THE RECOVERY OF AN AFROMONTANE FOREST AFTER SLASH AND BURN: A CASE STUDY FROM THE NKANDLA FOREST

by

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Preface

The research presented in this dissertation was conducted in the Forest Biodiversity Programme as part of the requirements for the degree of Master of Science in the Centre for Environment and Development, University of Natal, Pietermaritzburg. The research was carried out from August 1999 to December 2000, under the co-supervision of Prof. M. J. Lawes, Dr J. E. Granger and Dr T. Hill.

These studies represent the original work by the author and have not otherwise been submitted in any other form for any degree or diploma to another university. Where use has been made of the work of others, it is duly acknowledged in the text.

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Abstract

Clear cutting and subsequent agricultural processes lead not only to species loss, but also have negative consequences for soil and water conservation. This study investigated the response to, and effect of, deforestation due to shifting cultivation on the Nkandla forest complex (NFC), a subtropical Afromontane forest. As a consequence of shifting agriculture, abandoned areas are nutrient poor, have depleted seed banks and may lack the ability to regenerate into species rich mature forest. The ability of forests to regenerate after disturbance effects is extremely important for the maintenance of ecological diversity and the stability of forest ecosystems.

The present study focused on the recovery of the NFC, after shifting agriculture was practised along the forest margins. The NFC was sampled to determine: (1) how vegetation structure, composition and plant species diversity differ between regrowth forest and undisturbed forest; (2) how continued disturbance and subsequent land use affects the rate of recovery and regeneration of secondary forest; and (3) what species establishment pattern, if any, does the path of recovery follow during succession? Four different types of forest were sampled, disturbed margin (DM) forest, disturbed interior (DI) forest, undisturbed margin (UM) forest and undisturbed interior (UI) forest.

The study showed that recovery does occur and that in the NFC recovery patterns (in terms of species diversity trends, biomass and basal areas) are similar to those found in other tropical and sub-tropical regions. Floristic recovery proceeded in a way that required the prerequisite establishment of forest margin tree species that would ultimately lead to a climax condition described by undisturbed interior forest. Unimodal trends were found for stem density and species richness across all four forest types, with basal area increasing steadily from disturbed to undisturbed interior forest. These forest types and their floral composition and structure described a gradient of decreasing disturbance, with disturbed margin forest being the most disturbed type.

Continued harvesting of selected species is detrimental to the survival of these species. Analyses showed that *Rapanea melanophloeos, Cassipourea gummiflua, Curtisia dentata, Ochna natalitia, Olea capensis* subsp. *macrocarpa* and *Strychnos henningsii* have been over-used. Continued harvesting could result in critically low densities of these species and even their local extinction.

Contents

Chapter 1: Introduction

1.1 Introduction

Clear cutting and subsequent agricultural processes lead not only to species loss, but also have negative consequences for soil and water conservation (Edwards, 1967; Bormann & Likens, 1979). This study investigates the response to, and effect of, deforestation due to shifting cultivation on the Nkandla forest complex (NFC), a subtropical Afromontane forest. Due to the nature of shifting agriculture, abandoned areas are nutrient poor, have depleted seed banks and can lack the ability to regenerate into species rich mature forest (Nepstad *et al.*, 1991; Duncan & Chapman, 1999). The questions I addressed in this study were: (i) once subjected to shifting agriculture is local forest irreversibly damaged or can the forest recover; (ii) at what rate does forest recover; and (iii) to what state does it recover?

1.2 The Ecology of Forest Regeneration

The evergreen forests of South Africa are an important biome in terms of species richness, and thus have significant conservation value (Geldenhuys, 1990). Understanding the potential of forest to recover and the successional processes that are followed after disturbance is important because it promotes more effective management of the forest biome, ultimately ensuring the survival and ongoing evolution of forest biodiversity.

Succession is defined as 'the non-seasonal, directional and continuous pattern of colonisation and extinction on a site by species populations'. Succession can be further divided into various sub-types of succession namely, primary, secondary, allogenic, autogenic and degradative succession (Begon *et al.*, 1990). When studying abandoned old-fields ecologists are mainly interested in the effects of secondary and autogenic succession. Secondary succession deals with the patterns and processes of communities that are able to colonise and develop on abandoned lands that were disturbed either through natural or anthropogenic means. The process of plants colonising these abandoned lands and changing the conditions for future colonists is known as autogenic change, hence the term autogenic succession (Ricklefs & Miller, 1999).

Successional processes and the path that regeneration will follow are dependant on numerous abiotic and biotic factors as well as the ability of different plant species to use specific resource niches created during these successional pathways (Clements, 1916; Gleason, 1917; Egler, 1954; Finegan, 1984; Bazzaz, 1996). Agricultural activities and the grazing of livestock degrade forested ecosystems (Rivera, 1998; Duncan & Chapman, 1999; Chapman & Chapman, 1999). Large areas of forest can be cleared for these purposes, but as the soil is nutrient poor, these areas are abandoned after a couple of years (Chapman & Chapman, 1999). When abandoned these sites start a process of regrowth and colonisation. It is argued that this regeneration would ultimately lead to the establishment of an ecosystem that is similar in composition to the adjacent ecosystem (Finegan, 1984; Bazzaz, 1996). Numerous theories have been presented to explain the nature and processes involved in succession, with no evidence of a single unifying theory emerging for long term successional patterns (Clements, 1916; Gleason, 1917; Egler, 1954; Connell & Slatyer, 1977; Finegan, 1984; Luken, 1990; Bazzaz, 1996).

Studies of early secondary forest in the tropics and subtropics show that regeneration after human disturbance does occur (Uhl *et al.*, 1981; Kammesheidt, 1998; Rivera & Aide, 1998; Chapman & Chapman, 1999; Li *et al.*, 1999; Zahawi & Augspurger, 1999). The various studies on abandoned agricultural land suggest that forest follows no specific path and is dependent on local conditions and past disturbance regimes. Speed of recovery and forest composition is dependant on numerous factors, including seed rain, remnant trees, soil condition and fire history (Miller & Kauffman, 1998; Chapman & Chapman, 1999; Duncan & Duncan, 2000).

For instance, in their study of secondary succession in the Amazon, Uhl *et al.* (1981) found that species diversity initially increased after disturbance, but that the regenerated forest was dependent on the initial floristic composition of the abandoned lands. They also showed that fire regimes had a significant affect on secondary succession dynamics, regular burns damage or killed coppice shoots and damaged the seed bank preventing rapid recovery of secondary forest. In Uganda (Kibale Forest), abandoned lands recovered very slowly and were not favourable for the establishment of secondary forests suggesting that under certain conditions forest recovery is not possible (Chapman & Chapman, 1999). However, in China, subtropical forest recovered to secondary forest within 30-35 years with species diversity remaining stable throughout the succession (Li *et al.*, 1999). This clearly shows the variation in succession in different areas of the world and the reason why no unifying theory on forest succession has emerged.

In southern Africa, research on forest dynamics after disturbance has been confined to the Southern Cape forests (Geldenhuys, 1990; Midgley *et al.*, 1997) and little has been done on the KwaZulu-Natal forests (Everard *et al.*, 1995). Lübbe & Geldenhuys (1991) examined data from permanent slash-and-burn plots established in 1932 in the Cape Afromontane forests. In their study species diversity in the initial stages of recovery was higher than that of mature forest and the severity of disturbance had an affect on site composition (Lübbe & Geldenhuys, 1991). More light tolerant 'pioneer species' typified disturbed sites whereas undisturbed sites were dominated by shade-tolerant species.

1.3 Conservation and management of the Nkandla forest complex

The management of the NFC is complex because of the fragmented way in which conservation areas within the forest have been demarcated (Fig 1.1). The core forest of the NFC is divided into one forest reserve and three nature reserves; the Nkandla forest reserve, Mome nature reserve, Vungwini nature reserve and Sibudeni nature reserve (Guy, 1999, pers. comm.). The forest reserve and the three nature reserves were originally proclaimed in 1918 (National Government Notice 318/18, 1918) and 1948 (National Government Notice 902/48, 1948) without consultation with the tribal authorities. In 1992 the KwaZulu government re-proclaimed the forest reserve and the three nature reserves, once again without consultation with the surrounding tribal leaders. As a result, the only nature reserve recognised by the local people is the Nkandla forest reserve (Guy, 1999, pers. comm.). All forests outside the Nkandla forest reserve fall within tribal land and are 'managed' by the respective tribal authorities in these areas. The tribal authorities have no forest management structures in place, and consequently harvesting takes place on an uncontrolled basis (pers. obs.).

A system of permits implemented by the KwaZulu-Natal Nature Conservation Service (KZNNCS), controls harvesting of resources within the main reserve. In the past, this system has not operated efficiently (Louw, 1999, pers. comm.). The reserve is actively managed although patrols are restricted to familiar footpaths and trails. The patrols are concentrated in the vicinity of rangers' accommodation. Patrols are on foot and due to the extreme nature of the terrain only a small percentage of the forest can be covered in any one day (pers. obs.). The unpatrolled areas are unprotected and within close reach of the surrounding communities. No previous studies of this forest have investigated the combined affects of legal and illegal harvesting on the status of the resource base and its resilience to traditional patterns of use (Guy, 1999, pers. comm.).

1.4 Socio-economic structure of communities surrounding the Nkandla forest complex

Three tribal authorities surround the NFC. The Chube land to the north, west and southwest, controlled by Inkosi Shezi. The Izindlozi land to the south controlled by Inkosi Khanyile and the Mangidini land to the east controlled by Inkosi F. Biyela (Fig. 1.2).

The communities surrounding the NFC are extremely poor, with a mean annual household income of R1024 (Ardington, 1995). These communities are mainly subsistence farmers and rely heavily on forest resources for building materials, fuelwood and medicinal purposes. Harvested material is mainly restricted to bark, roots, poles and laths with the latter two product's being restricted to smaller diameter classes (diameter at breast height (dbh) < 100 mm) (Guy, 1999, pers. comm.).

In the past these communities lived on or very close to the forest edge. Analysis of aerial photographs from 1937 indicated that large areas (up to 5ha in one area) of forested land were cleared, either for agriculture or to extend grazing areas, at various points along the forest boundaries (pers. obs.). A number of large trees were left standing in these clearings, and the clearings were burned periodically to improve grazing. Analysis of recent aerial photographs (1996) shows that many of these people relocated closer to roads and other infrastructure. The subsequent abandonment of fields has provided an opportunity for the forest to re-establish in areas that it once occupied (pers. obs.).

1.5 Aims and objectives

Knowledge of the successional pathways that recovering vegetation follows would be useful in the management of resources (Finegan, 1984; Geldenhuys, 1990, Ricklefs & Miller, 1999). Even though successional pathways are not always predictable, the recovery potential of vegetation, and the rate of this recovery, can be useful to managers in order to maintain biodiversity within a specific environment. The NFC is a unique example of an evergreen Afromontane forest that has not been exploited by European settlers in the past. The only disturbances have arisen from the activities of rural subsistence farmers surrounding the forest. This study focused on the patterns and processes of regrowth forest in areas now abandoned by local communities. Areas of forest that were previously used in the NFC showed clear signs of recovery. I addressed the following questions:

1. How does vegetation structure, composition and plant species diversity differ between regrowth forest and undisturbed forest?
2. How does disturbance and subsequent land use affect the rate of recovery and regeneration of secondary forest.
3. Does the path of recovery follow any deterministic sequence?

1.6 Study Site

The Nkandla forest complex (28° 44'S, 31° 06' E) is a Mistbelt Mixed *Podocarpus* forest (Cooper, 1985) composed of a core forest surrounded by a number of smaller forest patches. The forest is located in the Ngongoni veld type with all forest surrounded by *Aristida junciformis* dominated grassland (Acocks, 1988).

The forested area covers ca. 3100ha and is found at altitudes ranging from 800m to 1370m on predominantly southerly aspects although north-facing slopes do occur (pers. obs.). The area, within which the NFC is situated, is characterised by deep valleys and steep slopes. The forested area encloses small grassland patches that are regularly burned to provide grazing for cattle. Soils are typically shallow and are dominated by leached acidic soils derived from the Insuzi, Nkandla and Archaean Granite geological formations (Edwards, 1967). The climate is warm and humid with mean daily temperatures of 25.5° C (Edwards, 1967). The region receives light to moderate frosts and annual rainfall ranges from 1064mm to 2020mm (mean 1586.8 ± 244.1mm, 1940-1992; Computer Centre for Water Research). The primary form of precipitation is mist.

Dominant tree species are *Olea capensis* subsp. *macrocarpa, Kiggelaria africana, Ochna natalitia, Homalium dentatum, Combretum kraussii, Syzygium gerrardii, Rinorea angustifolia* and *Rapanea melanophloeos* (Edwards, 1967). The herbaceous layer of the forest is sparse (< 20%), possibly due to low moisture levels (Edwards, 1967, Macpherson, unpublished data) or the presence of cattle grazing inside the forest (Guy, 1999, pers. comm.).

Chapter 2: Floristic Structure

2.1 Introduction

Throughout the tropics and sub-tropics, degradation of forests due to shifting agriculture and slash-and-burn activities has resulted in large areas of forest being clear cut and burnt. These areas are often subjected to cultivation and after a couple of years are abandoned due to the poor soil conditions. Once abandoned, provided suitable conditions exist, these lands are able to recover (Ricklefs & Miller, 1999).

Some common verifiers of early and mid successional recovery include species richness, canopy cover, stem density and basal area (Ghazoul & Hellier, 1999). These verifiers have different trends through the different stages of recovery (Finegan, 1996), and have been used to develop different successional models (Finegan, 1984; Bazzaz, 1996). In forests, recovery follows a fairly uniform process, provided that conditions are available for the recovery of forest (Ricklefs & Miller, 1999). Bormann & Likens (1979) proposed a biomass model for this recovery after clear cutting. Their biomass model has four stages: reorganisation, aggradation, transition and steady state. In the first phase, there is a net loss of biomass although living biomass increases. Net biomass decreases as a result of the death of short lived herbs and shrubs. During aggradation, the system increases its total biomass to a peak and then goes into the transition phase where total biomass is reduced. Eventually the forest reaches a steady state where biomass fluctuates about a mean (Bormann & Likens, 1979).

The pattern exhibited by the biomass model (increase to a peak and then decrease to a steady state) is similar to the intermediate disturbance hypothesis (IDH) proposed by Connell (1979). However, the IDH model is based on changes in biodiversity. This pattern in species richness data was first observed in the Budongo forest, Uganda (Eggeling, 1947). The decrease in species richness, after a peak has been reached, is attributed to resource partitioning and the ability of a select suite of species to out-compete earlier colonising species and dominate in a shaded forest environment with little disturbance (Finegan, 1984). It is assumed that patterns of basal area in both these models would increase continually throughout the stages of succession. This continual increase would occur even though the initial high numbers of individuals are reduced through self-thinning, because the surviving plants continue to grow in size. Although both these models are based on different indicators they are convergent ideas with similar underlying trends, i.e. the trends increase to a peak and then stabilise in the later stages of recovery. Both these models are generally applicable in succession studies.

Studies of forest regeneration have found that in tropical forests stem density follows a similar pattern to that of species richness (Aide *et al.*, 1995; Rivera & Aide, 1998; Zahawi & Augspurger, 1999). Initially, large numbers of seedlings colonise the abandoned lands and as self-thinning and competition for the limited resources occurs, stem density declines. Stem density reaches a peak during the mid-stages of recovery and then drops in the later stages.

