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Spatial variation of arthropod communities in virgin and managed sites in the Kibale Forest, western Uganda

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Abstract

The structure of arthropod communities in the forest floor vegetation in four differently managed forest sites (virgin forest, lightly selectively logged, heavily selectively logged, and exotic *Pinus caribaea* plantation) in Kibale Forest National Park, western Uganda, was studied by sweep net between March and May 1985 and July 1995. For the analysis three (or four) 800 sweeps samples were collected from each habitat. In the samples eight arthropod groups (Araneae, Hymenoptera, Heteroptera, Homoptera, Coleoptera, Orthoptera, Lepidoptera, caterpillars (Lepidoptera larvae)) formed over 95% of all the individuals of the arthropod caught in all habitats. The variation within one habitat was smaller than variation between habitats in samples of the same year. Thus, the arthropod communities in differently managed forests differ from each other after over 20 years of management practices (selective logging and clear-cut plus pine plantation) as well as from adjacent virgin forest, and the differences seem to become greater during the succession in managed sites. Samples taken in the same habitat type, 10 years apart, differed greatly from each other. This is the result of both long-term succession and seasonal variation.

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1. Introduction

Studies on arthropod diversity in virgin tropical forests are scarce (Hammond, 1990; Stork and Brendell, 1993); especially from east African rain forests (Nummelin and Nshubemuki, 1998; Zilihona et al., 1998; Zilihona and Nummelin, 2001; NORPLAN, 2001, 2002; Robertson, 2002). The main focus of insect studies in tropical forests has been on forest

plantations and pest species (e.g., Madoffe and Bakke, 1995 and references therein). The arthropods in clear-cuts (Cambefort, 1984) as well as selectively logged sites have been studied to some degree (Howden and Nealis, 1975; Wolda et al., 1983; Holloway, 1987; Wolda, 1987; Nummelin, 1989, 1992, 1996, 1998a,b; Nummelin and Borowiec, 1991; Nummelin and Fürsch, 1992; Nummelin and Hanski, 1989; Hill et al., 1995; Ghazoul and Hill, 2001; Ghazoul, 2002).

Some information is available on the effects of different types of forest management on east African rainforest arthropod communities. Nummelin (1996) showed differences in the arthropod community between differently managed sites based on samples

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taken monthly from the same site within habitat having different management history (virgin, selectively logged, exotic pine). However, his results did not take into account the possible spatial variation within the visually uniform looking habitat. The extent of the spatial variance of arthropod occurrence within visually uniform looking rainforest habitat has also implications to the methodology of applied ecology, since sweep netting of arthropods is used as a tool for environmental impact assessment in rainforests (Zilihona and Nummelin, 1999, 2001).

This study reports the results of spatial variation within four forest habitats in the Kibale forest. Each habitat is internally visually uniformly looking. Pine forest and heavily logged forest habitats looked to naked eye different than virgin forest and lightly logged sites. The study was done during two intensive study periods 10 years apart.

The purpose of this study is to give a description of the effects of tropical forest management on forest floor arthropods and the spatial variation within forest types, as well as to describe the magnitude of long-term and seasonal variation of the arthropod communities in an east African rainforest. The possible causes of the observed differences between virgin and managed sites are discussed as well as the causes for temporal variation. This report is part of a long-term project studying the ecological effects of forestry practices in Kibale Forest (see Struhsaker, 1997; Fimbel et al., 2001).

Specifically, this study attempts to answer the following questions: (1) How great are the differences in arthropod communities within and between adjacent virgin, lightly and selectively logged and exotic pine plantation forests? (2) Are the arthropod communities in managed forest sites progressing towards the virgin forest community within 25 years after management?

2. Study sites

Kibale Forest is a medium-elevation (average 1500 m), moist evergreen forest of about 560 km² in western Uganda (0°13'–0°41'N and 30°–30°32'E). The yearly rainfall is roughly 1500 mm with two rainy seasons (September–November and March–April) per year. Kibale differs from lowland tropical rain forest in having lower minimum temperature (ca.

+11°C), and lower rainfall, but otherwise it possesses most of the typical structural features of lowland forests (Langdale-Brown et al., 1964). The forest topography is gently undulating, replaced by swamps and rivulets in low-lying areas and by grasslands on hilltops in some disturbed places.

