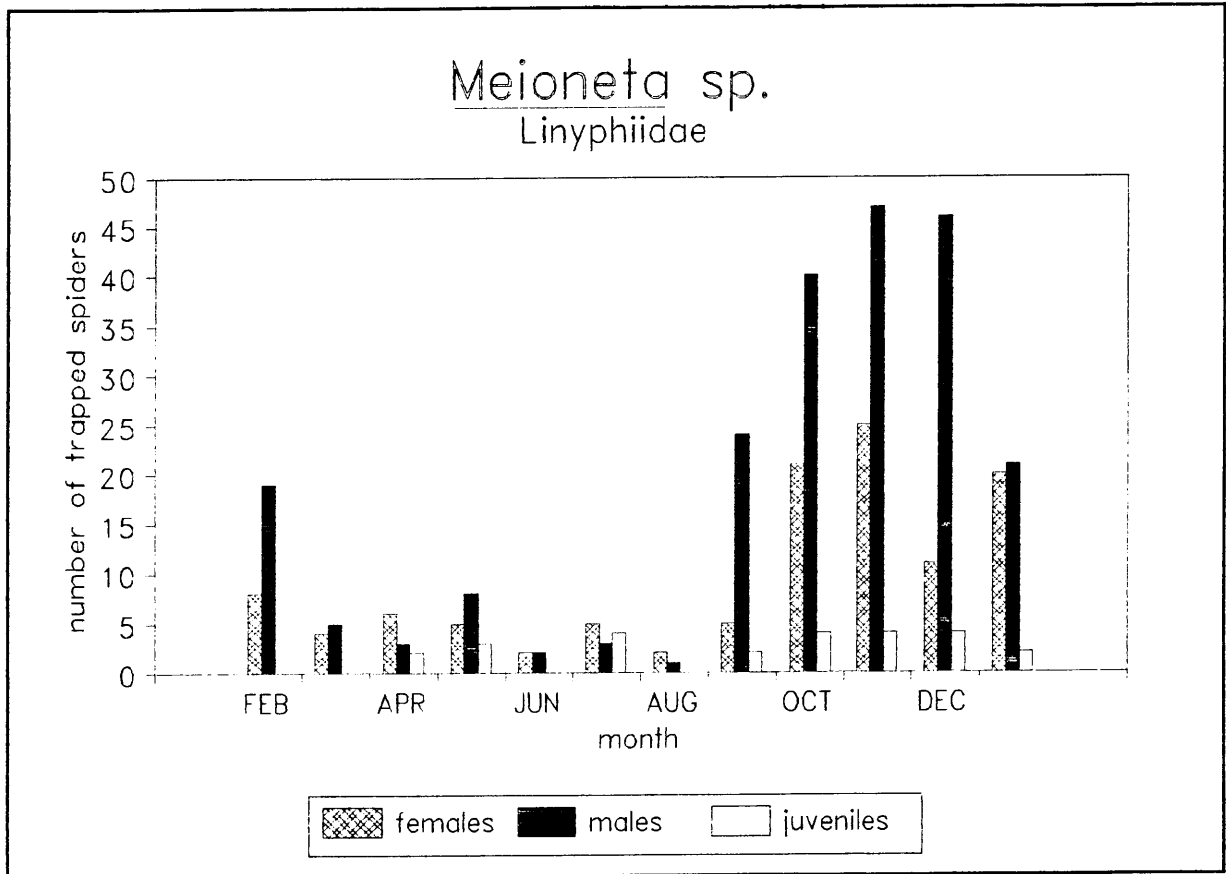
Metaleptyphantes sp.  
Linyphiidae



**Figure 22:** The monthly pitfall catch in all habitat types for female, male and juvenile spiders of *Metaleptyphantes* sp. (Linyphiidae), during 1992/1993 at Ngome State Forest.

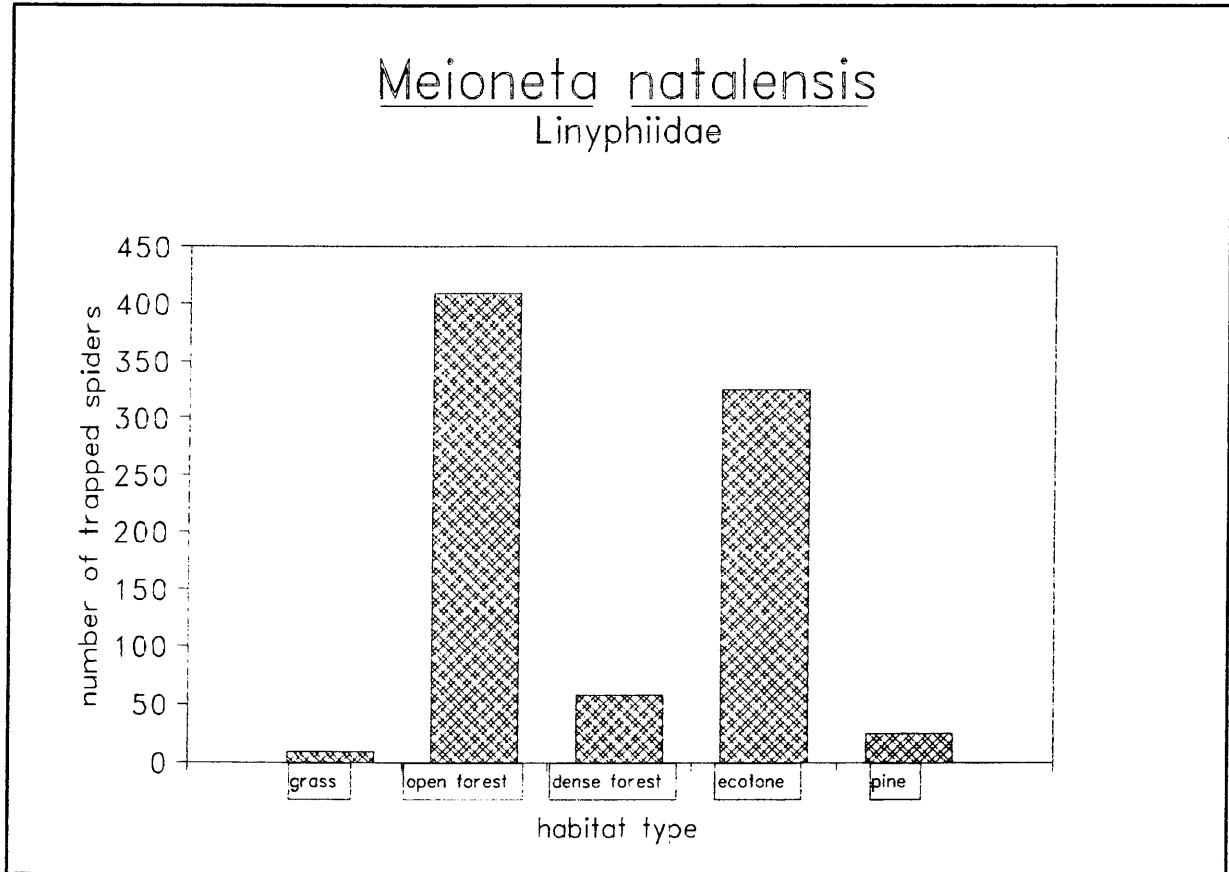


**Figure 23:** The total number of individuals of *Meioneta* sp. (Linyphiidae) trapped in pitfall traps for each of the five habitat types during 1992/1993 at Ngome State Forest.