The main aims of this study were to determine whether or not there were differences in composition and structure between regrowth forest and mature undisturbed forest and whether or not the regrowth forest is following a trajectory that would eventually result in mature forest. This study focused on areas within the Nkandla forest complex (NFC), a mistbelt mixed *Podocarpus* forest, in KwaZulu-Natal, that had been subjected to shifting agriculture in the early 1900's and now shows signs of recovery to forest (pers. obs., Chapter 1).

The section presented here examines the structure and composition of different forest types sampled within the NFC. Based on the models described earlier I expected that (1) total basal area would be low in disturbed areas and high in undisturbed areas, and (2) stems/ha and species richness would both be at their greatest in disturbed interior forest/undisturbed margin and lower (possibly lowest) in undisturbed mature forest.

2.2 Methods

2.2.1 Changes in forest extent and shifting agriculture

The earliest reliable evidence of the extent of the NFC was from aerial photographs of 1937 (Scale 1:21 000). Subsequent epochs of 1956 (1:30 000), 1967 (1:30 000), 1975 (1:50 000) and 1996 (1:30 000) together with 1:10 000 orthophotos (1984) were used in this study to track the shifting agricultural patterns. Major changes in forest boundaries, locations of homesteads and allied agriculture were contrasted between 1937 and 1996. Because of distortion and scale differences inherent in the aerial photography, forest boundaries, hut positions, hut numbers, roads and visible trails were translated by eye onto overlays of the orthophotos.

The overlays from two epochs (1937 and 1996) were digitised using Arcview 3.0 (ESRI, 1996). Tree species sampling was restricted to areas that had visibly changed from 1937 to 1996 and site visits verified that mapped forest was either primary forest or regrowth forest with a closed canopy.

2.2.2 Sampling forest structure and regeneration

Areas of forest were designated into four types of forest, (i) undisturbed mature forest (UI), (ii) undisturbed forest margins (UM), (iii) disturbed interior forest/advanced regrowth forest (DI), and (iv) disturbed forest margin/regrowth forest margin (DM). A total of 48 sample plots were randomly located in areas the above forest types (Fig. 2.1, Appendix 1). The number of sample plots varied for each forest type because of size and availability of each forest type. Undisturbed mature forest was located in stands of forest that were not disturbed in the past. Although the word 'undisturbed' is used to describe UM and UI forest, it is possible that both these forest types have been subjected to continuous use by local communities for the collection of building material, firewood and medicinal plants (Cardew, 1891; Storr Lister, 1902; King, 1941; Edwards, 1967; Cooper, 1985). This collection, however, is species selective and does not result in the deforestation of large areas of land for cultivation purposes (pers. obs.). The collection of building material, fuelwood and tree material for medicinal purposes occurs in all forest types. The impacts of this collection are dealt with later (Chapter 4).

Undisturbed forest margin plots were located in areas of forest expansion since 1937. All disturbed forest plots were located in forest patches that showed severe signs of disturbance (clear cutting and or shifting agriculture) in the aerial photographs from 1937-1996. Disturbed interior forest was located in advanced regrowth forest that had been clear cut and/or ploughed in 1937. Disturbed margin forest plots were located along disturbed interior forest margins.

All plot data were collected from $400m^2$ (20m x 20m) square plots. All plots were subdivided into four 10m x 10m quadrats (Fig. 2.2). The diameter at breast height (dbh) and the height of all woody species within the dbh range 10-100mm were measured in diagonally opposite quadrats in each plot, as well as the occurrence of all woody species with a dbh <10mm. The dbh and height of all woody species present with a dbh>100mm were measured over the entire plot (Table 2.1). This type of nested sub-plot sampling method was based on similar methods used by Li *et al.*, 1999. This method was used in order to sample a large number of plots in the limited time period allowed. The method allows for smaller sample areas when sampling trees in the lower dbh categories (dbh < 10mm) while still maintaining a large sample area for sampling of larger trees (dbh > 10mm).

2.2.3 Species diversity and stand structure

In each of the 48 sample plots the abundance of each woody species was recorded. Species numbers were averaged for each forest type to determine the general change in species numbers across the four different forest types. The Jacknife-1 estimator was used to verify that sampling intensity was sufficient for each forest type. The Jacknife-1 estimator is an estimation method to predict how many species would have been discovered had the sampling area included the entire community. Colwell & Coddington (1994) showed that the first-order Jackknife estimator provided adequate estimates of species richness for small sample sizes.

The Jacknife-1 estimator is based on the number of species that occur in only one sample (L) using the following formula:

$$\text{Jacknife-1} = S_{obs} + L\left(\frac{n-1}{n}\right).$$

Where S_{obs} is the observed number of species in a sample and n the number of samples (Colwell & Coddington, 1994).

For each of the four forest types, Hill's N1, Hills N2 and Pielou's evenness (J') indices were calculated (Ludwig & Reynolds, 1988; Magurran, 1988). These indices allowed the four forest types to be compared for dominance and evenness. Hill's indices are measured in species units, N1 indicates the number of abundant species and N2 indicates the number of very abundant species (Ludwig & Reynolds, 1988). Pielou's evenness measure provides a measure of equitability and is the most common form of evenness used in the literature (Krebs, 1989).

Stem density (number of stems/ha), basal area (m^2/ha) and canopy cover (% of total canopy cover) were calculated for all trees >10mm dbh in each of the 48 plots. In each plot canopy cover was measured using straight line transects set out within each plot in the shape of a diamond (Fig 2.3). Canopy cover was recorded as present/absent at five points (spaced 2.35m apart) along each of the four transects using a densitometer (Stumpf, 1993).

2.2.4 Statistical Analyses

A balanced MANOVA was performed to determine differences between the four forest types. A MANOVA was used to avoid Type I errors induced by testing the same null hypothesis many times (i.e. the difference between the four forest types DM, DI, UM and UI forest). The MANOVA was calculated using species richness, basal area, stem density and canopy cover. Univariate test statistics (ANOVA) were calculated *a posteriori* for each of the above response variables. Scheffe's range test was used to indicate the within-group similarities of the different forest types. All statistics were calculated using Statgraphics version 7 (Manugistics and Statistical Graphics Corporation, 1993) and Minitab release 12 (Minitab Statistical Software, 1998) computer software.

The Jaccard coefficient of similarity for each of the four forest types was measured to show the differences between the forest types. Binary species values were used to measure similarity (Jaccard estimates; Krebs, 1989). The Jaccard coefficient of similarity ranges from 0-1, with 0 indicating no similarity and 1 complete similarity (Ludwig & Reynolds, 1988).

2.2.5 Species importance values and relative abundance

Importance values for each of the four forest types were determined to show overall dominance by any one species (Mueller-Dombois & Ellenberg, 1974). The following equations were used:

$$\text{Relative abundance (RA)} = \frac{\text{no. stems of sp B in plot A}}{\sum \text{total stems for each plot}} \times 100$$

$$\text{Relative frequency (RF)} = \frac{\text{frequency of sp B in plot A}}{\sum \text{absolute frequency of all species in each plot}} \times 100$$

$$\text{Relative Dominance (RD)} = \frac{\text{basal area of sp B in plot A}}{\sum \text{total basal area for each plot}} \times 100$$

Importance Value (IV) = RA + RF + RD.

As an index of the occurrence of species in the four different forest types, relative abundance values using total species counts in each forest type were determined. Six classes of relative abundance were used (Miller & Kauffman, 1998): infrequent species had a relative abundance of < 1%, occasional species a relative abundance of 1.1 – 3%, uncommon species 3.1 – 5%, common species 5.1 – 7%, abundant species 7.1 – 9% and very abundant species > 9%. Rank abundance curves were plotted for each of the four forest types.

2.3 Results

2.3.1 Species diversity and richness

A cumulative total of 117 species were identified across the four forest types (Appendix 2). The Jacknife-1 estimator was used to ascertain the degree to which the four forest types had been sampled and suggested that 79%, 83%, 80% and 78% of species in the DM, DI, UM and UI forest types respectively, had been sampled. Total species counts of all woody species (Table 2.1) were highest in disturbed margin forest (89), and lowest in undisturbed interior forest (49). Disturbed interior (85) and undisturbed margin (73) forest types had intermediate richness.

A significant difference existed between species numbers present in the four forest types (ANOVA, $F_{3,44} = 8.07$, $p < 0.001$). Average species number for the four forest types followed a unimodal pattern, with a peak occurring in the UI forest (Table 2.1). The within-group differences for species richness are shown in Table 2.1. Difference in cumulative species counts and average counts per plot suggest that there is a high turnover of species within the disturbed forest communities possibly as a consequence of the initial composition of the abandoned clear cut. A number of large trees were left in the clear cut areas and these could have influenced the species composition in localised areas within the regrowth forest (Macpherson, unpublished data).

For disturbed margin and disturbed interior forest N2 and Pielou's J' indices of species diversity were identical (Table 2.1), with N1 being slightly lower in DM than DI forest (15.3 compared to 16.1). In undisturbed margin forest N2 index was slightly higher (10.4) than in both the disturbed forest types and J' index was lower (0.84). N1 index for UM forest was the same as DI forest (16.1). In undisturbed interior forest, all indices differed greatly from the other three forest types (Table 2.1). N1, N2 and J' indices all showed a decreasing trend from disturbed areas to undisturbed areas (Table 2.1). This suggests increasing dominance of fewer species from the disturbed to the undisturbed forests.

2.3.2 Stand structure of forest types

The values for basal area (m^2/ha), stem density (stems/ha) and canopy cover (% of complete cover) for each forest type are shown in Table 2.1. The results of the general MANOVA showed that the four forest types differed significantly in terms of basal area, stem density and canopy cover (Wilk's test statistic = 0.21435, $F_{9,102}$ = 10.043, $p < 0.001$). Within plot differences vary for each of these measures in each of the four forest types (Table 2.1).

Basal area of the four forest types differed significantly (ANOVA; $F_{3,44} = 20.49$, $p<0.001$). Basal area increased steadily from disturbed to undisturbed interior forest. Basal area was lowest in the DM forest (14.3) and highest in the UI forest (47.4) with DI and UM forests being intermediate (Table 2.1).

Stem densities for the four forest types differed significantly (ANOVA; $F_{3,44}$ = 7.64, $p<0.001$). Stem density exhibits a unimodal pattern from disturbed to undisturbed interior, with a peak in the undisturbed margin forest. Stem density was highest in UM forest and lowest in DM forest (Table 2.1). The Scheffe's range test showed that DM and DI forest did not differ significantly in stem density (Table 2.1).

The undisturbed interior forest was characterised by a closed canopy (96.0%). The forest floor was covered with a thick litter layer, with many saplings present and scattered over the area of the plots. The canopy was dominated by *Ochna natalitia* and *Olea capensis* subsp. *macrocarpa,* with the sub-canopy dominated by *Rinorea angustifolia* (Appendix 3).

Undisturbed margin forest canopy cover was the lowest (83.0%). However, the overall structure was far more ordered with the ground layer being dominated by short shade-tolerant grasses. There was a distinct canopy usually with no sub-canopy. Dominant trees in UM forest were *Rapanea melanophloeos, Syzygium gerrardii* and *Protorhus longifolia* (Appendix 3).

In disturbed interior forest, Scheffe's range test showed that canopy cover (90.0%) differed significantly from both UM and UI forest (Table 2.1). Although this is higher than disturbed margin, canopy gaps in disturbed interior forests were few but large, resulting in high light intensities reaching the forest floor. These increased light levels could be providing suitable conditions for the establishment of the dominant herb layer of *Isoglossa hypoestiflora* observed in these forest types. The plots were generally dominated by trees in the smaller size classes and had numerous creepers. The dominant species in DI forest were *Celtis africana* and *Ficus sur* (Appendix 3).

The disturbed margin forest canopy cover (84.7%) was similar to UM forest (Table 2.1). Both DM and UM forests were located on the forest margins. Smaller size classes dominated DM forest with numerous creepers cluttering the general vegetation. The dominant species in DM forest were *Anastrabe intgerrima, C. africana, F. sur* and *Bridelia micrantha.*

2.3.3 Community similarity between forest types

Jaccard measures of similarity identified the differences and similarities between the four forest types. These measures are shown in Table 2.2. There was a close similarity between both DI and DM forest (0.72), with little similarity between UI and DM forest (0.36) and UI and DI forest (0.46). UM forest showed a similarity to UI forest (0.60), as well as to DI forest (0.57). This suggests that DM and DI forests are similar with UM forest being intermediate between the disturbed forests and undisturbed interior forests.

2.3.4 Species Abundance

Relative species abundance of each of the four forest types are shown in Table 2.3. In disturbed areas (DM and DI forests) the majority of the species were infrequent or occasional and accounted for a significant proportion of the total population. This resulted in an even population with no single species dominating the disturbed forest types. This trend shifted in undisturbed margin forests, were there was a tendency for single species to dominate. Finally in undisturbed interior forests, a single species dominated the forest (Table 2.3, Fig. 2.4). This species was *Rinorea angustifolia* and was found as a sub-canopy species.

2.4 Discussion

The trends in species diversity and the forest recovery verifiers have important implications for the management of forest biodiversity and recovering forests (Ricklefs & Miller, 1999). These trends once determined may be used to judge the stage of recovery and how diversity within the forest is changing.

The high species richness in the disturbed forest types in the NFC could be due to large mature trees being left in clear cut areas in the past. These trees could have provided suitable microclimates for shade-tolerant species that would not normally generate in high light intensities. A similar pattern was found in the tropical forests of Ecuador. In this study abandoned pastures with nurse trees had higher species richness than open abandoned sites (Zahawi & Augspurger, 1999). The resultant colonisation by shade-tolerant and shade-intolerant trees increases the species richness of sites that have residual trees after shifting cultivation. The trend in species richness in the NFC followed those typically found in recovering forests in tropical areas (Finegan, 1984, 1996; Aide *et al.*, 1995).

Jaccard measures of similarity showed that both disturbed margin forests and disturbed interior forests were very similar and that undisturbed interior forests had little similarity with these disturbed areas. The Jaccard measures of similarity showed that undisturbed margin forests were similar to both UI and DI forests, suggesting that this forest type is intermediate between the disturbed and undisturbed areas.

Basal area increased steadily from the disturbed to the undisturbed forest types in the NFC, reaching a high in the UI forest type. This trend was similar to those found in the tropical forests of the Rio Negro Region (Uhl & Jordan, 1984; Uhl, 1987), Brazil (Uhl *et al.*, 1988) and Tonga (Franklin *et al.*, 1999). The unimodal trend in stem density found, is also found in other tropical forests (Uhl, 1987; Aide *et al.*, 1995; Franklin *et al.*, 1999).

The DM and DI forests had low average stem densities and basal area. *Isoglossa* sp. dominated the herb layer of these plots. Low stem densities and basal areas of these plots suggest that the development of these forests is slow or hindered, possibly because of the increased herb layer. Similar patterns of arrested forest development because of an increased herb layer were also found in Nxumeni forest in KwaZulu-Natal (Moll & Haigh, 1966; van Wyk & Everard, 1993a), Puerto Rico (Aide *et al.*, 1995) and Ecuador (Zahawi & Augspurger, 1999).