In 1969, mechanised selective felling was applied to ca. 35% of the northern and central forest area. During this study, 15–25 years after logging, logged areas were still easily recognisable due to the large gaps. One of the studied forest compartments was more heavily logged (ca. 21 m³ ha⁻¹ timber removed) than another studied compartment (14 m³ ha⁻¹) (Skorupa and Kasenene, 1984). Both logged sites had denser forest floor vegetation than virgin sites, especially during the late rainy season (Nummelin, 1992).

Some areas adjacent to the forest were planted with exotic conifers in 1969. Since then there has not been any other forest management in the area. The plantation study site was composed of over 20-year-old non-native *Pinus caribaea* Morolelet. The exotic pine plantation had quite lush forest floor vegetation which is unusual by comparison with more typical, bare ground pine plantations in Uganda (Struhsaker, 1987).

The arthropod communities were studied in one natural forest site, lightly selectively logged site, heavily selectively logged site and an exotic pine plantation. In this study several samples were taken within the same habitat at the same time. Nummelin (1989, 1992, 1996, 1998a) give a closer description of each sampling habitats, their vegetation and arthropod communities.

3. Methods

Arthropods were collected by sweep netting in adjacent sites by repetitive sampling in 1985 and 1995. Four habitats (virgin site, lightly selectively logged site, heavily selectively logged site and an exotic pine plantation) were studied in May 1985 and four samples were collected from each habitat. In July 1995, three samples were collected from each studied site, except lightly selectively logged site that was not sampled. Both sample times represent early dry season. One sample consisted of 800 sweeps. The sweep net was a standard 38 cm diameter muslin insect net with 61 cm handle (Janzen, 1973a). All

study sites had a 50 m × 50 m trail grid system. Sweeps were made only in places where the net could hit forest floor vegetation. Thus, open gaps in forest floor vegetation were avoided. Depending on the height of the vegetation, the minimum sweeping height varied from 20 to 80 cm. Sweeping took place on dry early afternoons. For more details on the sweeping method and equipment used see Janzen (1973a).

Collected data were analysed using percentile similarity (Renkonen) index (Wolda, 1981) and principal component analysis (Stagraphics, 1986).

4. Results

The eight most common arthropod groups: Araneae, Hymenoptera (includes wasps and Formicidae, mainly *Crematogaster* spp.), ‘caterpillars’ (mainly of Lepidoptera, but occasional Symphyta larvae), Heteroptera, Homoptera, Coleoptera, Orthoptera (includes Acrididae and Tettigonidae), and Lepidoptera, formed over 95% of all the arthropod fauna caught by sweep net from the forest floor vegetation in the Kibale Forest (Fig. 1). The remaining groups consisted, primarily, of Phasmidae, Mantidae, Opiliones and Blattidae.

When the average values (means of all samples taken from the same habitat at the same time) of the

Table 1

Means of the pairwise percentile similarities (Renkonen index, see Wolda, 1981) of the arthropod communities in the samples taken from four habitats (HL: heavily selectively logged, LL: slightly selectively logged, VI: virgin forest, EX: exotic pine plantation) in Kibale Forest in 1985 and 1995

HL 85	HL 95	LL 85	VI 85	VI 95	EX 85	EX 95	
82	71	80	73	58	58	77	HL 85
	90	70	58	73	46	77	HL 95
		83	72	58	65	80	LL 85
			81	62	61	72	VI 85
				90	40	63	VI 95
					75	62	EX 85
						83	EX 95

The highest similarity in each column marked by bold.

pairwise percentile similarities index of all samples taken from four habitats were compared in all cases the highest percentile similarity was found in the samples taken within the same habitat during the same year (Table 1), indicating that within habitat variation is smaller than between habitats variation. The highest similarities (90%) were found in heavily selectively logged forest and virgin forest, both in 1995. This indicates that the arthropod communities both in virgin and selectively logged forests are fairly homogeneous. The lowest indices were found in the exotic pine forest 1985 samples both within the pine habitat (75%) and between pine and other habitats (40%)