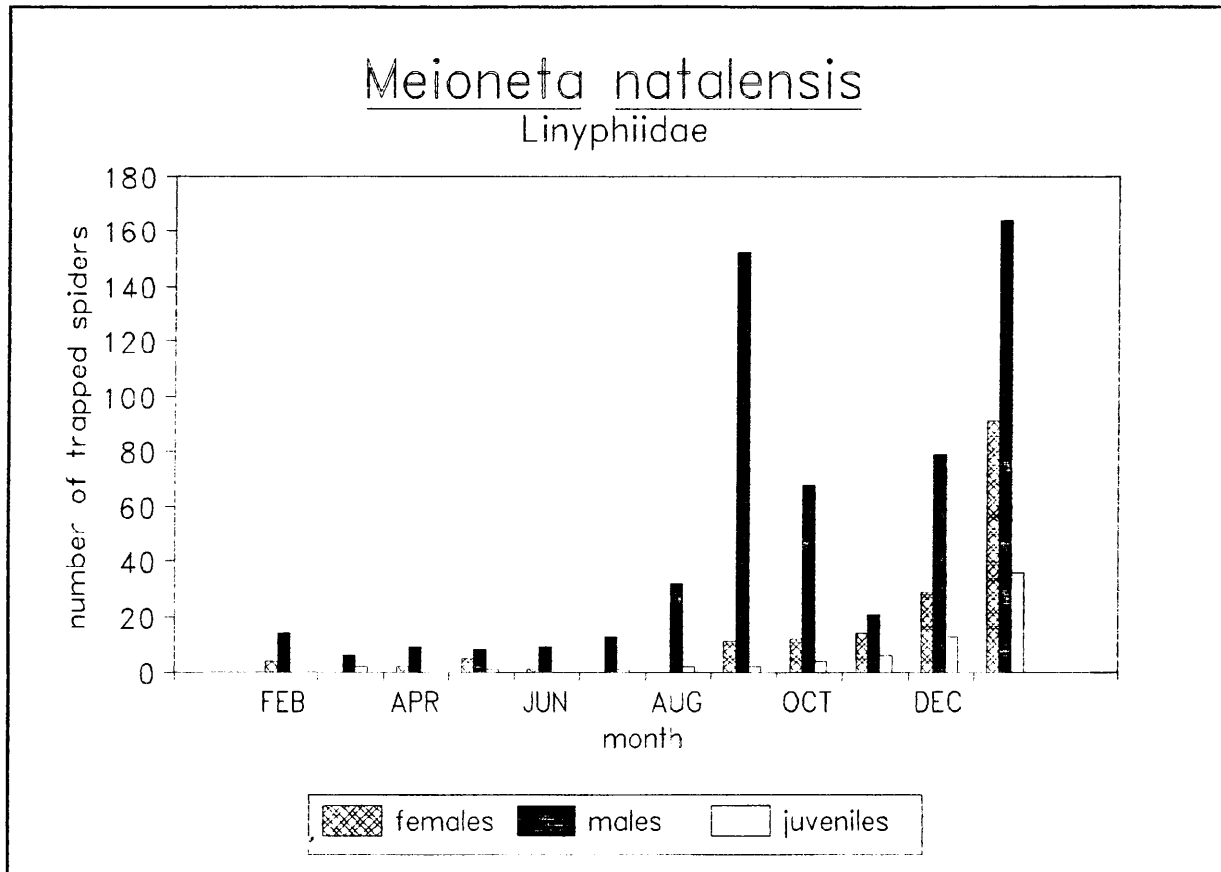
**Figure 24:** The monthly pitfall catch in all habitat types for female, male and juvenile spiders of *Meioneta* sp. (Linyphiidae), during 1992/1993 at Ngome State Forest.

Meioneta natalensis  
Linyphiidae

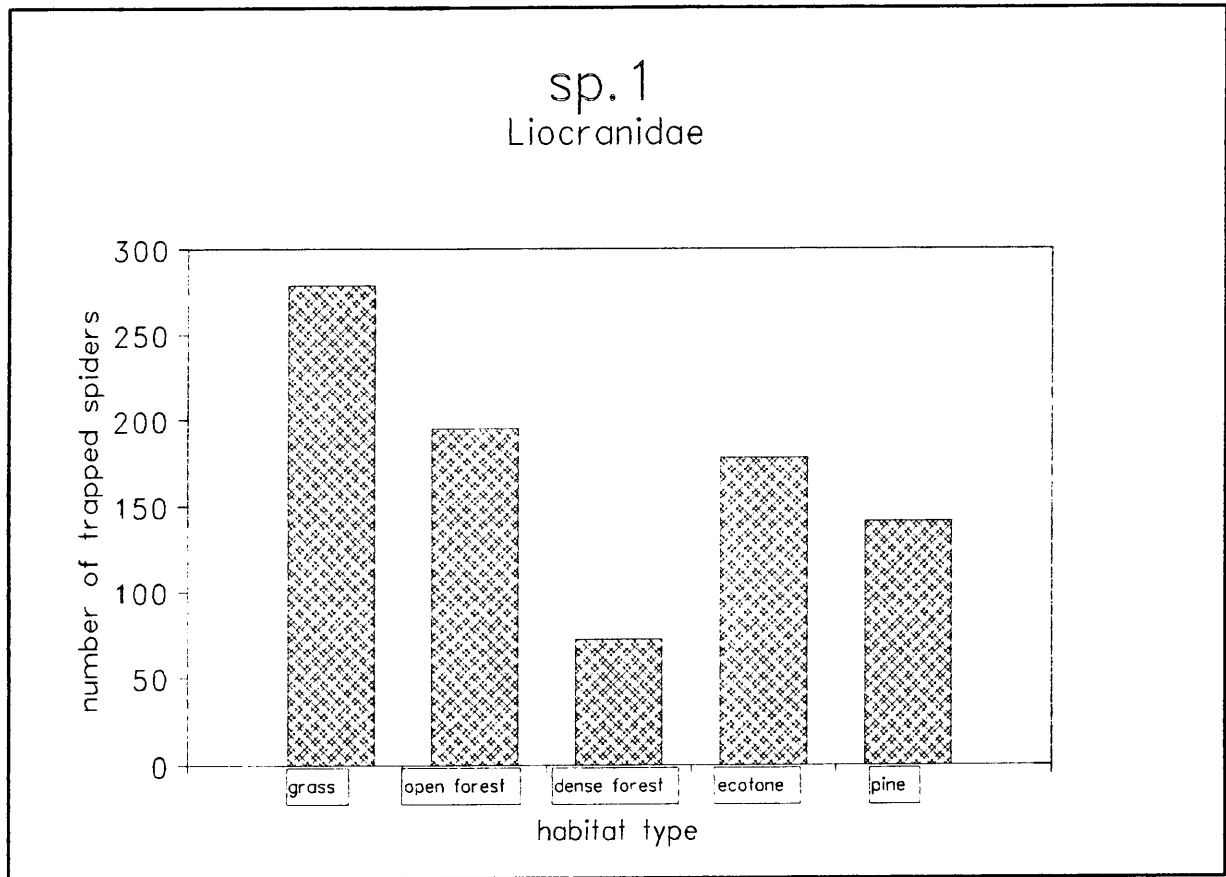


**Figure 25:** The total number of individuals of *Meioneta natalensis* (Linyphiidae) trapped in pitfall traps for each of the five habitat types during 1992/1993 at Ngome State Forest.