The DM and DI forest types in the NFC were characterised by a large number of species with many individuals in the lower diameter size-classes. This was reflected in the high evenness values of DM and DI forests. Many of the species in DM and DI forests were typical edge species such as *A. intgerrima*, *Maesa lanceolata*, *Heteropyxis natalensis*, *Smodingium argutum* and *Trema orientalis* (Coates Palgrave, 1977; Pooley, 1997). However, none of these species were found in the undisturbed margins of the UM forest type. The lack of typical edge species in UM forest, that are found in the later stages of regrowth forest, suggests that UM forest is in a later stage of development than the disturbed forest communities. Alternatively the disturbed areas could be hindered due to the increased herb layer (Moll & Haigh, 1966; van Wyk & Everard, 1993a).

Van Wyk & Everard (1993b) studied the floristic structure and dynamics of Ngome forest, KwaZulu-Natal. They studied three different forest communities within Ngome forest, namely interior communities, edge communities and slip scar communities. The slipscar communities represented a forest community that had recovered from disturbance. From their data, they proposed a conceptual model of forest dynamics for Ngome forest. This forest is a Mistbelt Mixed *Podocarpus* forest and is situated in a similar climatic and vegetative zone as the NFC in the present study (Cooper, 1985). The model proposed that typical intermediate species in the path from edge to interior include *S. gerrardii, Cassipourea gummiflua, P. longifolia, R. melanophloeos and Combretum kraussii.* In UM forest dominant species in terms of relative abundance were, *R. melanophloeos, R. angustifolia, P. longifolia* and *S. gerrardii*, suggesting that this forest type represents an advanced stage of succession. Hence the lack of typical edge species in this forest type.

UI forest type was dominated by, R. *angustifolia* in the understory and *Ochna natalitia, O. capensis* subsp. *macrocarpa* and *S. gerrardii* in the canopy. The high dominance of *R. angustifolia* in the sub-canopy resulted in the low N2, N1 and evenness indices for this forest type. This forest type is significantly different from all the other three types and is dominated by large shade-tolerant individuals. This pattern of dominance in the UI forest type is similar to patterns of composition found in the Cape afromontane forests, north-eastern Transavaal afromontane forests and the afromontane forests of KwaZulu-Natal (Lübbe & Geldenhuys, 1991; Geldenhuys & Pieterse, 1993; van Wyk & Everard, 1993a, 1993b).

2.5 Conclusion

It is clear that the four forest types, sampled in the NFC, can be divided into three separate groups namely (1) DI and DM, (2) UM and (3) UI. The trends of species diversity, basal area and stem densities across the four forest types follow those typically found in other tropical forests. Species richness and stem density follow a typical unimodal pattern, with basal area increasing from disturbed to undisturbed forests, peaking in UM forest.

The first group, regrowth forest, was typified by DM and DI forest types. The general structure in these communities was a tangled "jungle", with stems being in the smaller diameter classes.

The second group, UM forest, was typified by intermediate tree species and high stem densities. These plots have high evenness and were not dominated by any one particular species.

The third and final group, UI forest, typified mature forest and was dominated by shade-tolerant species. This forest type had a high dominance index and low evenness. There was a distinct canopy, sub-canopy and lower stratum, with *Rinorea angustifolia,* a sub-canopy species dominating this community type.

Further analysis of the species and environmental variables in the following chapter shall reinforce these divisions and provide clearer indications as to the ability of the forest to regenerate after disturbance.

Chapter 3: Floristic Regeneration in Response to Disturbance

3.1 Introduction

The previous section highlighted the differences between disturbed margin, disturbed interior, undisturbed margin and undisturbed interior forests. The majority of these differences were based on species richness, basal area, stem density and canopy cover. A clear distinction existed between disturbed and undisturbed areas, with the results suggesting that undisturbed forest margin was intermediate to disturbed forest areas and mature undisturbed forest. The disturbed margins had higher species richness than UI forest and were characterised by light-demanding species with shade-tolerant species characterising undisturbed interior forest (Chapter 2).

Studies of forest regeneration in tropical regions suggest that there is a general pattern of species replacement across the seral stages of succession (Finegan, 1984; Uhl, 1987; Uhl *et al.*, 1988; Chapman *et al.*, 1999; Zahawi & Augspurger, 1999). In the initial stages of succession, forbs and grasses dominate abandoned lands. This is followed by colonisation of short lived, light-demanding, pioneer species that grow quickly. These pioneer species form a canopy under which shade-tolerant species start to propagate. The longer lived pioneers persist in the canopy but are unable to regenerate in the low light intensities and are ultimately replaced by the shade-tolerant forest species (Finegan, 1996; Ricklefs & Miller, 1999).

Studies of secondary forest recovery in the southern Afromontane forests are few (Geldenhuys, 1990; Everard *et al.*, 1995). These studies have concentrated on gap dynamics in the southern Cape forests, with a lack of information on species dynamics on abandoned lands subjected to shifting cultivation. Species replacement patterns in gaps in the southern Cape forests were found to follow a lottery model (Midgley *et al.*, 1995; Midgley *et al.*, 1997). Replacement patterns are dependent on the number of individuals per species in each gap. Gaps in these forests are relatively small (mean diameter : height ratio 0.24 and canopy gap : expanded gap ratio 0.3) and created through biotic factors rather than environmental or anthropogenic factors (Midgley *et al.*, 1997). This results in low levels of disturbance with the sapling bank remaining intact. It is assumed that this would not favour the establishment of light-demanding pioneer trees in these gaps and hence I suggested the characteristic replacement patterns found on abandoned lands would not be similar to those found in the gaps of the southern Cape forests.

Only two studies have dealt with patterns of regeneration in highly disturbed lands in southern Africa. Lübbe & Geldenhuys (1991) found that species replacement on lands subjected to clear cutting and agriculture (Diepwalle Arboretum in the southern Cape forests) were initially characterised by light-demanding colonisers such as *Clutia affinis* and *Burchellia bubalina*. A significant finding in this study was the ability of a common forest canopy species (*Olea capensis* subsp. *macrocarpa*) to establish itself in both disturbed and undisturbed plots. The ability of *O. capensis* subsp. *macrocarpa* to regenerate over a variety of conditions accounts for its abundance in the mature forests of the southern Cape (Lübbe & Geldenhuys, 1991).

Van Wyk & Everard (1993b) found that succession in Ngome forest in KwaZulu-Natal on slipscars, i.e. disturbed lands, followed patterns similar to those found in tropical regions. They found that slipscar sites were colonised by typical light-demanding pioneer species such as *Maesa lanceolata*, *Trema orientalis*, *Anastrabe intgerrima* and *Rapanea melanophloeos*. Whereas older mature forests were characterised by shade-tolerant individuals namely, *Olea capensis* subsp. *macrocarpa*, *Drypetes gerrardii*, *Podocarpus falcatus* and *Rothmannia capensis*.

Recovery on the abandoned lands in the Nkandla forest complex was predicted to follow a similar pattern of species turnover, i.e. disturbed forests and undisturbed margin forests would be characterised by light-demanding 'pioneer species', while undisturbed interior forests would be characterised by shade-tolerant forest species.

In this chapter I describe the patterns of establishment (i.e. light vs. shade demanding) in the NFC. The following section attempts to distinguish the patterns associated with forest recovery from disturbed to undisturbed forests in the Nkandla forest complex. Understanding the dynamics of species turnover from disturbed areas to undisturbed areas (i.e. along a disturbance gradient), and the ability of certain species to persist from early to later seral stages in ecosystems is important for long term sustainability of species biodiversity within the forest.

3.2 Methods

3.2.1 Sampling methods

Data from the Nkandla forest complex were collected from 48 sample plots stratified among the four forest types identified in the previous chapter (Chapter 2.2). In addition to these data several environmental variables were either measured or estimated and used in multivariate analysis (canonical correspondence analysis) of species response to disturbance.

The following environmental variables were measured at each sample plot:

(1) Slope angle (degrees) measured using a clinometer;

(2) Aspect (degrees) measured by compass and converted to a linear scale by taking the cosine of the angle;

(3) Age since abandonment (rank scale: 1 = < 33 yr., 2 = < 44 yr., 3 = < 63 yr. 4 = > 63 yr., 5 = undisturbed);

(4) Level of disturbance (rank scale 1 = undisturbed, 2 = mild disturbance, 3 = clear cut, 4 = clear cut + cultivated);

(5) Herb cover (rank scale 1 = 0-19 %, 2 = 20-39 %, 3 = 40-59 %, 4 = 60-79 %, 5 = 80-99 %); and

(6) Litter cover (rank scale 1 = 0-19 %, 2 = 20-39 %, 3 = 40-59 %, 4 = 60-79 %, 5 = 80-99 %).

Age and the level of disturbance were estimated from the aerial photographs of 1936, 1956, 1967, 1975 and 1996. Herb and litter cover were measured using straight line transects set out within each plot in the shape of a diamond (Fig 2.3). Herb/litter cover was recorded as present/absent at five points (spaced 2.35m apart) along each of the four transects using a densitometer (Stumpf, 1993). These values were used to calculate percentage covers that were subsequently converted to rank scales.

3.2.2 Multivariate analyses

Canonical correspondence analysis (CCA) was used to describe species turnover and differences among the four forest types, using a Q-strategy approach based on the composition of sample plots and their position relative to the environmental gradients. Multivariate analyses were done using CANOCO for Windows v4.02 (ter Braak & Šmilauer, 1998). Species abundance data (stems/plot) were used to calculate the species and site scores for the ordination. The data were square-root transformed to reduce the dominance of the few species that had large abundance values (Palmer, 2000). Rare species were down-weighted so that they did not unduly influence the ordination (ter Braak, 1995).

CCA is an extension of correspondence analysis and uses a linear combination of the measured environmental variables to maximise the dispersion of the species scores, i.e. show direct gradients of vegetation-environment relationships (ter Braak, 1995). The use of environmental variables in CCA allows one to look for indications of species composition gradients and to establish correlations between species composition and environmental variables (ter Braak, 1995).

The six measured environmental variables were used in the CCA ordination. Age and disturbance histories were predicted to have a combined influence on site recovery. It is possible that heavily disturbed sites abandoned long ago may not have recovered to levels seen in undisturbed sites of younger age. To test this, the interaction of age and level of disturbance were used (age*disturbance) as the seventh composite environmental variable (ter Braak & Šmilauer, 1998). Monte Carlo tests, using 199 iterations, were used to check the significance of all environmental variables on the ordination (ter Braak & Šmilauer, 1998).

The CCA data were plotted using Canodraw (ter Braak & Šmilauer, 1998) to show species and site separation along the ordination axes. All environmental data with a significance of $p < 0.05$, were included in the ordination diagram as vectors pointing in the direction of increasing magnitude of each environmental variable (ter Braak, 1995).

3.2.3 Species response curves along an environmental gradient

Examining the composition of sites with different ages and levels of disturbance can provide a meaningful pattern of species replacement in a successional process (Russell-Smith, 1996). The underlying environmental gradients extracted using CCA were used *a priori* to infer patterns about species turnover and successional gradients. Species response curves were plotted using species abundance data per plot (Morris, 2000, pers. comm.). Responses of individual species were plotted against the gradient indicated by the 1st axis. Species that showed more than 25% variation along the 1st CCA axis were selected. Additional species that did not show large variation along the first axis, but that showed high importance values (Appendix 3) in any one of the four forest types, were included. Trends of species replacement and their responses to disturbance were compared to values found in the literature.

3.2.4 Species regeneration potential in the Nkandla forest complex

Seedling and sapling numbers (stems/ha) for each forest type were calculated for individual species as well as for total number of seedlings and saplings. Seedlings had dbh <10mm. Saplings were woody stems with a dbh >10mm but <2m in height. The seedling and sapling numbers were used to give an indication of species turnover and the ability of the different species to regenerate in the different environments of each of the four forest types (Geldenhuys & Murray, 1993; Geldenhuys & Pieterse, 1993).

3.3 Results

3.3.1 Direct gradient analysis (Site and Environmental Variable Ordination)

The CCA ordination shows a clear separation of the sites across the disturbance gradient (Fig. 3.1), with the older and more mature stands and the younger and highly disturbed stands at either end of the ordination gradient. There was a marked separation of the sites with ±4 SD units between the extremes of the disturbed and undisturbed plots.

The first CCA axis accounted for 15.5% of the variation in species composition across the sites (Table 3.1). Most of the variance in the ordination was associated with the environmental variable of disturbance (Table 3.2). However, litter layer, age*disturbance, herb cover and age were also significant. Slope and aspect were not significant in the CCA ordination (Table 3.2).

The ordination diagram (Fig. 3.1) showed that level of disturbance was positively correlated to the first axis and age was negatively correlated (Table 3.2). Sites dominated by high levels of herb cover were indicative of disturbed sites, while sites dominated by a heavy litter layer were relatively undisturbed. The dominant herb in the undisturbed sites was *Isoglossa* spp. Although the combined variable of age*disturbance accounted for a significant amount of the explained variance, it was not highly correlated with the first axis, and the combination of age and disturbance did not explain the first axis well (Table 3.1; ter Braak, 1995).

Minimum convex polygon envelopes were created for the sites within the four forest types UM, UI, DM and DI. There is a clear separation between disturbed and undisturbed site groupings (Fig. 3.2), although DI and DM sites do overlap and are thus similar in composition. These findings support the conclusions from the previous chapter, DI and DM sites are similar while UM and UI sites differ from each other and the disturbed sites.

There was large variation in the ordination diagram within the DI sites and plots 2, 6, 10, 21 and 30 were most similar to UM sites (Fig 3.2). These plots were sited at the margin in 1937 (Fig 2.1) and were subjected to lower levels of use and recovery has been faster than in the more disturbed sites. This was confirmed by a general MANOVA using height and dbh, for trees with a dbh>100mm. The analyses showed plots 2, 6, 9, 10 and 30, differed significantly from the other DI forest plots (Wilk's Test Statitic = 0.412, MANOVA, $F_{2,10} = 7.124$, $p = 0.012$).

3.3.2 Species response to disturbance

The CCA ordination diagram only showed where certain species occur in ordination space (Fig 3.3). To obtain an understanding of species dynamics, individual species response curves were constructed (Fig 3.4).

Three clear patterns emerge from the response curves (Table 3.3):

- Edge or pioneer species - species abundance was low in the undisturbed areas and gradually increased along the 1st axis towards the more disturbed sites;
- Interior or late seral stage species - species abundance was high in undisturbed areas and decreased with disturbance towards the disturbed sites; and
- Intermediate seral stage species - species show a unimodal pattern, with their maximum abundance located toward the midpoint of the disturbance gradient. These patterns describe a definite species turnover from the disturbed areas to the undisturbed areas (Table 3.4).

3.3.3 Regeneration of seedling and sapling species in response to disturbance

Density of regeneration of seedlings was highest in the UI forest and lowest in DM forest (Table 3.5). More than 50% of the species in each forest type, except for UM forest (46%), regenerated as seedlings. Dominant trees (importance values, Appendix 3) in UI forest such as, *Olea capensis* subsp. *macrocarpa, Cassipourea gummiflua, Ochna natalitia, Rinorea* *angustifolia, Syzygium gerrardii* and *Trichilia dregeana*, were found as seedlings in the DM and DI regrowth forest. They were also found in UM forest. As would be expected, none of the typical pioneer tree species such as *Maesa lanceolata* and *Anastrabe intgerrima* were found as seedlings in UI and UM forest. *Rinorea angustifolia* behaved like a typical forest understory species in UM forest, where it was the dominant tree, although both seedling and sapling regeneration of *R. angustifolia* was abundant in UI forest.