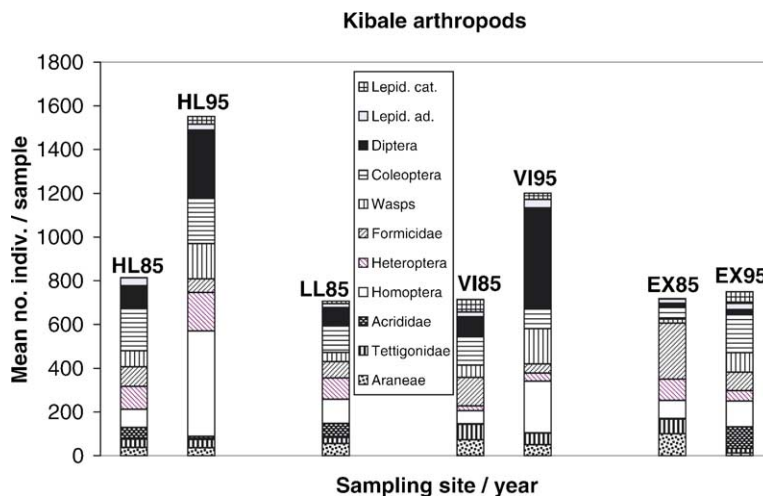


Fig. 1. The number of individuals of the most common arthropod groups in the sweep net samples in four habitats in the Kibale Forest in 1985 and 1995 (HL: heavily selectively logged; LL: lightly selectively logged; EX: exotic pine plantation; VI: virgin forest).

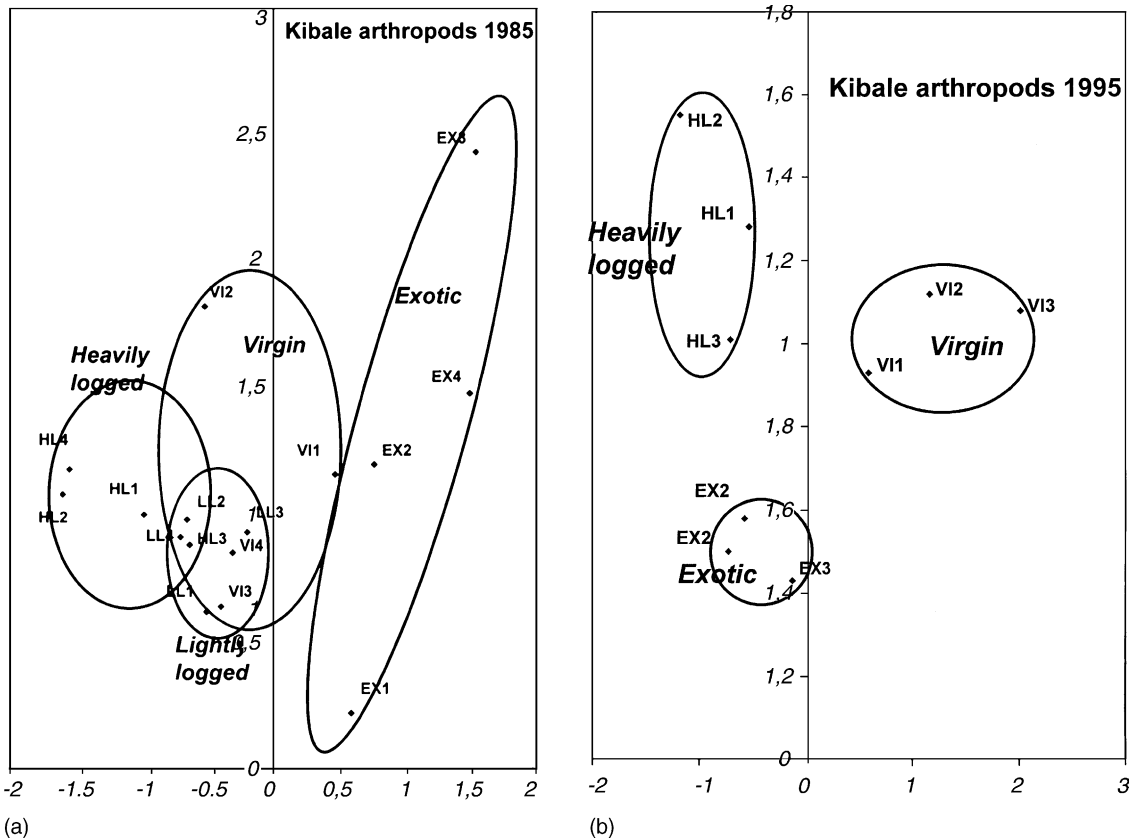


Fig. 2. (a) Results of the principal component analysis based on the arthropod communities in different habitats of the Kibale Forest in 1985 when habitats are arranged along the two first principal axis (explain 97% variation). (b) Results of the principal component analysis based on the arthropod communities in different habitats of the Kibale Forest in 1995 when habitats are arranged along the two first principal axis (explain 97% variation) (HL: heavily selectively logged; LL: lightly selectively logged; EX: exotic pine plantation; VI: virgin forest).