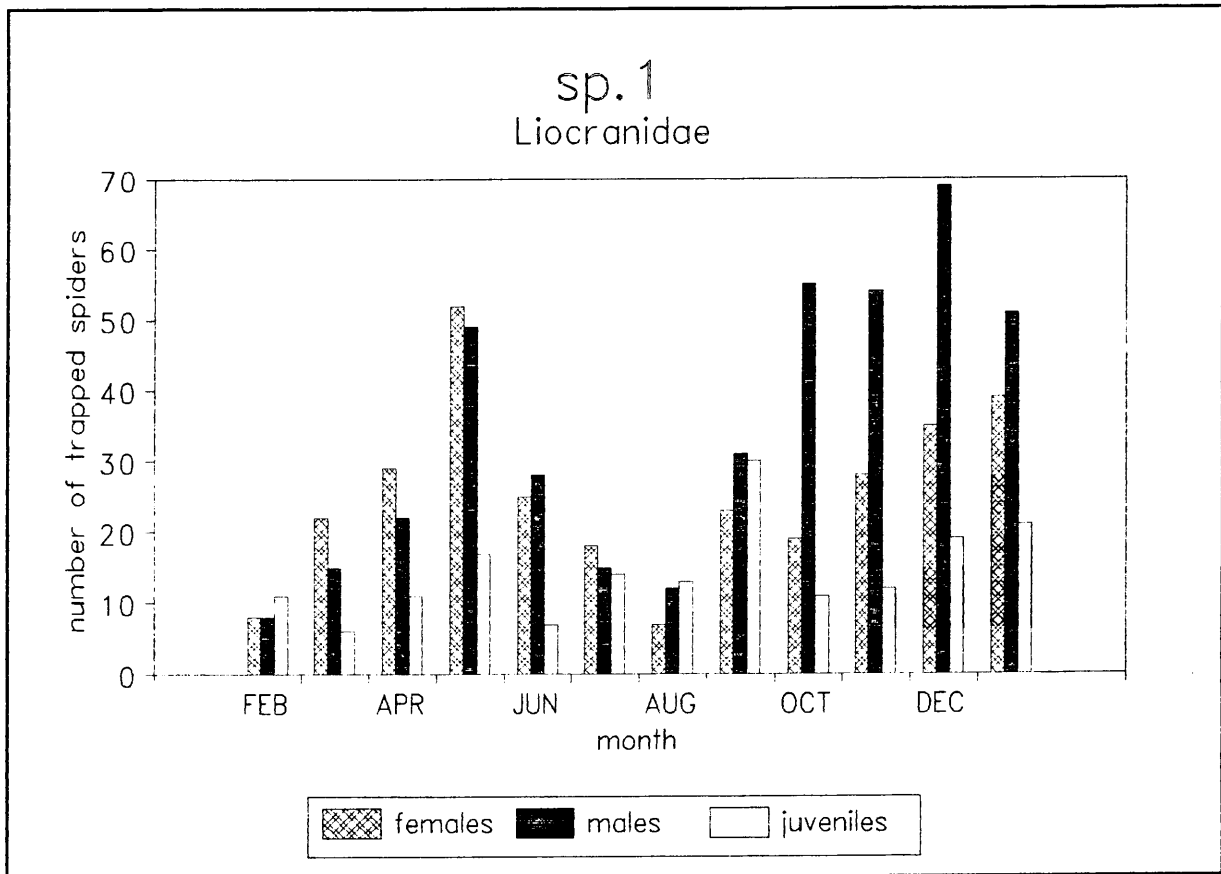
Meioneta natalensis  
Linyphiidae



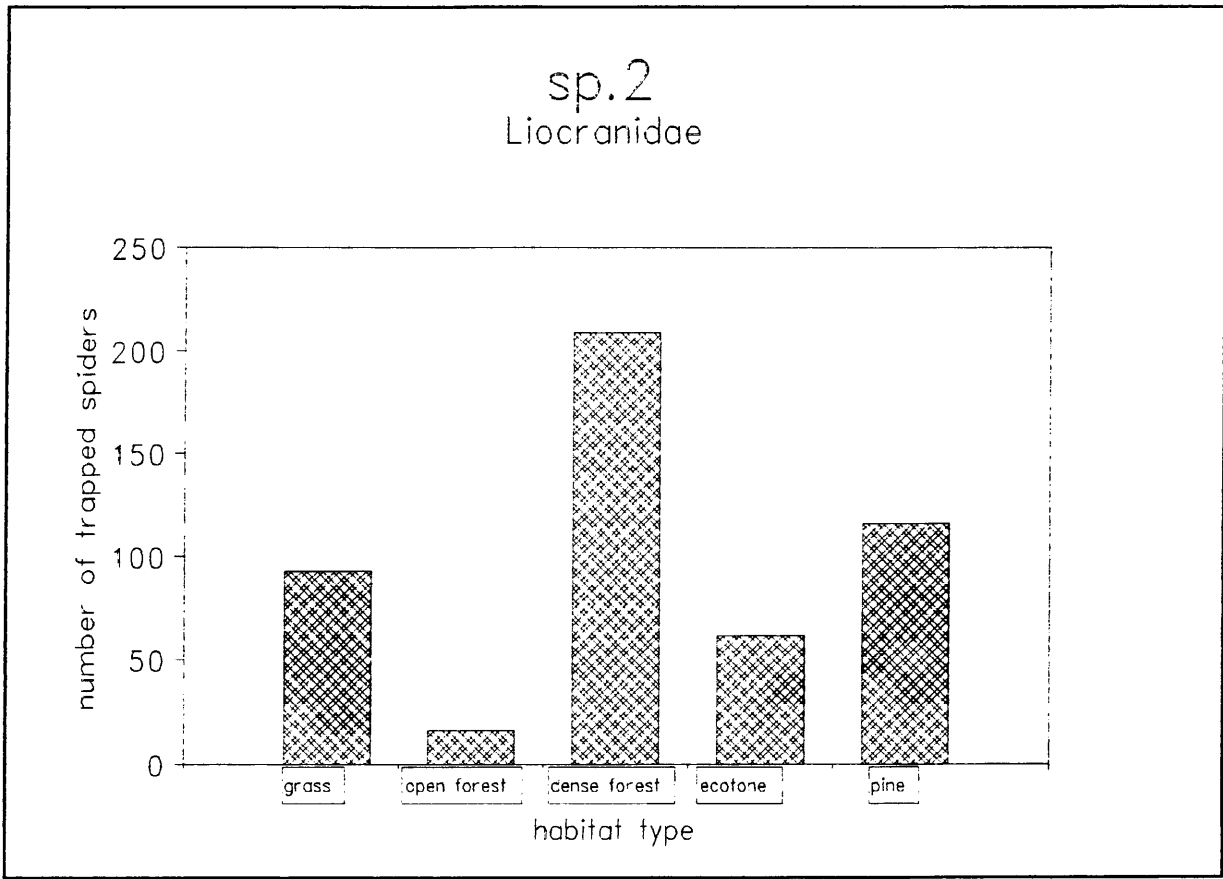
**Figure 26:** The monthly pitfall catch in all habitat types for female, male and juvenile spiders of *Meioneta natalensis* (Linyphiidae), during 1992/1993 at Ngome State Forest.



**Figure 27:** The total number of individuals of sp.1 (Liocranidae) trapped in pitfall traps for each of the five habitat types during 1992/1993 at Ngome State Forest.