Density of sapling regeneration (Table 3.6) was low, suggesting a high mortality from the seedling to sapling stage with the seedling bank thinning out. In DM, DI, UM and UI forest types only 24%, 28%, 27% and 12% of the tree species were found as saplings respectively. Many of the dominant trees in UI forest, such as *Olea capensis* subsp. *macrocarpa, Cassipourea gummiflua, Ochna natalitia, Rinorea angustifolia and Syzygium gerrardii* were found as saplings in the DM and DI regrowth forest. None of the typical pioneer tree species such as *Maesa lanceolata* and *Anastrabe intgerrima* were found as seedlings in UI and UM forest and their numbers decline steeply from DM to DI forest. The light-demanding nature of these species can explain this and therefore their preference for disturbed habitats.

3.4 Discussion

An obvious successional continuum exists between the disturbed and undisturbed sites at Nkandla forest. Theory suggests that recovery on abandoned lands is first by light-demanding colonisers that are out competed in the later successional stages by more shade-tolerant species (Finegan, 1996; Ricklefs & Miller, 1999). The species response curves supported these findings.

Species turnover occurred, from light-demanding pioneer species such as *Maesa lanceolata* and *Anastrabe intgerrima* in the disturbed margin forests to shade-tolerant species such as *Ochna natalitia, O. arborea, Olea capensis* subsp. *macrocarpa* and *Rinorea angustifolia* in UI forest (Fig. 3.4). Although there was a recovery continuum, the species composition of regrowth forest will not necessarily converge on the composition of UI forest. Highly disturbed areas that were sampled have yet to revert to a composition similar to that of the UI forest. The ordination does, however, suggest that recovering disturbed sites have a trajectory that could result in a composition similar to that of UI forest. This pattern of species replacement, from light-demanding colonisers to more shade-tolerant species in the latter stages of development, was similar to that found in Ngome forest (van Wyk & Everard 1993b).

The results (Chapter 2) showed that DM forest sites were not similar to UM forest. DM forest sites were located on severely disturbed lands and were found to be different in composition and structure to UM forest, even though they were the same age or older. This suggests that regrowth forest requires longer periods to develop into the 'climax vegetation' commonly found in the forest area. Most DM plots were covered by a thick herb layer of *Isoglossa*, which could be having an affect on the potential for seedlings to grow into adult trees. The *Isoglossa* layer could be out-competing tree species and thus causing succession to be arrested (Chapter 2.4). In UI plots were regeneration was abundant, *Isoglossa* spp. was absent. This pattern of arrested succession due to increased disturbance levels and an increasing herb layer are similar to recovery patterns in South Africa (Moll & Haigh, 1966; van Wyk & Everard, 1993a), Puerto Rico (Aide *et al.*, 1995) and Ecuador (Zahawi & Augspurger, 1999).

Cumulative seedling numbers (stems/ha) for all species in each of the four forest types were high. This suggests that there is adequate seed supply, germination and seedling establishment. As would be expected there was high seedling mortality. Although UI plots had the highest seedling regeneration on average, this did not result in high stem densities in the sapling class. The high stem densities in the seedling class in UI plots were exaggerated by the prolific regeneration of *Rinorea angustifolia* seedlings.

In UI plots, *R. angustifolia* regenerated in large patches of hundreds of individuals particularly in areas adjacent to canopy gaps. This suggests that increased light levels for short periods (due to the movement of the sun these patches would experience high light intensities for a very short duration) could be beneficial for the regeneration of *R. angustifolia*. This explanation was supported by field observations which found that densities (significant visual differences), of *R. angustifolia* along the forest edge ±20m from the dirt roads cut through UI forest, were higher than interior UI forest. There is an apparent level of shade tolerance that prohibits the abundant regeneration of *R. angustifolia*. Further research needs to be undertaken on this species in order to establish its ability to regenerate in differing light intensities. This is important, as *R. angustifolia* is the dominant sub-canopy tree species in UI forest. *Rinorea angustifolia* was the only individual tree species that exhibited a tendency for extremely high regeneration (> 500 stems/ha) of seedlings that resulted in a dominance of saplings and adult trees. However, this could be as a result of fruiting in previous years that would not have been detected by this survey.

Other dominant trees in UI forest, i.e. *Olea capensis* subsp. *macrocarpa, Ochna natalitia* and *Syzygium gerrardii* regenerated in large numbers in both disturbed sites and undisturbed edges. This dominance at the seedling stage was carried forward into both the sapling and adult stages in undisturbed sites. This suggests that these species which, are amongst the most dominant seedling regenerators, could eventually become the dominant canopy species and agrees with results of Lübbe & Geldenhuys (1991). This needs further investigation using permanent plots and larger temporal scales. One exception to this was *Trichilia dregeana.* This species was found as a dominant (importance values, Appendix 3) in UI forest, however it had low seedling and sapling regeneration (< 50 stems/ha) in disturbed forests and no regeneration in undisturbed forest. Everard *et al.* (1995) found that in coast scarp forest shade-intolerant trees such as *T. dregeana* maintained their canopy dominance by colonising tree-fall gaps. Unless *T. dregeana* has an effective seed dispersal mechanism that would allow dispersal of seeds into gaps, the ability of this tree to maintain its dominance in UI forest is doubtful.

Dominant tree species in the DM and DI forest, such as *Anastrabe intgerrima, Croton sylvaticus* and *Harpephyllum caffrum* had low seedling regeneration (< 25 stems/ha). However, *Anastrabe intgerrima* did have greater numbers of saplings than seedlings. *Anastrabe intgerrima* is a pioneer species and as such would not continue to regenerate in shaded forest, hence the larger number of saplings compared to seedlings in the disturbed forests.

3.5 Conclusion

Disturbed forest is indeed different from undisturbed forest in terms of species richness composition and abundance. However, the similarity of some DI plots to plots found in UM forest, suggests that recovery is on a trajectory towards a composition similar to UI forest. Forest recovery in the Nkandla forest complex follows general patterns of species replacement similar to those found in other tropical and subtropical forests, i.e. abandoned areas are colonised by light-demanding pioneer species.

Although the forest is recovering from disturbances in the past, the effects of continued harvesting by the surrounding communities are unknown. However, the important finding of this study is that shifting agriculture along forest margins does not cause an irreversible loss of forest, but if allowed to lie fallow will with time recover to a state similar to the original condition. The following chapter attempts to examine this continued harvesting of the forest resources and its impact on forest structure.

Chapter 4: Dynamics of selected woody species and the implications of human patterns of use on ecological sustainability

4.1 Introduction

The preceding chapters show that after clear cutting areas along the forest margin of the Nkandla forest complex; these are able to recover to a condition resembling undisturbed margin (Chapter 2 & 3). These regrowth forests recover at different rates depending on the levels of disturbance. Although the forest is recovering from the effects of past agricultural practices and is increasing in size, increasing population numbers and the commercialisation of the indigenous medicinal plant trade could have a negative effect on forest dynamics. The ability of the forest to recover from shifting agriculture could be slowed and possibly arrested due to over-use of tree species that form a critical part of the successional continuum.

A large number of woody tree species are used for construction, and it is estimated that 84% of the black population of KwaZulu-Natal uses traditional medicines (Mander, 1998). The effects of this use are often subtle and go undetected, especially where selected species deep in the forest are harvested. In particular harvesting materials for construction are restricted to the smaller size classes (10-100mm dbh).

The selective removal of tree species in the smaller diameter classes can alter the composition of the forest. In the long-term, extreme harvesting can lead to a disruption of the species and even local extinction (Peters, 1996). For example the unsustainable harvesting of bark for medicinal purposes has a negative impact on forest composition. In KwaZulu-Natal over-use of trees for their bark has led to the extinction of *Warburgia salutaris* outside protected areas with large specimens of *Ocotea bullata* and *Curtisia dentata* becoming rare in the wild (Lawes *et al.*, 2000).

This chapter investigated the effects of harvesting pressure on the size-class distribution (SCD) of selected woody tree species; i.e. their demography. These analyses were undertaken in order to establish whether or not any of the dominant species were over-used in the Nkandla forest complex. In order to maintain the present biodiversity within the forest and to ensure that the natural processes of succession would not be halted, the removal of woody tree species from the Nkandla forest complex must be at a sustainable level. No quantitative studies on harvesting levels and the type of species used in the Nkandla forest complex have previously been undertaken (Guy, 1999, pers. comm.).

4.2 Methods

4.2.1 Species Sampling

Data from the Nkandla forest complex were collected from 48 sample plots stratified among the four forest types identified in the previous chapter (Chapter 2.2). Diameter at breast height (dbh) values, in millimetres, were used in the construction of size-class distributions (SCDs) to indicate species trends.

4.2.2 Change in population and homestead size

Preliminary analysis of the aerial photos revealed that human populations had increased and there was a tendency for communities to move closer to the roads to gain access to infrastructure such as electricity and water. To estimate this, buffers of 200m and 2000m around the NFC margins were created as well as a 500m buffer around the road network. All digital analyses were undertaken using Arcview 3.0 (ESRI, 1996). Changes in homestead numbers from 1937 to 1996 were determined for all homesteads within these buffer zones respectively. Population figures for the Nkandla Magisterial District were obtained from censuses carried out by the South African government during 1936 and 1996.

4.2.3 Size-class distributions

Size-class distributions for selected species were constructed using 10 size-classes. Diameter at breast height values (mm) were separated into the following intervals, 10-29.9, 30-49.9, 50-69.9, 70-99.9, 100-149.9, 150-199.9, 200-299.9, 300-399.9, 400-499.9 and >500. These classes were chosen so that the smaller size-classes could be analysed. It is known that building material harvested is in the smaller size-class ranges between 10-100mm (Guy, 1999, pers. comm.; Lawes *et al.*, 2000). Size-class distributions were calculated by forest type and the cumulative number of stems per plot, were used for the construction of histograms (Condit *et al.*, 1998). Tree species were selected on the basis of their dominance in a particular forest type (importance values, Appendix 3) and their large variation in the canonical correspondence analysis along the observed environmental gradient. Heavily harvested species were also identified based on interviews with the local community and staff members of the Nkandla forest reserve. These were also included in the analyses.

Size-class distributions were used to infer species population dynamics. Four general responses were expected in the histograms. Species showing an inverse-J shaped curve, are normally shade-tolerant trees. They usually have large numbers of smaller individuals (high recruitment) compared to adults (Everard *et al.*, 1995; Everard, 1996). Uniform distributions indicate little recruitment and unimodal distributions indicate no recruitment (Everard, 1996). Species showing positive exponential growth are indicative of species that were colonisers and that have persisted in the older seral stages (Everard *et al.*, 1994).

4.3 Results

4.3.1 Human population dynamics

Tribal customs and the construction of roads influence population dynamics in the areas surrounding the Nkandla forest complex. In tribal areas it is a traditional custom for fathers to give their sons an area within or very close to their homestead (Ngcobo, 2000, pers. comm.). This has resulted in highly localised concentrations of people, scattered over a large area (pers. obs.). However, the size of each homestead can also increase due to polygamy, as each wife bought into the homestead requires a house of her own (Ngcobo, 2000, pers. comm.). Infrastructure such as electricity, sanitation and health services are located along roads. To gain access to these facilities, people are forced to locate their homesteads closer to the roads.

Population numbers in the Nkandla Magisterial District has increased three-fold from 1936 to 1996 to 134 308 individuals (Table 4.1). Homestead density has increased by 35% from 1936 to 1996 to 2.33 homes/km^2. Although there was an increase in homestead density and population numbers, homestead numbers within 200m of the forest have almost halved from 47 to 26. Homestead densities along roads have shown a nine-fold increase from 21 homes in 1936 to 188 homes in 1996.

4.3.2 Resource use and size class distributions of selected woody tree species

Many woody tree species found in the Nkandla forest complex are used for building material and medicinal purposes (Macpherson, unpublished data). Some of the more commonly harvested species together with the Zulu names are listed in Table 4.2. Few species namely, *Ochna natalitia, Strychnos henningsii* and *Drypetes gerrardii* are selected for building purposes (Table 4.2). All three species grow with very straight stems and are hard, insect-resistant trees thereby making them extremely valuable as supports in hut building

(Geldenhuys, 1990). Some of the species in Table 4.2 lacked sufficient stem numbers for analyses to be meaningful and the SCDs of the 12 common (importance values) and/or heavily used woody species were analysed.

The dominant species (Appendix 3) in disturbed areas (DM and DI forest types) showed three different types of size-class distribution (Fig 4.1). *Ficus sur* showed a unimodal pattern in DM forest, but a bimodal pattern in DI forest. There was however, no regeneration of *F. sur* (dbh 10-30mm) in either of these forests. In DM forest there were many more small stems of *Celtis africana* than in DI forest although larger specimens were found in DI forest. With *Anastrabe intgerrima,* bimodality was evident only in DM forest. In DI forest, the trend was much flatter, with fewer individuals in each size class. These three distributions did not show evidence of missing SCDs.

Dominant species in UM forest included *Rapanea melanophloeos, Protorhus longifolia* and *Syzygium gerrardii* (Fig 4.2). The histogram trend in all these species for all forest types was an inverse-J shape. In *R. melanophloeos* and *P. longifolia* the distribution patterns remained the same in the individual forest types. However, in DI forest, the number of individuals in each size class of *R. melanophloeos* and *P. longifolia* were lower. In addition *R. melanophloeos* had no individuals present in DI forest in the 70-100 mm size class. Individual species abundance was highest in UM forest, with *P. longifolia* having a high number of individuals in the 10-30mm SCD. *Syzygium gerrardii* showed an inverse-J shape trend for DM and DI forest types, and a bimodal distribution in UM forest. In UI forest *S. gerrardii* had an unimodal distribution, with the peak occurring in the larger SCDs. Very little regeneration of this species occurred in UI forest. *Syzygium gerrardii* was not harvested for its wood or bark, but the fruit of the tree was utilised by the local communities. *Syzygium gerrardii* showed no signs of over-use, and had a healthy standing-stock and a large number of adult trees distributed in three of the four forest types.

Species that dominated UI forest included *Rinorea angustifolia, Olea capensis* subsp. *macrocarpa* and *Cassipourea gummiflua* (Fig. 4.3). The distributions varied by forest type for *R. angustifolia* and *O. capensis* subsp. *macrocarpa. Rinorea angustifolia* was uncommon in DM forest and no trend was evident in the histogram (Fig. 4.3). In DI forest an inverse-J shape was evident for *R. angustifolia*, with UI and UM forests having flat distributions. Limited numbers of individuals were found in UM forest, but *R. angustifolia* was abundant in

UI forest and less disturbed DI forest (pers. obs.). The local communities do not harvest *Rinorea angustifolia*. *Olea capensis* subsp. *macrocarpa* had a unimodal distribution in UI forest, a bimodal distribution in UM forest and an inverse-J shaped distribution in DM and DI forest. However, the number of individual species encountered in DM forest was low. Both *C. gummiflua* and *O. capensis* subsp. *macrocarpa* are used as medicinal plants in the Nkandla area (Blose, 1999, pers. comm.; Makhaye, 2000, pers. comm.). The SCDs of both these species showed signs of use. Only three individuals in the 50-70 mm size class, and one in the 70-100 mm size class were recorded for *C. gummiflua*. *Olea capensis* subsp. *macrocarpa* had five, one and four individuals in the 30-50, 50-70 and 70-100 mm size classes respectively showing their relative paucity in these size-classes.