virgin forest 1995, 46% heavily logged forest 1995). This indicates that the arthropod community in exotic pine forest is more heterogeneous than in other habitats and, also, that its composition differs greatly from deciduous indigenous habitats.

Since there were great differences between years in the same habitat, the years 1985 and 1995 were analysed separately in the principal component analysis to describe the habitat and arthropod order similarities. During both years arthropod samples taken in exotic pine plantation differ greatly from the other habitat types (Fig. 2a and b). Also, the heavily selectively logged forest and virgin forest arthropod communities form their own distinct groups in the principal component analysis in both years. In

the principal component analysis the arthropod communities were more clearly separated in the 1995 samples than in samples taken 10 years earlier (Fig. 2a and b). The lightly selectively logged forest samples (taken only in 1985) mix both with virgin and heavily selectively logged forest arthropod community samples and they cannot be considered to form a clear group in the principal component analysis as did the other habitats (Fig. 2a).

The structure of arthropod communities changed considerably within 10 years, when assemblages of different groups are organised by principal component analysis (Fig. 3). Formicidae and Araneae seems to be apart from other groups in 1985 while Diptera and Heteroptera did so in 1995.

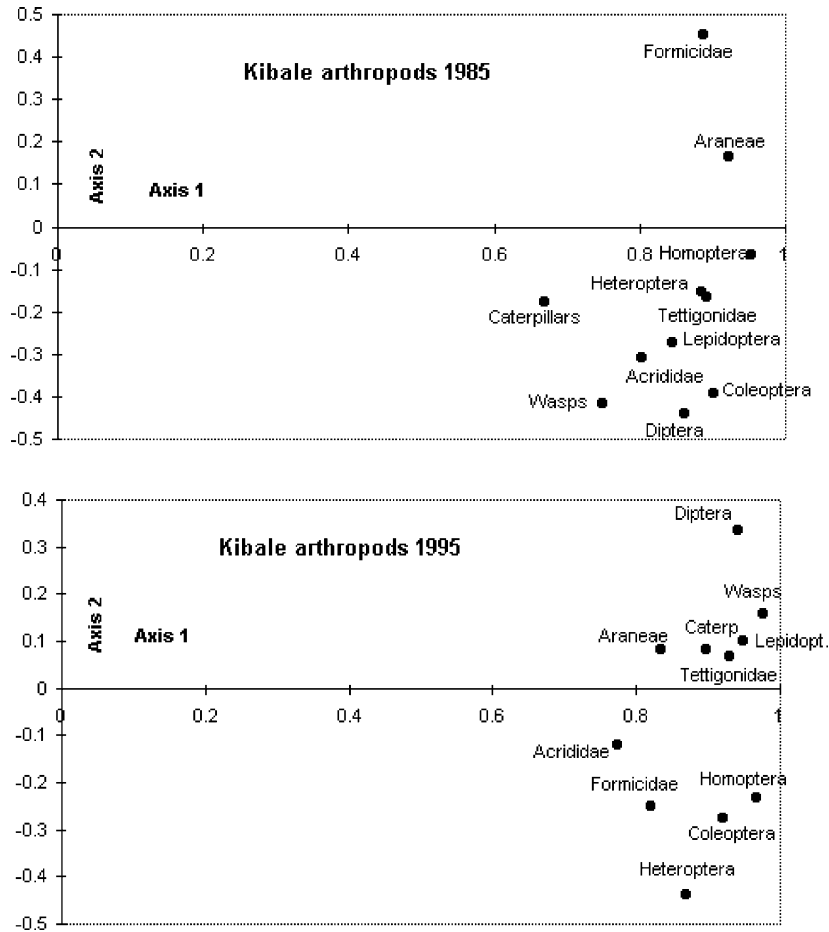


Fig. 3. Results of the principal component analysis based on the arthropod communities in different habitats of the Kibale Forest in 1985 and 1995 when insect groups are arranged along the two first principal axis (explain 97% variation).