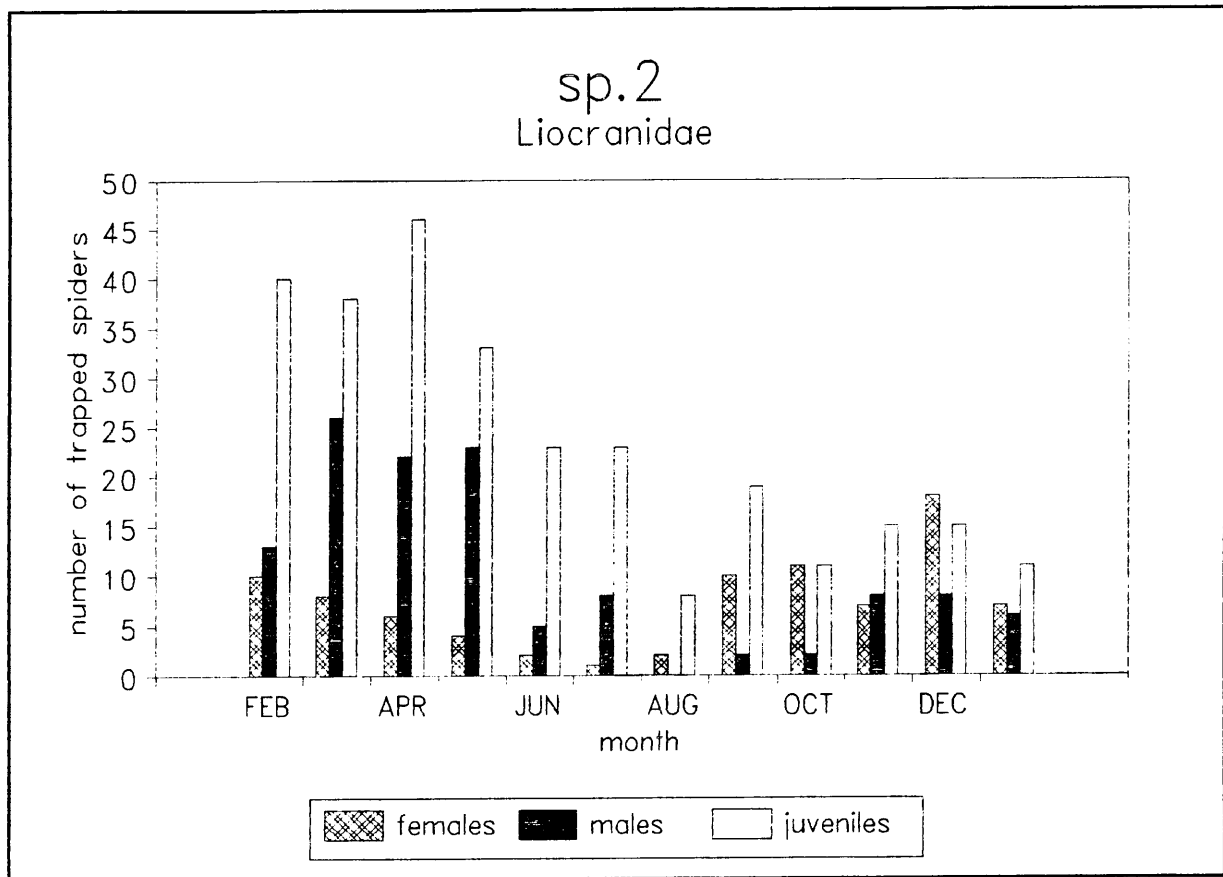


**Figure 28:** The monthly pitfall catch in all habitat types for female, male and juvenile spiders of sp.1 (Liocranidae), during 1992/1993 at Ngome State Forest.



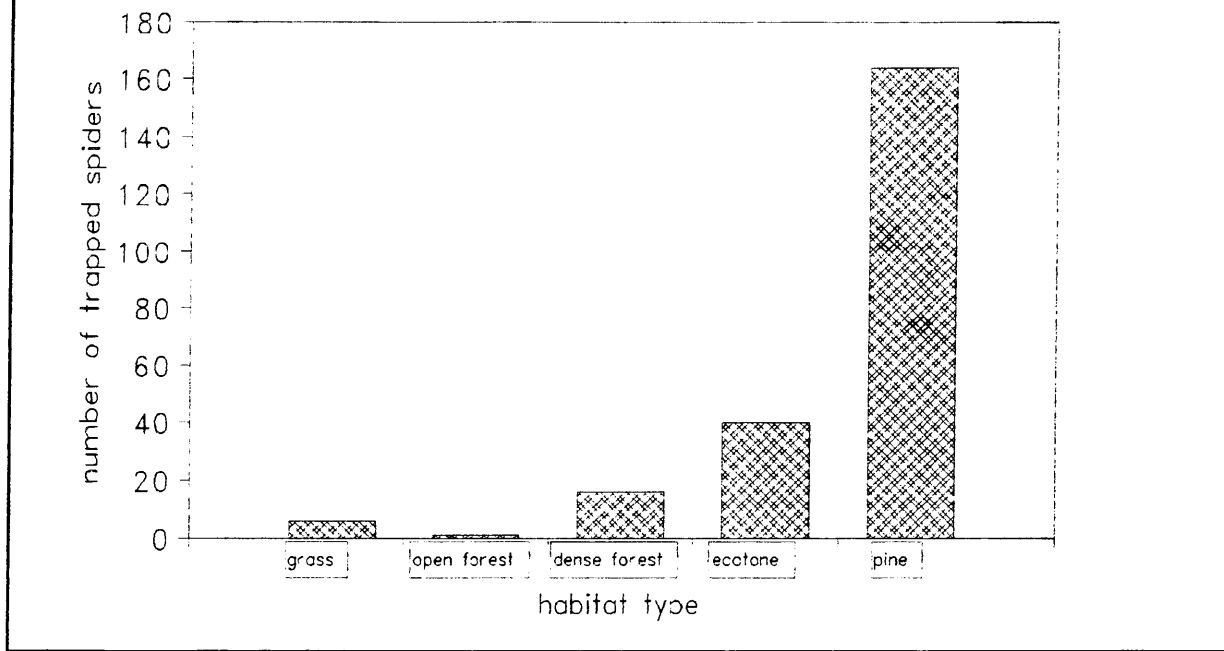
**Figure 29:** The total number of individuals of sp.2 (Liocranidae) trapped in pitfall traps for each of the five habitat types during 1992/1993 at Ngome State Forest.



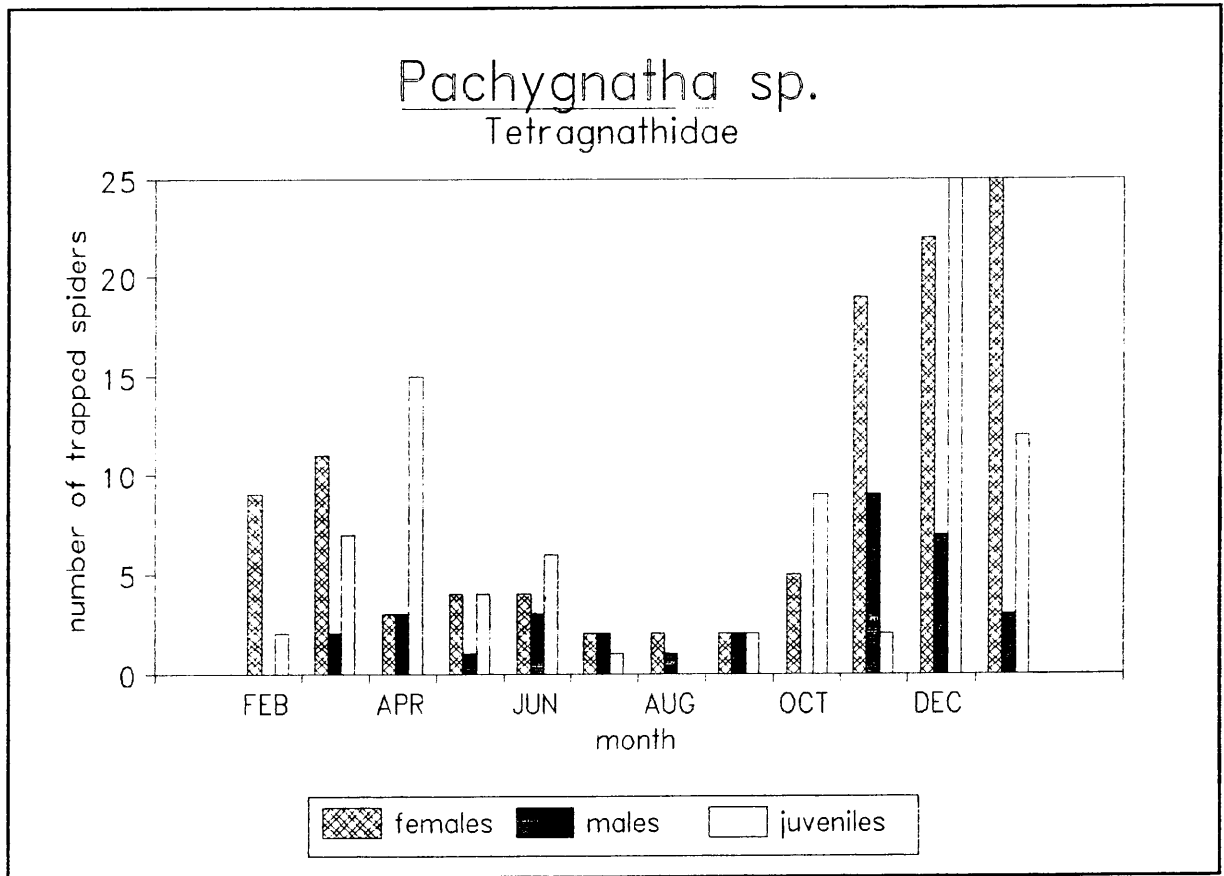


**Figure 30:** The monthly pitfall catch in all habitat types for female, male and juvenile spiders of sp.2 (Liocranidae), during 1992/1993 at Ngome State Fore

Pachygnatha sp.  
Tetragnathidae



**Figure 31:** The total number of individuals of *Pachygnatha* sp. (Tetragnathidae) trapped in pitfall traps for each of the five habitat types during 1992/1993 at Ngome State Forest.