Species that were used extensively as either medicinal plants or for building material include *Ochna natalitia*, *Strychnos henningsii* and *Curtisia dentata* (Fig 4.4). All three species had bimodal distributions with apparently missing size classes in the different forest types. *Ochna natalitia* showed evidence of sufficient regeneration in UM forest but not in any other forest type. Low numbers of individuals (missing size classes) occurred in the 30-50 and 70-100 mm size classes, with numbers increasing dramatically in the following size classes. The SCD of *S. henningsii* showed a decline in number of individuals in the 50-70 mm size class with a steep increase in the following size classes. The stems of both *O. natalitia* and *S. henningsii* were used in the building of huts (Ngcobo, 2000, pers. comm.). Overall numbers of *C. dentata* were low; it was not found in UI forest and was infrequent in UM forest. The available data indicated a decrease in numbers towards the 50-70 mm size class and then a sharp increase in numbers in the following size classes. *Curtisia dentata* is a heavily used medicinal plant and ring-barking, to obtain greater quantities of bark, could be having an effect on species numbers (Lawes *et al.*, 2000).

4.4 Discussion

It is clear that human population and homestead numbers have increased significantly from 1937 to 1996. With an increase in population one would expect the forest to face increased pressure and possibly show signs of shrinkage due to over-use by the local communities. However, this is not the case. There is quantitative evidence showing that the forest is in fact expanding (Macpherson, unpublished data). One of the possible reasons for this expansion was the move away from a sole dependence on the NFC, towards using timber grown in commercial plantations. Lückhoff (1973) attributed the establishment of wattle plantations in the Transkei area as one of the main reasons that significant forest patches remain in the area today. In the Nkandla area there were many commercial plantations that were used by the local communities for both firewood and construction purposes (Ngcobo, 2000, pers. comm.; pers. obs.).

Although commercial plantations seem to have eased past pressures that were placed on the NFC for structural timber and fuelwood, many of the people in the communities cannot afford to purchase timber from these plantations. Another factor contributing to increased pressure being placed on the forest was the fact that medicinal plants found in the forest were not cultivated in large numbers to alleviate pressures placed on the NFC (Louw, 2000, pers. comm.; pers. obs.). Together, poverty and the increased commercialisation of the medicinal plant trade have led to the continued harvesting of selective species in the NFC (Louw, 1999, pers. comm.). Analysis of the SCDs of certain selected species, that were known to be used either for construction or medicinal purposes, suggests that these species are under extreme pressure.

Analysis of the SCD diagrams can reveal trends in use of species (Peters, 1996), but must also consider the dynamics of each particular species. Peters (1996) showed that at a harvest level of 85%, excessive fruit collection could eventually lead to local extinction of species (Fig 4.5). It is clear that excessive harvesting results in a progression from an inverse-J shaped distribution through a bimodal distribution to the final unimodal distribution in which there are only senescing large trees left in the canopy (Fig 4.5). Excessive harvesting of selected species in specific size classes would have a similar result. Although there would initially be sufficient regeneration of smaller individuals, these would be harvested before reaching maturity. Continued use of these specific size classes would result in no young or large adult trees and eventually the senescence of older trees would leave no reproductive individuals and thus lead to local extinction in extreme cases. This entire process would be lengthy and at no time would there be visible indications of over utilisation (Peters, 1996).

The results suggest that 10 of the 12 selected species show signs of use according to Peters' (1996) model. However, the dynamics of these species also need to be taken into account as shade-intolerant species also show unimodal and bimodal characteristics (Everard *et al.*, 1995). This is a consequence of gap dynamics; tree falls allow shade-intolerant species to establish in mature forest due to the increased light levels in the resultant gaps. Of the nine species *A. intgerrima, C. africana* and *F. sur* are shade-intolerant species, which would explain their bimodal and unimodal distributions. These species are commonly found on forest edges (van Wyk & Everard, 1993b). There was no evidence, both from interviews with local inhabitants and by estimating the numbers of relic stumps, to suggest that these distributions resulted from excessive harvesting.

The SCDs suggest that *S. gerrardii* can regenerate in shaded conditions but prefers light. Van Wyk & Everard (1993b) classified it as an intermediate species, which fell between edge species and true interior forest species. Based on Peters' (1996) model the SCD of *S. gerrardii* suggests over harvesting is occurring with this species. This is highly unlikely, as it is not known to be of any importance as a medicinal plant or for use as construction material. The lack of trees in the middle size classes requires further investigation.

Van Wyk & Everard (1993b) also classified *C. gummiflua* and *R. melanophloeos* as intermediate species. Both are heavily used as medicinal plants in the NFC (pers. obs.). This is reflected in the low number of individuals occurring in the 50-100 mm size classes. There were no individuals recorded in DI, UI and UM forest for *C. gummiflua* in the 70-100mm size-class. The results suggest that *C. gummiflua* does not show any preference for shade or light and that harvesting levels are also having negative impacts on the 50-100 mm size classes.

Rapanea melanophloeos had low abundance values in DI forest and was not found in UI forest. Observations suggested that this species preferred forest margins. This suggests that although *R. melanophloeos* was classified as an intermediate species (van Wyk & Everard, 1993b), it seems to prefer high light intensities. The lack of numbers in UM forest together with the knowledge that it is used for medicinal purposes suggests that usage levels and/or harvesting methods are having negative effects on the 50-100 mm size classes. *Rapanea melanophloeos* is found on the edges of forest margins and acquires strong fire resistance (van Wyk, 1994; Midgley *et al.,* 1997; Nichols, 2000, pers. comm.). This ability to survive fire results in a protective buffer of these trees along the forest margins in the Nkandla forest complex (pers. obs.). Without this buffer of fire resistant trees, continuous fire could result in grassland encroachment and a reduction in forest area.

Olea capensis subsp. *macrocarpa, O. natalitia* and *S. henningsii* are all typical interior forest species (van Wyk & Everard, 1993b). The SCDs suggest that harvesting of these tree species is having a negative effect on the 30-100 mm size classes. *Ochna natalitia* and *S. henningsii* were used for construction material and *O. capensis* subsp. *macrocarpa* was used as a medicinal plant. The results suggest that these species were excessively harvested and this could lead to the local extinction if the present patterns of use continue.

Curtisia dentata did not occur frequently in the forest and the SCDs of this species suggested that harvesting levels were having an effect on the smaller size classes. The specific dynamics of this species are not available and thus it is difficult to draw conclusions from the SCDs. However, it is known to be heavily used for medicinal purposes, and it is suggested that excessive use has led to its decline in many of the South African forests (van Wyk & Everard, 1993a, 1993b; Cunningham & Davis, 1997; Lawes *et al.*, 2000).

4.4 Conclusion

Although the forest is expanding in area, it is evident that certain woody tree species cannot continue to be used at current harvesting levels otherwise there the future structure and/or composition of the forest could be altered. Past and/or present levels of harvesting have caused *R. melanophloeos, C. gummiflua, C. dentata, O. natalitia, O. capensis* subsp. *macrocarpa* and *S. henningsii* to show signs of exploitation. The latter three species show excessive signs of exploitation in the 30-100 mm size classes.

Further research should be undertaken in order to establish the role that *O. natalitia, O. capensis* subsp. *macrocarpa* and *S. henningsii* play in the successional continuum. *Rapanea melanophloeos* is an important fire resistant species that provides a buffer against fire. Over-use of this species needs to be monitored in order to ensure that healthy standing-stocks are maintained in the Nkandla forest complex.

It can be seen that the use of SCDs together with the use of tree dynamics can provide a useful tool to serve as an indicator as to the effects of harvesting on specific tree species.

Chapter 5: Conclusion and Recommendations

5.1 Introduction

Shifting agriculture along forest margins in the tropical and sub-tropical regions of the world lays waste to large areas of forested lands. The consequences of this deforestation are numerous and include, increased soil loss, reduced water flow and a reduction in biodiversity (Edwards, 1967; Bormann & Likens, 1979). The ability of forests to regenerate after disturbance effects is extremely important for the maintenance of ecological diversity and the stability of forest ecosystems.

The present study focused on the recovery of the Nkandla forest complex (NFC), after shifting agriculture was practised along the forest margins. The NFC was sampled to determine: (1) how vegetation structure, composition and plant species diversity differ between regrowth forest and undisturbed forest; (2) how continued disturbance and subsequent land use affects the rate of recovery and regeneration of secondary forest; and (3) what species establishment pattern, if any, does the path of recovery follow during secondary succession? The study showed that recovery does occur to some extent (not yet fully) and that in the NFC recovery patterns (in terms of species diversity trends, biomass and basal areas) are similar to those found in other tropical and sub-tropical regions. Four different types of forest and the secondary succession process were sampled by space for time substitution: disturbed margin (DM) forest, disturbed interior (DI) forest, undisturbed margin (UM) forest and undisturbed interior (UI) forest. These forest types and their floral composition and structure described a recovery gradient of decreasing disturbance, with disturbed margin forest being the most disturbed type.

5.2 Trends and patterns of the four forest types sampled in the Nkandla forest complex

5.2.1 Floristic structure

Vegetation structure and species composition varied between the four forest types. Disturbed margin and disturbed interior forests were similar in structure (species richness, basal area and stem density) and composition, and were statistically grouped together. Undisturbed margin and undisturbed interior forests were grouped separately.

The trends in basal area, stem density and species richness (Fig. 5.1) across all four forest types were similar to those trends typical of recovering forest found in other tropical and subtropical forest ecosystems. Basal area increased steadily from disturbed to undisturbed interior forest. Stem density exhibited a unimodal pattern from disturbed to undisturbed interior, with a peak in the undisturbed margin forest. Average species number for the four forest types followed a unimodal pattern, with a peak occurring in the UM forest. These trends are consistent with the predictions of the intermediate disturbance hypothesis (Connell, 1979).

These trends show that the highest diversity of species was found in UM and DI forests. This suggests that moderate levels of disturbance are necessary in the Nkandla forest complex to maintain the high levels of biodiversity. In addition, margins should be protected from fire to allow for forest expansion and the maintenance of diversity.

5.2.2 Patterns of recovery in the Nkandla forest complex

The patterns of recovery were typical of those found in recovering abandoned lands in tropical and sub-tropical forests. Based on the ordination and dynamics of the NFC, a conceptual model of the recovery patterns is presented in Figure 5.2.

Highly disturbed sites were colonised by fast-growing pioneer species with the more mature interior forest being dominated by shade-tolerant individuals. The UM forest was older than disturbed forest but younger than UI forests. UM forest was considered to be at a stage of succession between that observed in disturbed forests and undisturbed interior forest. The disturbed forests were found to be on a recovery trajectory that was likely to culminate in structural and compositional characteristics found in undisturbed margin forests and undisturbed interior forests.

This suggests that floral recovery proceeds in a way that requires the prerequisite establishment of forest margins trees species (light demanding species) that facilitate the establishment of later species leading to a climax condition described by undisturbed interior forest. The past levels of disturbance resulted in different rates of recovery in disturbed areas. This resulted in DM forest showing a trajectory towards both UM and DI forest. A similar pattern was also found in DI forest, however, here the trajectory was towards both UI and UM forests. A dense herb cover typified the highly disturbed sites. Increased herb cover in the disturbed forests could have a negative effect on the speed of recovery in these forests.

5.2.3 Impact of selective harvesting on selected species and forest recovery

Continued harvesting of selected species is likely to be detrimental to the survival of these species. Analyses showed that *Rapanea melanophloeos, C. gummiflua, C. dentata, O. natalitia, O. capensis* subsp. *macrocarpa* and *S. henningsii* have been over-used. Continuing to harvest at these levels could result in critically low densities of these species and even their local extinction.

Rapanea melanophloeos is a fire resistant, edge species, dominant in both DM and UM forest (Appendix 3) and provides protection to the forest interior from fire. Further studies should be undertaken to establish sustainable harvesting levels for this species. Other over-used species namely *C. gummiflua, O. natalitia, O. capensis macrocarpa* and *S. henningsii* were dominant species in UI forest (Appendix 3). The removal of these species from the canopy would alter the species composition of the climax forest in the NFC and result in a loss of species diversity. It is not known how this removal would affect the internal dynamics of the forest.

This study showed that the NFC recovers from the effects of shifting agriculture and that forest composition is currently recovering along a trajectory towards a condition typical of undisturbed forest (Fig. 5.2).

5.3 Recommendations regarding the sustainable use of the Nkandla Forest Complex

In order to maintain the current species diversity, forest cover (total forested area) and empower the surrounding local communities, the following recommendations are provided.

5.3.1 Management priorities for the Nkandla Forest Complex

The formation of management boards to oversee the forested areas outside the Nkandla forest reserve (NFR) is crucial. The KwaZulu-Natal Nature Conservation Service (KZNNCS) is in the process of forming community conservation areas (CCAs) in the Sibudeni forest (Fig 1.1). These CCAs are formed in conjunction with the relevant tribal authorities and are managed by a board consisting of members from the surrounding tribal authorities and staff from the KZNNCS. **The formation of CCAs in areas of regrowth forest needs urgent attention. Along with the formation of these boards, efficient permit systems need to be**

incorporated into the management plans of surrounding forests and the NFR. This would promote forest regrowth and ensure that sustainable levels of disturbance, which are necessary to maintain species biodiversity, are achieved in the forests managed by the rural communities.

The current system of permits lacks information on the type and number of species that are being used. Material removed from the forest is classified as fuelwood, building material or medicinal plants. **A more detailed description of species should accompany better estimates of the amount of material removed**. This will allow for better estimation of harvesting off-take levels.

Daily patrols currently record detailed information on the locality and type of species that are illegally harvested within the NFR boundaries. This information remains in notebooks and is not available to upper management. **Daily patrol information needs to be recorded and passed on to the regional offices.**

5.3.2 Establishment of ecotourism ventures in the Nkandla Forest Complex

The surrounding communities do not see any economic benefits from the protection of the NFR or the CCAs. Many of the areas within the CCAs have significant potential for the establishment of small ecotourism ventures due to their scenic beauty and diverse bird life. **It is suggested that instead of building camps within the reserve, small rest camps should be built in the communities surrounding the forest**. This will serve two purposes. Firstly the local communities will see an immediate benefit and secondly the forest will not be sacrificed for the establishment of camps. Hikes could be taken into the forests from the surrounding communities using local guides. At the same time, facilities that are currently available at the NFR need to be marketed and made available to the general population. The establishment of ecotourism ventures within the local communities would reduce the pressures placed on the surrounding forests by generating a cash income.

Visitors to the reserve currently pay no admission fee and can even be accommodated in the reserve at no cost. This is an unnecessary loss of revenue, just because no system is in place to take money from day visitors. **A system for payment by day visitors and people wishing to overnight in the reserve needs to be implemented.** This would provide the reserve with increased funds for improved management of the reserve and a portion of this gate money could go to surrounding communities.

5.3.3 Education centre within the forest reserve

Facilities for outdoor education exist at the main offices of the NFR. These facilities are poorly utilised. **Education programs informing the local communities of the benefits that they derive from the forest need to be started.** Most of the people in the surrounding communities do understand how they indirectly benefit from the forested areas.

5.3.4 Establishment of community plantations

Individuals own many of the established plantations in the community areas and charge a fee for the removal of material. **Communal plantations that are available to the whole community need to be established.** This will reduce the demand for fuelwood from the NFC and the impact on forest margins. These plantations would be small and would be used to provide wood for building and energy production. Plantations need to be established in an environmentally sustainable manner that would not impact on water resources or soil erosion. These plantations must be planted away from the forest margins to prevent their invasion of gaps/margins.

Through education and empowerment the consequences of over-use of resources within the NFC and how this would affect the communities in the future would be highlighted. As a result the continued diversity and expanse of the NFC would be available for all future generations through the sustained use of the resources within the NFC.