5. Discussion

The total number of arthropods caught in 800 sweep samples were of the same order of magnitude when compared with similar samples in secondary vegetation taken in Neotropics (Janzen and Pond, 1975).

Furthermore, the community structure of arthropods in Kibale resembles the community structure of the samples obtained by sweep netting in the Neotropics (Boinski and Fowler, 1989; Elton, 1973; Janzen, 1973a, 1973b; Janzen and Schoener, 1968; Janzen et al., 1976; Nentwig, 1989; Tanaka and Tanaka, 1982). Published results on sweep net sampling in forest sites in old world tropics are available for comparison only from Uluguru Mountains, Tan-

zania (Nummelin and Nshubemuki, 1998), and it seems that the arthropod communities in Kibale and Uluguru moist forests resemble each other closely.

When the results of this study are compared to arthropod samples from the herb-layer vegetation from a rain forest in south east Asia collected by vacuum sampler (Stork and Brendell, 1993), Kibale seems to harbour less Thysanoptera, Psocoptera, Collembola and Acarina. However, the sweep method used in Kibale is rougher on specimens than vacuum sampling (no vacuum sampler was available in Uganda). All the above mentioned arthropod groups are small and mostly soft bodied, thus they often are destroyed by the sweep method. Sweep netting is known to favour larger insects (Hespenheide, 1979).

Zilihona and Nummelin (1999) recommend the use of sweep netting in such conditions where more sophisticated collecting methods are not available. The results of this study confirm that the effects of forest management can be detected by using this method and results are replicable. However, see the discussion on restrictions in the sweep method by, e.g., DeLong (1932), Beall (1935) and Janzen (1973a).

It can be concluded that according to our results the arthropod communities in the forest floor vegetation in managed forests adjacent to virgin forest remain different 20+ years after the management. It even seems that the differences between differently managed sites (virgin, heavily logged, exotic pine) have become greater as succession proceeds (Fig. 2a and b). It seems possible that as a result of a heavy selective logging as well as a clear-cut and planting pines, the arthropod community apparently is not returning towards to the virgin forest community in either site in Kibale forest, suggesting that new types of community equilibriums are developing in both managed sites differing from that of the adjacent virgin forest. Nummelin (1989, 1996, 2001) could not detect these trends in the arthropod communities in his study based on monthly samples taken in the very same sites during the proceeding 2 years of this study. This is apparently due the great seasonal variation, and the fact that the seasonal variation is not in phase in adjacent, but differently managed sites (Nummelin, 1996). We stress that Nummelin (1989, 1996) has shown the existence of wide variation in arthropod abundances between and within years in the very same study sites as in this study and, e.g., rainfall and other physic-chemical variables affecting arthropods are not identical in our samples taken 10 years apart. Thus one has to be cautious when drawing general conclusions on development trends of arthropod communities based on our results. On the other hand, Plumptre et al. (2001) studied the bird populations 3 years before our latter sampling period at the very same selectively logged sites as our study. They showed that bird populations have not returned to correspond those of the adjacent unlogged sites; thus confirming the long-term effects of the management to animal life. Mooney et al. (1996) stress that predicting long-term impacts of extirpated and persisting species after logging is difficult as forest ecosystems are likely to have a fair amount of redundancy.

Managed sites harbour more heteropterans and coleopterans than the virgin site; apparently these groups are utilising the increased forest floor vegetation (Nummelin and Fürsch, 1992). Logging operations opened the canopy, which led to increased light on the forest floor favouring the growth of dense floor vegetation. The dense forest floor vegetation and increase of herbivores hamper the growth of tree seedlings (Nummelin, 1992). According to our results, virgin sites harbour abundant dipterans, possibly indicating active decomposition processes. In the shade of closed, several layered canopy, the moist microclimate and light conditions remain fairly constant throughout the day and favour the growth of fungi and other decomposers. The exotic pine forest planted on a former rainforest site has developed its own type of arthropod community.

Comparative results to our paper are not available. Ghazoul and Hill (2001) state in their recent comprehensive review of the impacts of selective logging on tropical forests insects: “Little is known about invertebrates in tropical forests, despite their dominance of animal community”. We wish that our paper serves future research in this field.

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