**Figure 32:** The monthly pitfall catch in all habitat types for female, male and juvenile spiders of *Pachygnatha* sp. (Tetragnathidae), during 1992/1993 at Ngome State Forest.

**1) Family: Amaurobiidae**

**Species: new genus and species**

Habitat preferences (Figure 13):

It would seem that this medium-sized species prefer more open vegetation cover at ground level. No individuals were trapped in either dense forest or pine. Typically amaurobiids occupy habitats on forest floors in damp and dark places. However, there are a few species that are found in grassy and more open areas and this species could be one of them (Griswold 19??).

Phenology (Figure 14):

Males were the predominant group trapped in pitfalls. They became active in autumn with the highest peak in April/May. Juvenile spiders start to appear in early winter and were trapped through to late summer. Roughly the same pattern held for females. Because of the small number of juvenile and female spiders trapped, any inferred pattern for these groups should be treated with care.

**2) Family: Anapidae**

**Species: sp.3 (unidentified)**

Habitat preferences (Fig.15):

This minute species (typical of the family) was trapped mostly in dense forest and pine (in contrast to the previously discussed species) and were totally absent in grass. The Anapidae (dwarf ring-shield spiders) are typically found in forest litter and caves. Some species spin small orb-webs (2-3 cm diameter) pulled up into a cone at the centre. Due to their small size these spiders' main prey are probably Collembola. The collembolans were

most abundant in pine (pers. obs.) and this species's occurrence may be correlated to its prey. Its small size may also place physiological constraints on the range of habitats they are able to colonize (Peters 1983). This could explain their absence in grass which has more fluctuating microclimatic conditions. Very little is known about the ecology of anapids in Africa (A.S. Dippenaar-Schoeman, pers. comm.).

Phenology (Figure 16):

Male and female spiders showed a smaller peak in activity in autumn (April/May) and a larger peak in midsummer (December/January). Juvenile spiders were trapped in winter and again during midsummer. These results suggest the possibility that this species produces two generations over a one year period, which is not an uncommon occurrence among spiders (Schaefer 1987).

### **3) Family: Ctenidae**

#### **Species: *Ctenus spenceri***

Habitat preferences (Figure 17):

This is the dominant ground-living spider at Ngome State Forest. Ctenids are wandering spiders which do not make webs. They are generalists in their habitat preferences and were trapped in the highest numbers in all habitat types. Numbers trapped in pine and dense forest were somewhat lower than the numbers for other habitat types. Their medium to large body size will make them less susceptible to physiological constraints imposed by fluctuating microclimates. According to Lawrence (1937), *C. spenceri* is a common species in Natal where it can be found under logs and among forest litter. They are nocturnal (pers. obs.) and are easily collected alive in large numbers with the help of a

head lamp which reflects in their eyes at night.

Phenology (Figure 18):

Male and female spiders were most active in early summer and juveniles in late summer. Activity decreased in winter for both adults and juveniles. Most eggs are probably laid in early summer with juvenile spiders emerging at the same time to mature through the rest of the summer and winter seasons.

**4) Family: Hahniidae**

**Species: *Hahnia lobata***

Habitat preferences (Figure 19):

This species is a specialist in its habitat preferences and was collected predominantly in pine habitat. A few individuals were trapped in grass and ecotone habitats. No individuals were trapped in open forest and dense forest habitat. Hahniids are the comb-tailed spiders which make their delicate webs close to ground level among substrate vegetation. They are small spiders with possible physiological constraints confining them to certain habitat types. Main prey items are probably collembolans which may partly explain their predominance in pine.

Phenology (Figure 20):

Male spiders were trapped in high numbers all through summer with a peak occurring in autumn (April/May). Numbers declined again in winter. Female spiders were abundant through mid and late summer with numbers declining towards winter and numbers increasing again in early summer. Juvenile spiders basically followed the same pattern as females (though in lower numbers).

**5) Family: Linyphiidae**

**Species: *Metaleptyphantes* sp.**

Habitat preferences (Figure 21):

The Linyphiidae were represented by the most trapped individuals compared to all other trapped spider families. They are small spiders constructing sheet-like webs and hence their common name: sheet-web spiders. The *Metaleptyphantes* sp. was trapped only in pine and ecotone habitats. It is therefore a habitat specialist not occurring in more open habitat types. Its small body size may also prevent it from occurring in fluctuating microclimatic conditions.

Phenology (Figure 22):

The activity of adult spiders showed two peaks: a larger peak in autumn (April/May) and a smaller summer peak (October/November). Juvenile spiders showed peaks correlated with those for adult spiders, but with a 1-2 months delay, in other words a peak in winter (June/July) and a peak in summer (December/January). This may suggest two generations per year for this species (Schaefer 1987).

**6) Family: Linyphiidae**

**Species: *Meioneta* sp.**

Habitat preferences (Figure 23):

This species was trapped predominantly in dense forest and open forest, though it occurred in all other habitat types as well. It seems to prefer more open areas with higher humidity, and therefore the large number trapped in dense forest habitat (from a spider's vantage point the dense forest habitat is relatively

open due to the plant structure found at ground level). This is a small species (typical of the Linyphiidae).

Phenology (Figure 24):

Male and female spiders were most active from spring (August/September) through to mid summer (November/December), with a peak occurring in October/November. Juvenile spiders showed no clear pattern and were trapped throughout the year in smaller numbers.

**7) Family: Linyphiidae**

**Species: *Meioneta natalensis***

Habitat preferences (Figure 25):

This species occurred mainly in open forest and ecotone habitats. Small numbers were trapped in pine and dense forest and an even smaller number in grass. This is a small species which seems to prefer the dead leaf litter lying on the ground among which it constructs its small sheet-like web.

Phenology (Figure 26):

Male spiders were trapped in the largest numbers with peaks in spring (August/September) and mid-summer (December/January). Female spiders were absent during winter, with a small peak occurring in mid-summer. Juvenile spiders showed the same pattern as females, though with higher numbers.



**8) Family: Liocranidae**

**Species: sp.1 (unidentified)**

Habitat preferences (Figure 27):

Highest numbers for this species was collected in grass. However, it was also trapped in considerable numbers in other habitat types. This is a small species and this fact combined with its habitat preferences may indicate physiological adaptations to fluctuating environments. The family Liocranidae are wandering spiders.

Phenology (Figure 28):

Male and female spiders showed two peaks of activity for autumn (April/May) and mid-summer (November through to January). The activity for juvenile spiders peaked in spring (August/September). A possible smaller peak occurred in autumn (April/May). The two peaks of activity again suggest two generations per year.

**9) Family: Liocranidae**

**Species: sp.2 (unidentified)**

Habitat preferences (Figure 29):

This species preferred dense forest habitat, but was also trapped in other habitat types with the lowest number trapped in open forest. This is a medium sized spider.

Phenology (Figure 30):

Both male and female spiders are most active in summer. The same pattern was observed for juvenile spiders which occurred in much

larger numbers. Male spiders showed highest activity towards late-summer, while females showed a peak of activity in mid-summer (November/December).