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Figure 3.4 Species response curves for the Nkandla forest complex data. The abundance of each species is presented with a first order, smoothed line fitted for each species. Three trends are evident in the figures: Preference for disturbed areas (first row), intermediate preference (second row) and species with a preference for mature undisturbed sites (rows three and four). Y-axis denotes number of individuals, X-axis denotes CCA Axis I. ◊ = DM, □ = DI, Δ = UM and O = UI.

Figure 4.1 Size-class distributions of three disturbed forest margin species sampled in the Nkandla forest complex. DM = disturbed margin forest, DI = disturbed interior forest, UM = undisturbed margin forest and UI = undisturbed interior forest. X-axis values denote increasing size-classes. 1 = 10-29.9, 2 = 30-49.9, 3 = 50-69.9, 4 = 70-99.9, 5 = 100-149.9, 6 = 150-199.9, 7 = 200-299.9, 8 = 300-399.9, 9 = 400-499.9 and 10 = >500 (all measurements in mm)

Figure 4.2 Size-class distributions of three intermediate forest species sampled in the Nkandla forest complex. These three species did not show a preference for disturbed or undisturbed sites. DM = disturbed margin forest, DI = disturbed interior forest, UM = undisturbed margin forest and UI = undisturbed interior forest. X-axis values denote increasing size-classes. 1 = 10-29.9, 2 = 30-49.9, 3 = 50-69.9, 4 = 70-99.9, 5 = 100-149.9, 6 = 150-199.9, 7 = 200-299.9, 8 = 300-399.9, 9 = 400-499.9 and 10 = >500 (all measurements in mm)

Figure 4.3 Size-class distributions of three interior forest species sampled in the Nkandla forest complex. DM = disturbed margin forest, DI = disturbed interior forest, UM = undisturbed margin forest and UI = undisturbed interior forest. X-axis values denote increasing size-classes. 1 = 10-29.9, 2 = 30-49.9, 3 = 50-69.9, 4 = 70-99.9, 5 = 100-149.9, 6 = 150-199.9, 7 = 200-299.9, 8 = 300-399.9, 9 = 400-499.9 and 10 = >500 (all measurements in mm)

Figure 4.4 Size-class distributions of three species that were heavily used for building material or medicinal purposes in the Nkandla forest complex. DM = disturbed margin forest, DI = disturbed interior forest, UM = undisturbed margin forest and UI = undisturbed interior forest. X-axis values denote increasing size-classes. 1 = 10-29.9, 2 = 30-49.9, 3 = 50-69.9, 4 = 70-99.9, 5 = 100-149.9, 6 = 150-199.9, 7 = 200-299.9, 8 = 300-399.9, 9 = 400-499.9 and 10 = >500 (all measurements in mm)

Figure 4.5 Simulated changes in population structure of *Grias peruviana* in response to excessive fruit collection. Redrawn from Peters (1996). Note the change in scale in the latter three time periods accounting for the progressive decrease in population size. X-axis values denote increasing size-classes. 1 = 10-29.9, 2 = 30-49.9, 3 = 50-69.9, 4 = 70-99.9, 5 = 100-149.9, 6 = 150-199.9, 7 = 200-299.9, 8 = 300-399.9, 9 = 400-499.9 and 10 = >500 (all measurements in mm)

Figure 5.1 Summary of trends for basal area, species richness and stem density across the four forest types in the Nkandla forest complex. Y-values represent the standardised numbers (range 0.1 – 1.0) for each of the three structural characteristics using the original data (Table 2.1) SR = species richness, BA = basal area and SD = stem density. DM = disturbed margin forest, DI = disturbed interior forest, UM = undisturbed margin forest and UI = undisturbed interior forest.

Figure 5.2 Conceptual diagram of the forest dynamics in the Nkandla forest complex based on results of the study. Selected dominant woody tree species (Appendix 3) are shown in the frames for each forest type. Solid black arrows indicate the dynamic pathway. The size of the arrows provides an indication of the most likely path that succession would follow.

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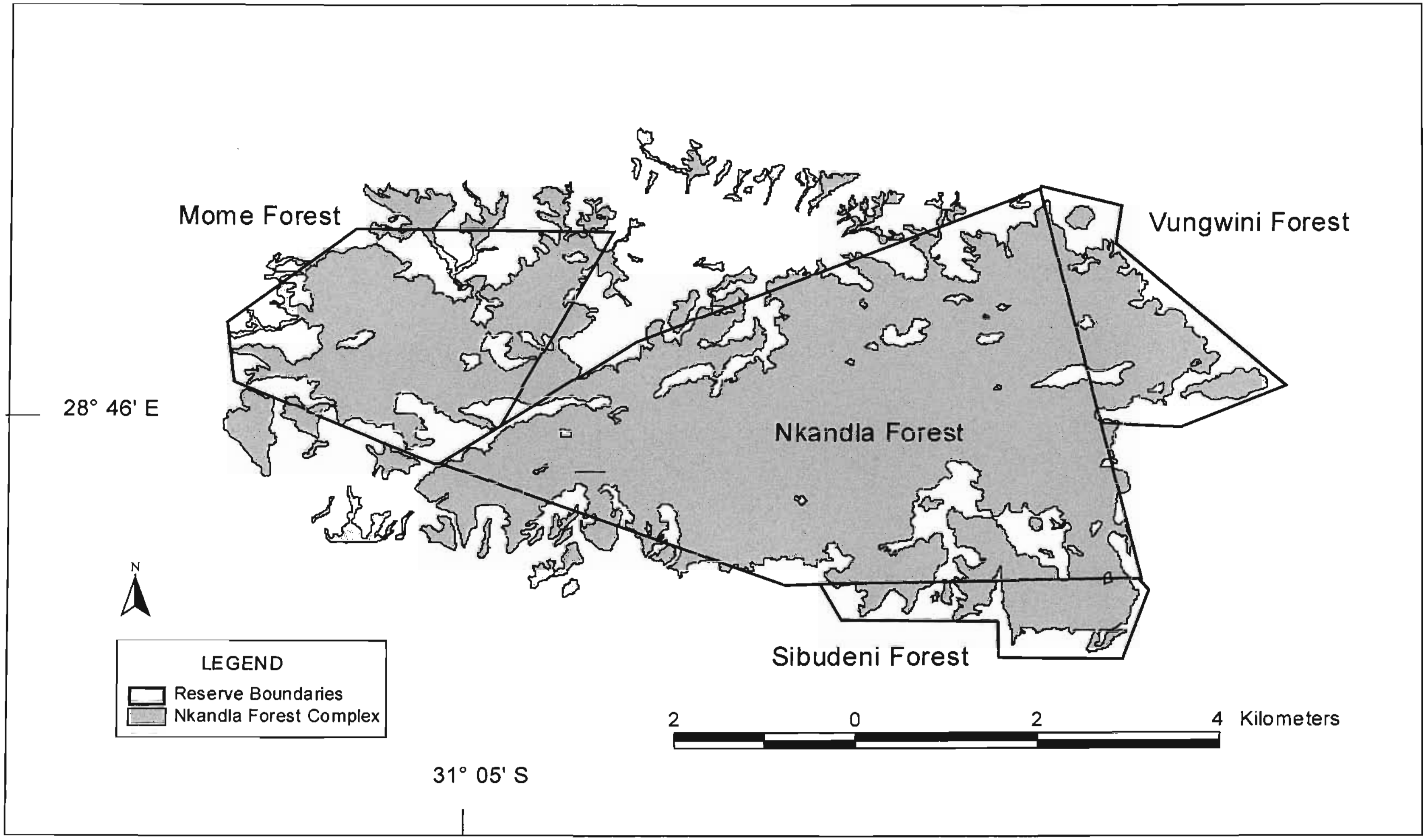
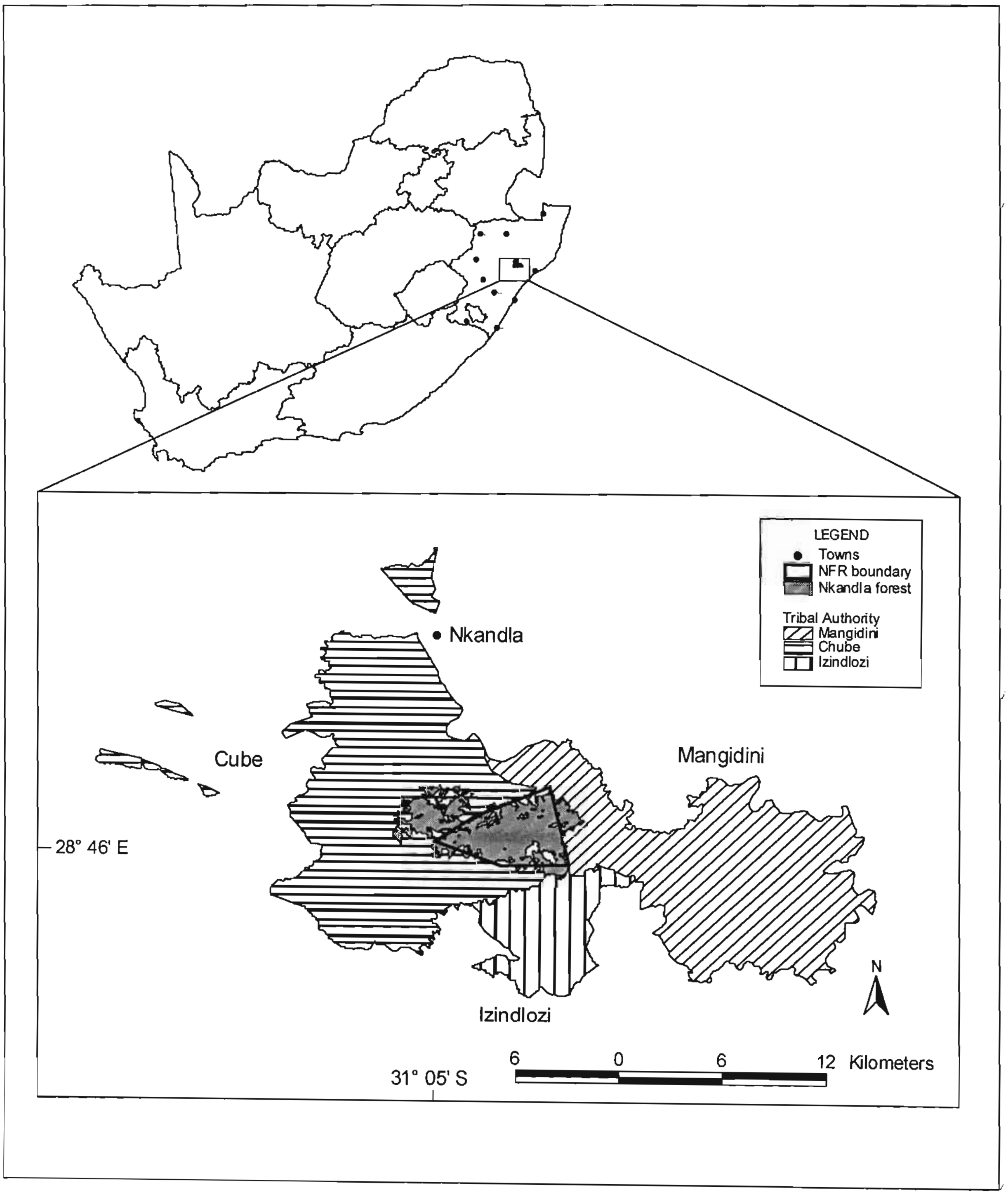
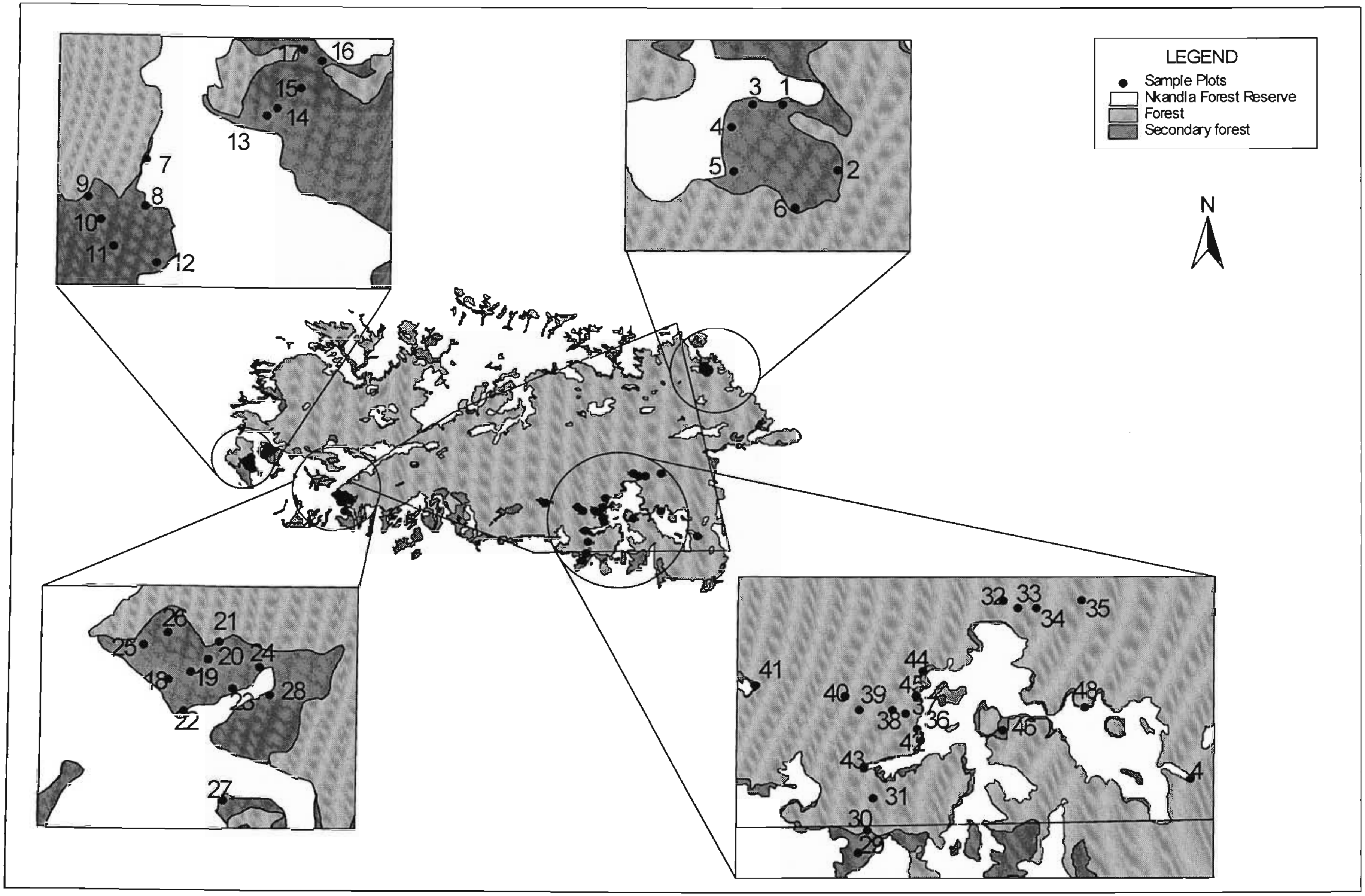

Mome Forest
Vungwini Forest
28° 46' E
Nkandla Forest
Sibudeni Forest
N
LEGEND
Reserve Boundaries
Nkandla Forest Complex
2
0
2
4
Kilometers
31° 05' S



LEGEND
Towns
NFR boundary
Nkandla forest
Tribal Authority
Mangidini
Chube
Izindlozi
Nkandla
Cube
Mangidini
Izindlozi
28° 46' E
31° 05' S
6
0
6
12
Kilometers
N


LEGEND
Sample Plots
Nkandla Forest Reserve
Forest
Secondary forest
N
1
2
3
4
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11
12
13
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18
19
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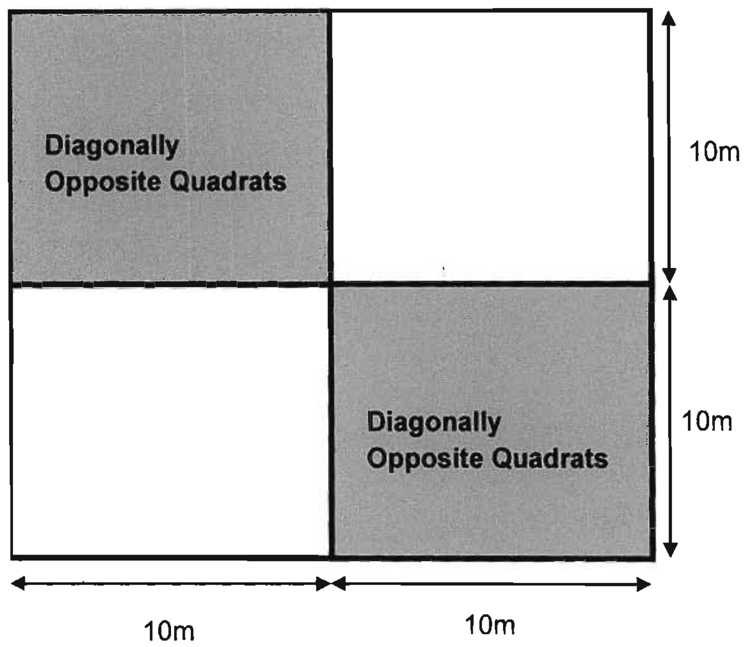
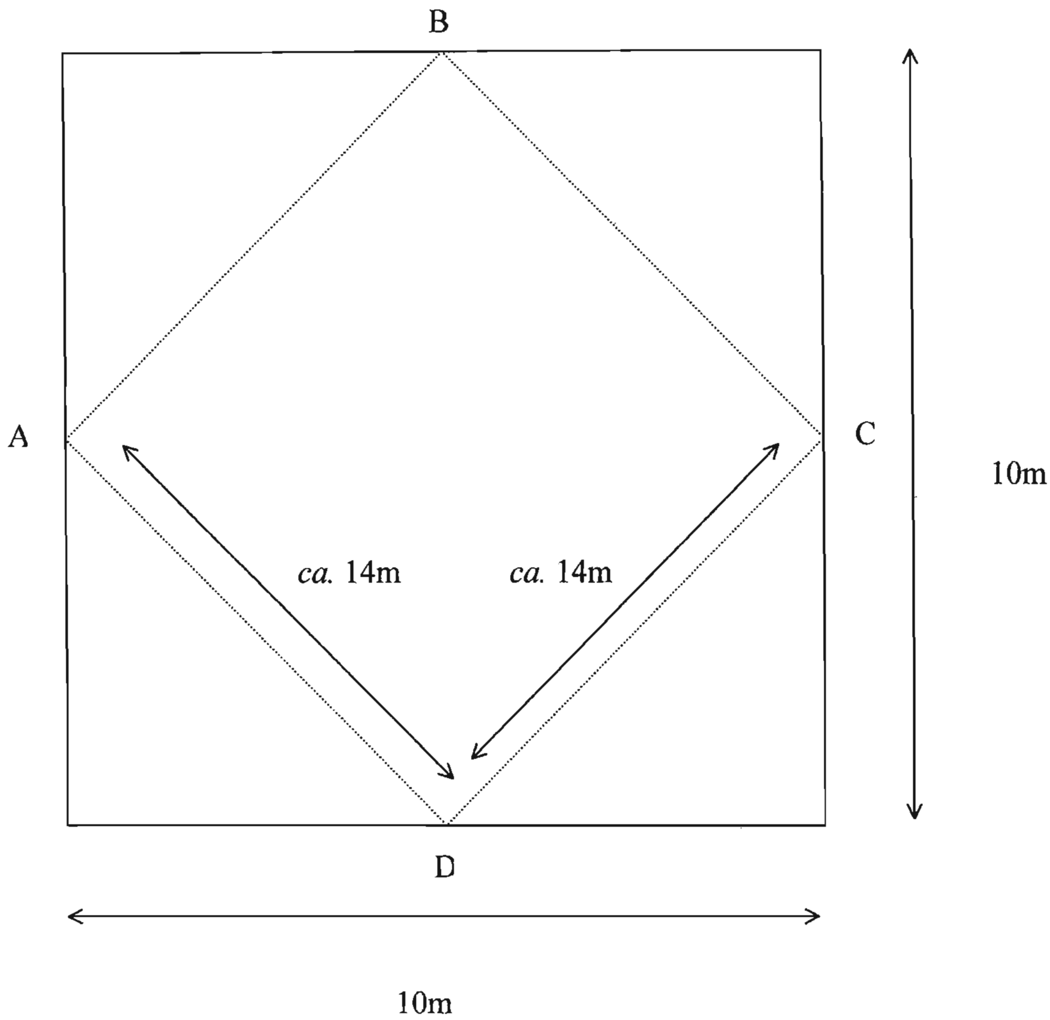
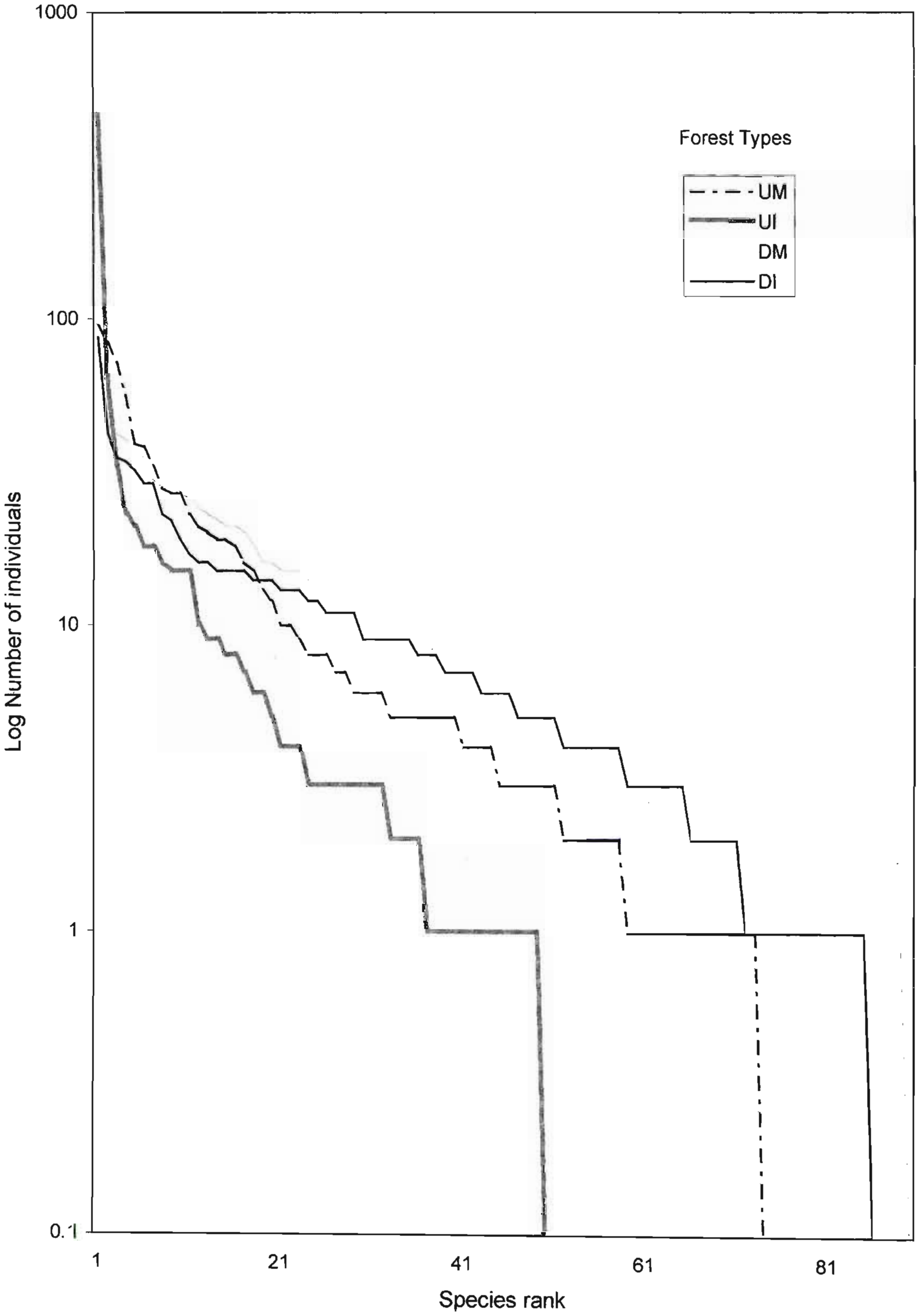
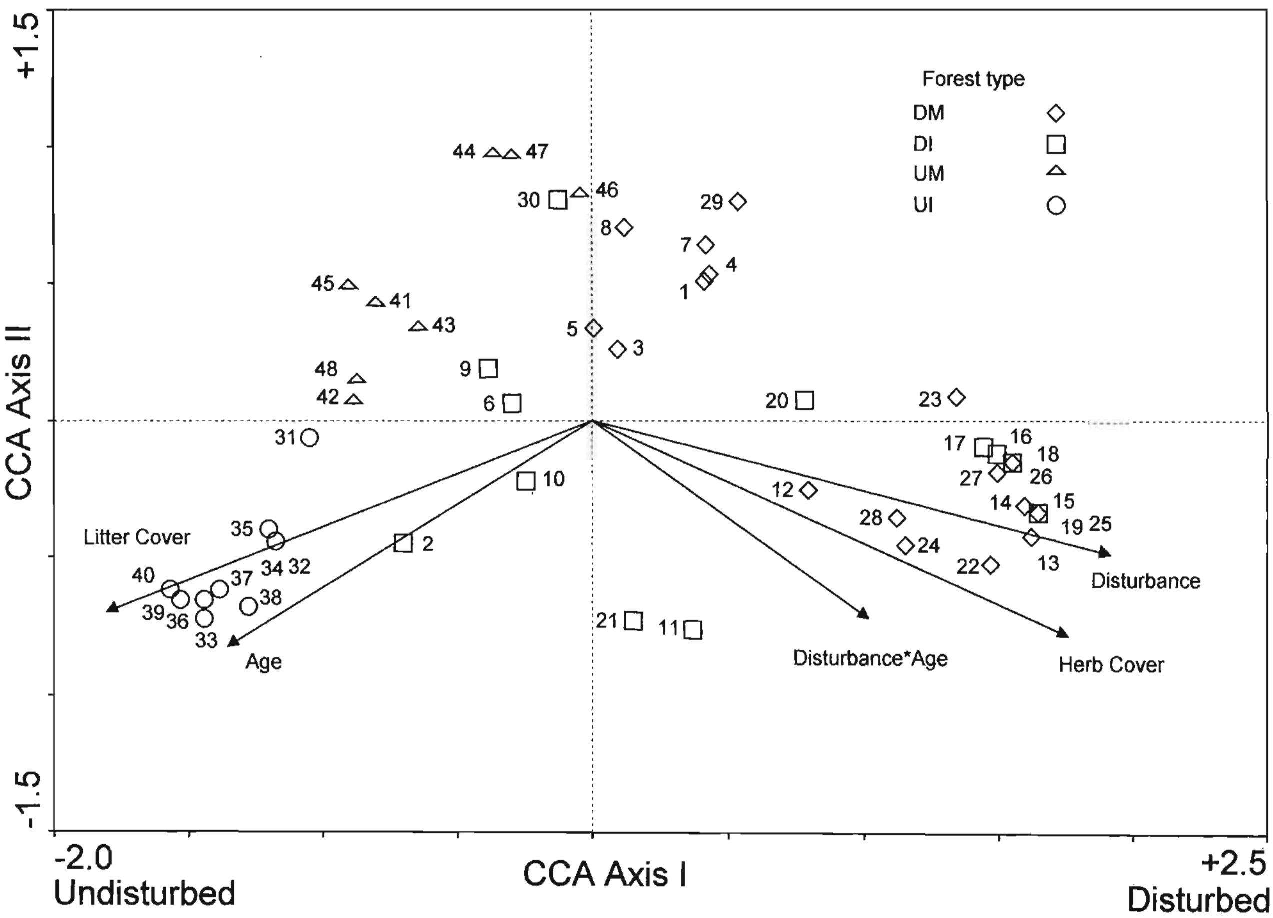


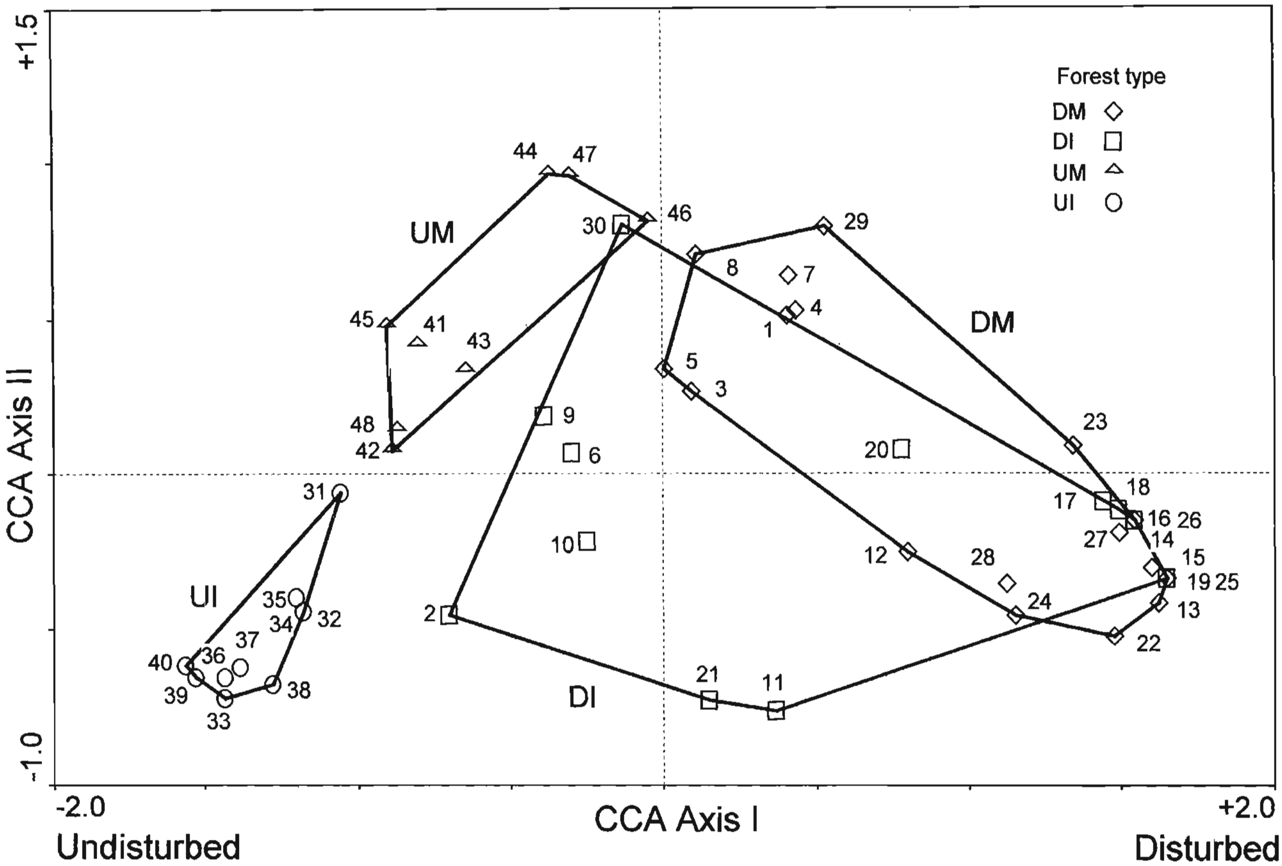
Diagonally
Opposite Quadrats
Diagonally
Opposite Quadrats
10m
10m
10m
10m