**10) Family: Tetragnathidae**

**Species: *Pachygnatha* sp.**

Habitat preferences (Figure 31):

This species preferred pine with numbers in all other habitat types significantly lower and ecotone having higher numbers than grass and indigenous forest. This is a small species which probably feeds predominantly on collembolans (pers. obs.). This may partly explain its prevalence in pine habitat.

Phenology (Figure 32):

More females than males were trapped. Male spiders showed a peak in activity during early summer (October/November). Female spiders were most active in summer and showed two peaks: a larger peak in mid-summer (December/January) and a smaller peak in late summer (February/March). Juvenile spiders showed the same basic pattern as female spiders.

## CHAPTER 6

### THE NGOME STUDY IN CONTEXT

#### 6.1 Crisis in community ecology

Worldwide concern over the degradation of natural environments is spreading at a rapid pace. Economical and political instability, increasing demands on food production for an exploding world population and escalating pollution levels are some of the more obvious causes for concern. It is expected of ecologists to provide solutions to environmental problems. Time to act on these problems is limited and ecology will have to provide a higher input of solutions than what is currently being produced. In view of failing financial support, the responsibility for hardline decisions towards research directions should be taken by the scientists themselves. This is only possible when scientists can present themselves confidently and capably to funding agencies.

Confidence and capability need to be based on scientific theory that has pragmatic value. Successful theories should be judged by their ability to predict accurately. Claims that theory represents some essence of truth or reality seem to be unnecessary, unwarranted and confining (for a more detailed discussion see Peters 1991). Theories are tools and we need reliable tools to alleviate our environmental problems.

Much of ecology's theoretical constructs are ill-founded on a lack of basic research. It is hardly surprising that the bulk of fashionable ecology fails in predictive power when compared to most other biological sciences (Peters 1991). Ecology deals with a complex subject matter. Theory simplifies and abstracts this complexity into its essential elements which can then be

manipulated and modified to produce a required result. The first step in this process of simplification is to identify recurring patterns. Once a recurring pattern has been identified it can be explained in terms of scientific theory. Theory then stimulates the production of hypotheses which could in turn predict new patterns to test more theory. Pattern recognition therefore forms an integral part of any scientific investigation. Pattern recognition is impossible without the foundation of descriptive research. The need for descriptive research in ecology cannot be overstated in providing the basis from which relevant questions and hypotheses are generated.

In a third world context this foundation of basic descriptive community ecological data is practically nonexistent. Platnick (1991) points out that the southern hemisphere's temperate regions are generally more species rich than their counterparts in the northern hemisphere, and that the notion of the tropics being vastly more species rich than the temperate parts of the world is nothing more than an assumption, rather than a demonstrated fact. This provides even more reason for alarm as most third world countries are situated in the south. It is important to know the extent of the richness and diversity of the communities we are trying to save (Bond 1989).

By far the most alarming situation exists concerning our invertebrate fauna. In a southern African context, zoologists' preoccupation with the larger animals has left us disturbingly ignorant of the primary basis of our ecosystems. The great diversity and large biomass of the invertebrate component are proving to be absolutely crucial in ecosystem functioning. Without a healthy primary base in any ecological food web, no populations of the secondary and tertiary levels will survive intact for very long to continue capturing the public's imagination. But what is a healthy primary base? To what extent

have man's diverse disturbances affected our invertebrate communities? Can ecological damage be reversed? For most ecological communities in South Africa, answers to these questions are simply not available. Environmental problems will only be addressed in an effective manner once our ignorance of the answers to the above questions has been alleviated.

Ecologists have to deal with field situations far from easily controlled. Field workers and theorists have always found it hard to relate to each other and ecology is a prime example of this situation. In many ways theory is much too idealistic to cope with the messiness of actual field conditions and sometimes loses contact with field observations. This does not change the fact that theoretical and field biology will ultimately have to be reconciled to be of any pragmatic value. It is still comparatively hard for an ecologist to enter field work in an unknown area armed with predictions that prove to be accurate. Rather than discourage, this should motivate ecologists to develop their growing subject, starting with a sound foundation of community surveying - the basis of community ecology.

## **6.2 Spiders in ecological context**

As frequent predators of invertebrates spiders play a key role in the structuring of invertebrate communities (Edwards 1963, Young & Lockley 1989), and are therefore potentially important in ecosystem functioning. Predator-prey models sustain the hypothesis that "predation pressure permits increased niche overlap among prey species" (Roughgarden & Feldman 1975) and may therefore have an important role in the maintenance of species diversity. The large numbers and omnipresence of spiders in most communities also indicate their potential importance in any holistic approach to ecosystems. By identifying the spatial and temporal communal patterns of spiders in different habitat types

and correlating these patterns with certain variables (microclimate, habitat structure, prey populations etc.), a workable outlay can be produced for recognising relevant questions and hypotheses concerning community structure and ecosystem functioning. Even without the additional data on correlating variables, the spatial and temporal information gained are of prime importance in the understanding of spider distribution and natural history.

Spiders are generally considered to be physiologically robust, highly adaptive animals, capable of withstanding the negative influences of considerable changes in their natural habitat. However, as with most other invertebrates, this view is both simplistic and based on very little empirical evidence. Literature on the northern hemisphere's spider communities contain several examples of the effects of human induced change on spiders (e.g. Duffey 1962; Lowrie 1963; Cherrett 1964; Rushton, Topping & Eyre 1987; Gunnarson 1988; Jennings, Houseweart, Dondale & Redner 1988; Rushton, Luff & Eyre 1989). A South African study reported on the negative effects pesticides can have on spiders (van den Berg, Dippenaar-Schoeman & Schoonbee 1990).

Particularly where human practices change plant structure, an effect on spider communities is almost sure to follow [it is interesting to note that even among higher animals living in the three dimensional world of the rain forests, species richness are often correlated with structural diversity of plants (e.g. Schwarzkopf & Rylands 1989)]. Numerous studies have demonstrated the effect of litter and plant structure on spider communities (e.g. Lowrie 1948; Uetz 1975, 1977, 1979; Bultman & Uetz 1982; Bultman, Uetz & Brady 1982; Cady 1984; Corey & Taylor 1988, 1989). The results of the Ngome study also support this conclusion. It is also highly probable that sensitive specialist

species exist and we should make an effort towards the identification and subsequent conservation of this part of our natural heritage.

### **6.3 Forests - our valuable heritage**

Forests have a special mysterious tranquillity and mystery that have proved to be fertile breeding grounds for many of man's primordial fears and desires. These places are still actively involved in man's spiritual well-being. This longing for areas where we can still feel isolated from modern intervention may be difficult to understand, but will most probably prove vital to psychological human development. Along the same line of argument, mention can be made of the important role forest plants (see Cunningham (1989) for indigenous plant uses in South Africa) and animals play in the cultures of people traditionally associated with the tropics.

Apart from these nonmarket arguments for conservation, it has been shown in several instances that many nonresources (like endangered species) have economic value, real or potential. In the face of the alarmingly fast disappearance of the world's natural forested areas, it seems sensible to look for ways in which we can keep track of human intervention, and to understand the effects of human intervention on our forests.

### **6.4 The potential effects of pine plantations on animal communities**

Many plant and animal species in plantations are in a situation where they are without natural predators which cannot cope with the exotic environment. Another possibility concerns species whose dispersal mechanisms cause them to end up in a suboptimal environment. Both of these situations can lead to highly

unpredictable population fluctuations, which may further present itself as either an external threat to neighbouring natural or agricultural areas (in the case of destructive pests), or as a 'black hole' which 'sucks up' dispersing individuals into an unfavourable environment.

Species persistence has always depended a great deal on the establishment of healthy subpopulations large enough to counter the effects of genetic drift, inbreeding depression and other associated problems of small population size. Research producing information which can be useful in understanding these processes is needed to provide a sound basis for sensible management objectives. The extent of South Africa's natural forests simply leaves no room for mismanagement. Agnew & Smith (1989) found that natural areas adjacent to agricultural crops act as sources of spider immigrants into the agricultural areas, which may in turn have beneficial consequences (Riechert 1990).

### **6.5 Conservation and biological diversity**

Conservation biologists are starting to recognise the importance of the invertebrate component in the functioning of healthy ecosystems. Monitoring and inventoring are two activities used in conservation planning in which terrestrial arthropod assemblages are valuable (Kremen, Colwell, Erwin, Murphy, Noss & Sanjayan 1993). Of prime importance in any conservational scheme is the identification of species sensitive to changing environmental factors (usually specialist species, in contrast to the more ecologically robust generalist species). When these vulnerable species prove to be functionally important it is an additional incentive to their able management and conservation. Information on species distribution and the compilation of biogeographical maps are important tools used in conservation planning.



A more recent approach identifying 'hot spot' areas for the conservation of biological diversity extends the use of genetic, ecological and systematic information on biological communities. The genetic component of biological diversity can be important in the short-term as centres of genetic material which could be applied to combat agricultural problems (Frankel 1974). Genetic diversity is threatened through various ways. Isolation and inbreeding can cause losses of genetic variation (Selander 1983, Ralls, Harvey & Lyles 1986), so can outbreeding (hybridization) to a lesser extent (Cade 1983, Templeton 1986). Small population sizes enhance the effect of genetic drift, which in turn enhances the possibility of losing genetic flexibility, or even extinction (Franklin 1980, Gilpin & Soulè 1986). Gene pools large and variable enough to be suitable for ongoing evolution are needed if long-term survival is to be guaranteed (Frankel 1974).

It is important to realise that most of the genetic problems that arise are not causal in themselves, but rather the symptoms of another underlying cause, namely habitat destruction. Active management in conservation areas is becoming the only viable approach to solve these problems (Frankel 1983). In an active approach to conservation the concept of uniqueness (or the 'differentness' of communities) is important when priority areas for conservation are to be identified. Traditionally diversity has always been measured as the number of species (species richness) or in the form of indices combining richness with abundance. Taxic diversity measures based on cladistic information have recently been developed (Vane-Wright, Humphries & Williams 1991; Crozier 1992) and are considered more adequate for conservation management. A firm taxonomic foundation, followed by basic ecological research, are the steps toward the realization of these goals.

With many groups of organisms it may be difficult to identify

the units of diversity (species) and their geographic distribution (Faith 1992). This has led to attempts to identify different units of diversity to be used in the place of species. Examples include biological diversity represented by 'attributes' of the community (Pressey & Nicholls 1989) or, similarly, 'indicators' of biodiversity (Noss 1990). Again, basic ecological information is needed.

From the above it should be clear that with an active approach to conservation one needs to know, before anything else, what the community under consideration consists of. An ecological survey of the kind undertaken in this study attempts to take that first important step.

### **PART III: ACKNOWLEDGEMENTS**

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## **PART IV: SUMMARY/OPSOMMING**

### **Summary**

A survey of ground-living spiders was conducted at Ngome State Forest, northern Natal. The area is situated on the southern African escarpment. The survey started in January 1992 and ended in January 1993. Five different habitat types were sampled with 180 pitfall traps. Pitfall traps were open continuously and were cleared once a month. Contents were sorted under a dissection microscope and all spiders were sorted into morphospecies, most of which were later identified. The habitat types that were compared were grass, open forest, dense forest, ecotone and pine. Grass, open forest and dense forest represented indigenous vegetation while pine represented exotic vegetation. Ecotone consisted of a mixture of indigenous forest plants and pine trees. Multivariate analysis of the data showed the different habitat types to support different ground-living spider communities. The composition of spider communities in pine differed most from all other habitat types. This result supports the hypothesis that the planting of pine trees largely affects the composition of ground-living spider communities. Spider diversity and richness indices indicated grass to be the most diverse habitat type, while pine was the least diverse habitat type (for ground-living spiders). However, due to the large variation in spider diversity within habitat types, the differences in spider diversity between habitat types were not clearly defined and the results do not unambiguously support the hypothesis that exotic vegetation has lower ground-living spider diversity than indigenous vegetation. The habitat preferences and phenology of the 10 most abundantly trapped spider species were graphically represented and discussed as to make a contribution to these species's autecological relationships. The need for more surveys of this kind in order to identify larger scale ecological

patterns is stressed.

### **Opsomming**

'n Opname van grondbewonende spinnekoppe in die Ngome Staatsbos in noord-Natal is gedoen. Die gebied is geleë op die suider-Afrikaanse platorand. Die opname is begin in Januarie 1992 en het geëindig in Januarie 1993. Die opname is gedoen in vyf verskillende habitattipes m.b.v. 180 putvalle. Putvalle was oop op 'n aaneenlopende basis en is maandeliks leeg gemaak. Die inhoud van putvalle is onder 'n disseksiemikroskoop gesorteer en alle spinnekoppe is aanvanklik tot op die vlak van morfospesies gesorteer. Meeste van die morfospesies is later geïdentifiseer. Die volgende habitattipes is vergelyk: gras, oop woud, digte woud, ekotoon en dennewoud. Gras, oop woud en digte woud het inheemse plantegroei verteenwoordig, terwyl dennewoud uitheemse plantegroei verteenwoordig het. Ekotoon het bestaan uit beide inheemse plante en dennebome. Multivariantsie analise van die data het getoon dat verskillende grondlewende spinnekopgemeenskappe in die verskillende habitattipes voorkom. Die samestelling van spinnekopgemeenskappe in dennewoud het die meeste verskil van spinnekopgemeenskappe van ander habitattipes. Hierdie resultaat ondersteun die hipotese dat die aanplanting van dennebome die samestelling van grondlewende spinnekopgemeenskappe grootliks verander. Indekse van spinnekopdiversiteit en spesiesrykheid het getoon dat gras die mees diverse habitattipe is en dennewoud die armste habitattipe is van grondbewonende spinnekoppe. As gevolg van die groot variasie in spinnekopdiversiteit binne habitattipes was daar nie duidelike verskille in spinnekopdiversiteit tussen habitattipes nie, en kon daar dus nie onomwonde aangetoon word dat uitheemse plantegroei 'n laer grondbewonende spinnekopdiversiteit het as inheemse plantegroei nie. Die habitatsvoorkeure en fenologie van die tien algemeenste spinnekopspesies is grafies voorgestel en bespreek, ten einde 'n

bydrae te lewer tot hierdie spesies se outekologiese verwantskappe. Die tekort aan soortgelyke opnames vir die identifisering van wyer ekologiese patrone word beklemtoon.

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## PART VI: APPENDIX

### APPENDIX A: CHECKLIST OF SPIDER SPECIES RECORDED FROM PITFALL TRAPS AT NGOME STATE FOREST

#### AGELENIDAE

1. Unidentified sp.1 (AGE1)

#### AMAUROBIIDAE

1. *Xevioso* new species? (AMA1)
2. *Xevioso amica* Griswold, 1990 (AMA2)
3. *Xevioso* new species? (AMA3)
4. New genus (AMA4)

#### ANAPIDAE

1. *Metanapis* (?) sp. (ANA1)
2. Unidentified sp.1 (ANA2)
3. Unidentified sp.2 (ANA3)
4. Unidentified sp.3 (ANA4)

#### ARANEIDAE

1. *Larinia* sp. (ARA1)

#### ARCHAEIDAE

1. *Archaea godfreyi* Hewitt, 1919 (ARC1)

#### CAPONIIDAE

1. *Caponia chelifera* Lessert, 1936 (CAP1)

#### CLUBIONIDAE

1. *Clubiona umbilensis* Lessert, 1923 (CLU1)
2. *Cheiracanthium silvicolum* Lawrence, 1938 (CLU2)
3. *Cheiracanthium* sp. (CLU3)

4. *Clubiona subtrivialis* Strand, 1906 (CLU4)
5. Unidentified sp. (CLU5)

#### CORINNIDAE

1. *Medmassa nitida* Lawrence, 1937 (COR1)
2. *Trachelas* sp. (COR2)
3. *Merenius alberti* Lessert, 1923 (COR3)
4. *Austrachelas* sp.1 (COR4)
5. *Austrachelas* sp.2 (COR5)
6. *Austrachelas* sp.3 (COR6)
7. *Austrachelas incertus* Lawrence, 1938 (COR7)
8. *Austrachelas* sp.4 (COR8)
9. *Copa benina* Strand, 1916 (COR9)
10. *Austrachelas* sp.5 (COR10)
11. *Medmassa* sp. (COR11)
12. *Austrophaea* sp. (COR12)
13. Unidentified sp. (COR13)

#### CTENIDAE

1. *Ctenus spenceri*, F.O.P.-Cambridge, 1898 (CTE1)

#### CYATHOLIPIDAE

1. *Cyatholipus icubatus* Griswold, 1987 (CYA1)
2. *Ilisoa* sp. (CYA2)

#### CYRTAUCHENIIDAE

1. *Ancylotrypa vryheidensis* Hewitt, 1915 (CYR1)
2. *Homostola zebrina* Purcell, 1902 (CYR2)

#### GNAPHOSIDAE

1. *Xerophaeus pallides* Tucker, 1923 (GNA1)
2. *Xerophaeus zuluensis* Lawrence, 1938 (GNA2)
3. *Zelotus montana* Purcell, 1907 (GNA3)

4. *Zelotus* sp.1 (GNA4)
5. *Zelotus* sp.2 (GNA5)

HAHNIIDAE

1. *Hahnia lobata* Bosmans, 1981 (HAH1)

HETEROPODIDAE

1. *Olios* sp. (HET1)
2. *Panaretalla* sp. (HET2)
3. Unidentified sp. (HET3)
4. *Palystes* sp. (HET4)

LINYPHIIDAE

1. *Metaleptyphantes* sp. (LIN1)
2. Unidentified sp.1. (LIN2)
3. *Atypena* sp. (LIN3)
4. *Walckenaeria* sp. (LIN4)
5. Unidentified sp.2 (LIN5)
6. *Meioneta* sp. (LIN6)
7. Unidentified sp.3 (LIN7)
8. *Microlinyphia sterilis* (LIN8)
9. *Meioneta natalensis* (LIN9)
10. Unidentified sp.4 (LIN10)
11. Unidentified sp.5 (LIN11)

LIOCRANIDAE

1. Unidentified sp.1 (LIO1)
2. Unidentified sp.2 (LIO2)

LYCOSIDAE

1. *Trabeae* sp. (LYC1)
2. Unidentified sp.1 (LYC2)
3. Unidentified sp.2 (LYC3)

4. *Pardosa* sp.1 (LYC4)
5. *Pardosa* sp.2 (LYC5)
6. Unidentified sp.3 (LYC6)
7. Unidentified sp.4 (LYC7)
8. Unidentified sp.5 (LYC8)
9. Unidentified sp.6 (LYC9)
10. Unidentified sp.7 (LYC10)

#### MICROSTIGMATIDAE

1. *Microstigmata zuluense* Lawrence, 1938 (MIC1)
2. *Microstigmata longipes* Lawrence, 1938 (MIC2)

#### MIMETIDAE

1. *Mimetus* sp. (MIM1)

#### OONOPIDAE

1. *Opopaea speciosa* Lawrence, 1952 (OON1)
2. Unidentified sp.1 (OON2)
3. Unidentified sp.2 (OON3)
4. *Orchestina* sp. (OON4)
5. Unidentified sp.3 (OON5)

#### ORSOLOBIDAE

1. *Azania lobus lawrencei* Griswold & Platnick, 1987 (ORS1)
2. *Azania lobus* new species? (ORS2)
3. *Afrilobus* new species? (ORS3)

#### PALPIMANIDAE

1. *Ikuma potteri* Lawrence, 1938 (PAL1)

#### PHILODROMIDAE

1. *Philodromus* sp.1 (PHI1)
2. *Philodromus* sp.2 (PHI2)

PHOLCIDAE

1. *Pholcus* sp. (PHO1)
2. *Pholcus ciliatus* Lawrence, 1938 (PHO2)
3. *Smeringopus* sp.1 (PHO3)
4. *Smeringopus* sp.2 (PHO4)
5. Unidentified sp. (PHO5)

PISAUROIDAE

1. *Euprosthenops* sp. (PIS1)

SALTICIDAE

1. Unidentified sp.1 (SAL1)
2. Unidentified sp.2 (SAL2)
3. Unidentified sp.3 (SAL3)
4. Unidentified sp.4 (SAL4)
5. Unidentified sp.5 (SAL5)
6. Unidentified sp.6 (SAL6)
7. Unidentified sp.7 (SAL7)
8. *Myrmerachne* sp. (SAL8)
9. Unidentified sp.8 (SAL9)
10. Unidentified sp.9 (SAL10)
11. Unidentified sp.10 (SAL11)
12. Unidentified sp.11 (SAL12)

SCYTODIDAE

1. *Scytodes* sp.1 (SCY1)
2. *Scytodes* sp.2 (SCY2)
3. *Scytodes maritima* Lawrence, 1938 (SCY3)
4. *Scytodes* sp.3 (SCY4)
5. *Scytodes caffra* Purcell, 1904 (SCY5)

SELENOPIIDAE

1. *Anyphops stauntoni* Pocock, 1902 (SEL1)

2. *Anyphops lawrencei* (SEL2)

TETRAGNATHIDAE

1. *Pachygnatha* sp. (TET1)

2. *Leucauge argyrescens* (TET2)

3. *Tetragnatha* sp. (TET3)

4. *Leucauge* sp. (TET4)

THERIDIIDAE

1. *Dipoena* sp. (THE1)

2. *Achaeearanea* sp.1 (THE2)

3. *Euryopis* sp.1 (THE3)

4. *Euryopis* sp.2 (THE4)

5. *Achaeearanea* sp.2 (THE5)

6. *Coleosoma* sp. (THE6)

7. *Steatoda capensis* Hann, 1990 (THE7)

8. *Achaeearanea* sp.3 (THE8)

9. Unidentified sp.1 (THE9)

10. *Euryopis* sp. (THE10)

11. *Theridion* sp. (THE11)

12. *Latrodectus* sp. (THE12)

13. Unidentified sp.2 (THE13)

14. Unidentified sp.3 (THE14)

15. Unidentified sp.4 (THE15)

THERIDIOSOMATIDAE

1. Unidentified sp.1 (THR1)

THOMISIDAE

1. *Runcinia aethiops* Simon, 1901 (THO1)

2. *Thomisus* sp.2 (THO2)

3. *Monaeses griseus* Pavesi, 1897 (THO3)

4. *Tmarus foliatus* Lessert, 1928 (THO3)



ZODARIIDAE

1. *Cydrela spinimanus* Pocock, 1898 (ZOD1)
2. *Psammorygma* sp. (ZOD2)
3. *Cydrela* sp. (ZOD3)
4. *Diores* sp. (ZOD4)
5. *Chariobas* sp. (ZOD5)

**APPENDIX B: RAINFALL DATA RECORDED AT NGOME STATE FOREST FOR 1992.**

	RAINFALL (MM) (1992)	AVG. RAINFALL (MM) (1959- 1992)	MIN. RAINFALL (MM) (1959- 1992)	MAX. RAINFALL (MM) (1959- 1992)
JAN	144.3	227.3	85.3	831
FEB	147.6	213	59.7	543.5
MAR	46.3	159.4	46.3	601
APR	9.2	87.6	4.5	190.4
MAY	0	48.6	0	147.5
JUN	0	26	0	150
JUL	12.5	37.6	0	376.4
AUG	5.5	49.8	2	125.8
SEP	56.2	86.3	1	346.1
OCT	145.4	154.7	52.4	276
NOV	122.1	215.6	84.6	606
DEC	150	201.8	84.5	349.5
TOT	839.1	1507.7	839.1	2310.9