B
A
C
10m
ca. 14m
ca. 14m
D
10m



1000
100
10
1
0.1
Log Number of individuals
1
21
41
61
81
Species rank
Forest Types
UM
UI
DM
DI


+1.5
-1.5
CCA Axis II
-2.0
Undisturbed
CCA Axis I
+2.5
Disturbed
Forest type
DM
DI
UM
UI
Litter Cover
Age
Disturbance*Age
Herb Cover
Disturbance



Forest type
DM
DI
UM
UI
+1.5
-1.0
-2.0
+2.0
CCA Axis II
CCA Axis I
Undisturbed
Disturbed
UM
DM
UI
DI
44
47
46
30
29
8
7
4
1
45
41
43
5
3
48
42
9
6
20
23
18
17
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21
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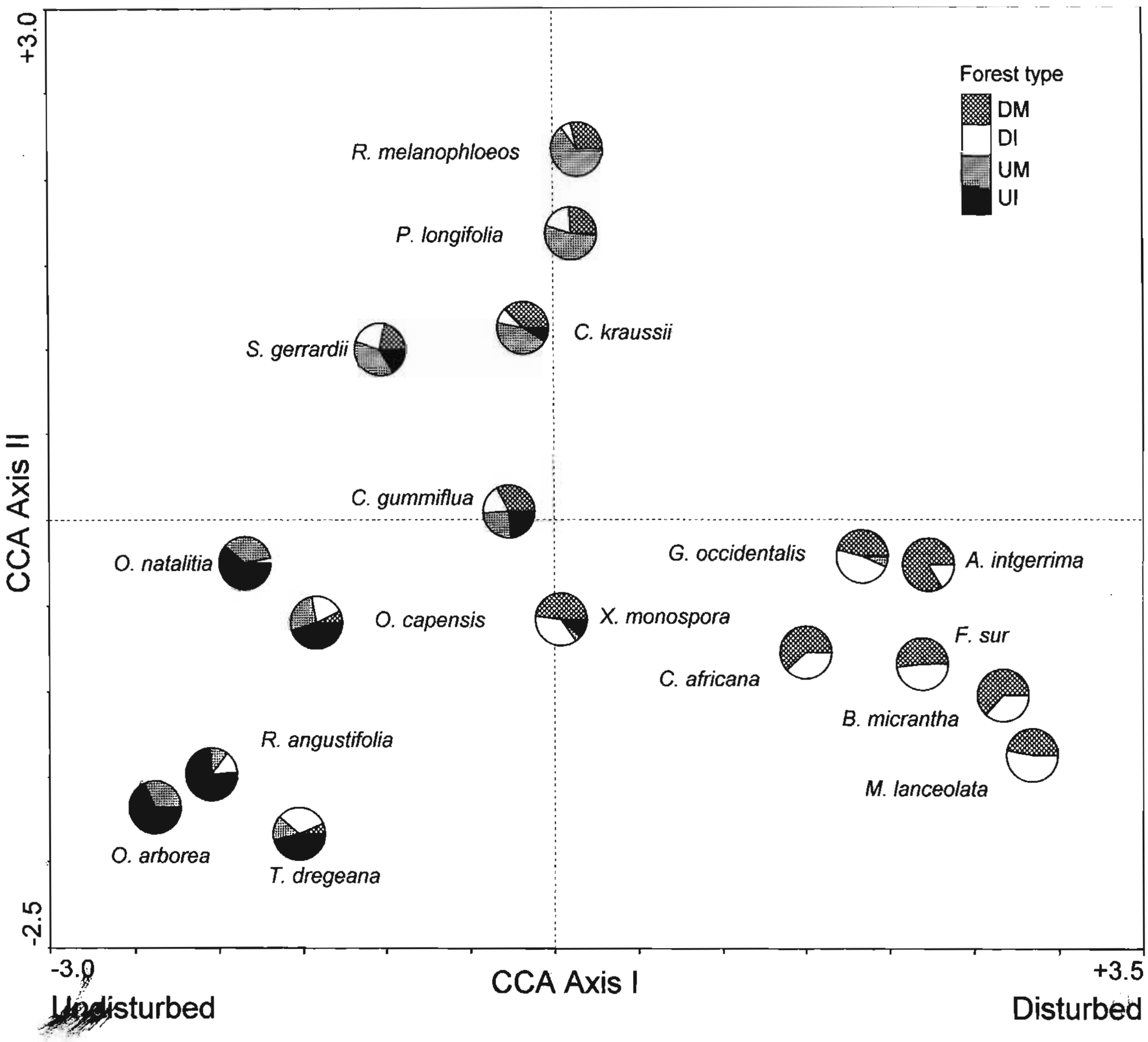
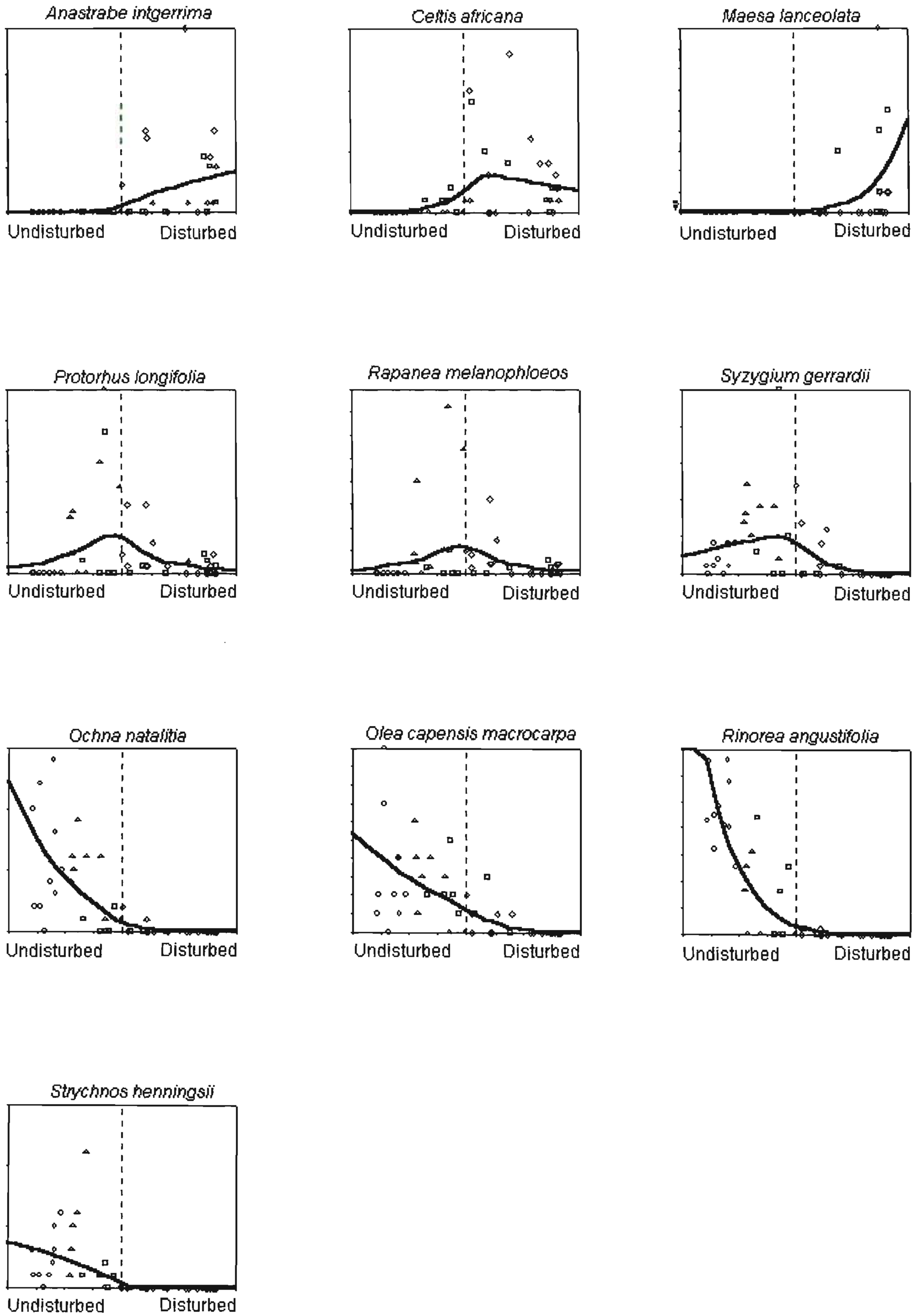
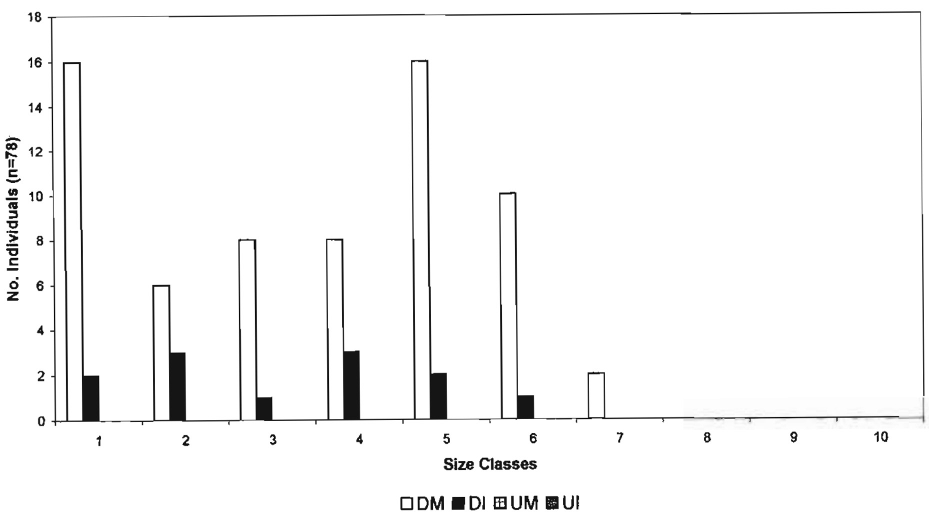


+3.0
-2.5
CCA Axis II
-3.0
+3.5
CCA Axis I
Undisturbed
Disturbed
Forest type
DM
DI
UM
UI
R. melanophloeos
P. longifolia
S. gerrardii
C. kraussii
C. gummiflua
O. natalitia
O. capensis
X. monospora
G. occidentalis
A. intgerrima
C. africana
F. sur
B. micrantha
M. lanceolata
R. angustifolia
O. arborea
T. dregeana



Anastrabe intgerrima
Undisturbed
Disturbed
Celtis africana
Undisturbed
Disturbed
Maesa lanceolata
Undisturbed
Disturbed
Protorhus longifolia
Undisturbed
Disturbed
Rapanea melanophloeos
Undisturbed
Disturbed
Syzygium gerrardii
Undisturbed
Disturbed
Ochna natalitia
Undisturbed
Disturbed
Olea capensis macrocarpa
Undisturbed
Disturbed
Rinorea angustifolia
Undisturbed
Disturbed
Strychnos henningsii
Undisturbed
Disturbed

Anastrabe intgerrima



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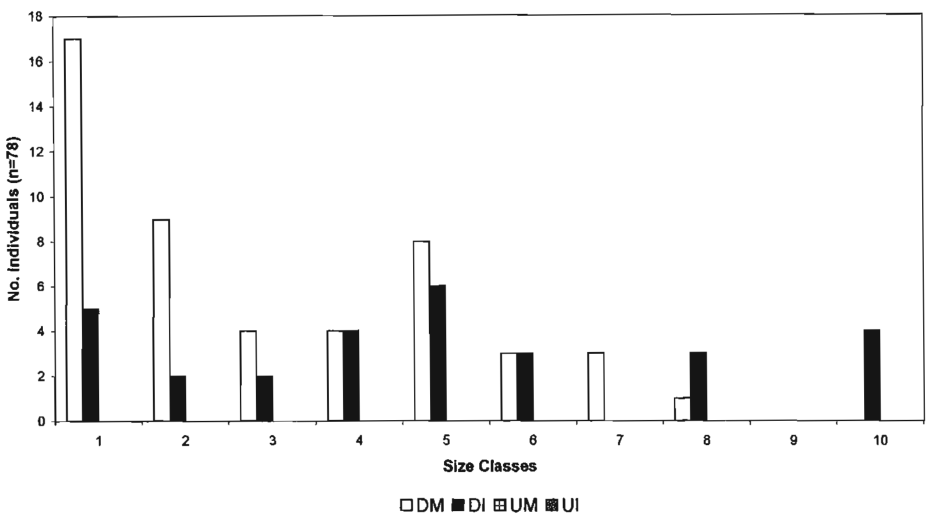
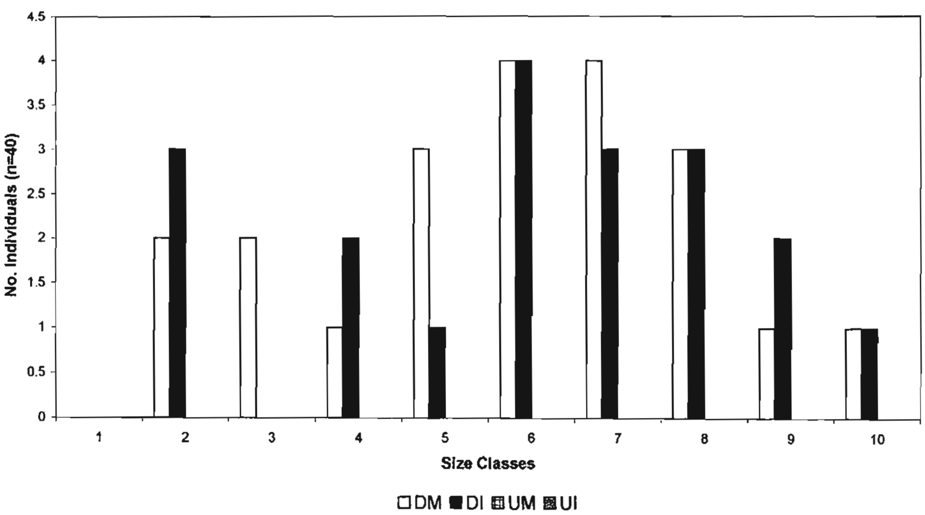


Ficus sur



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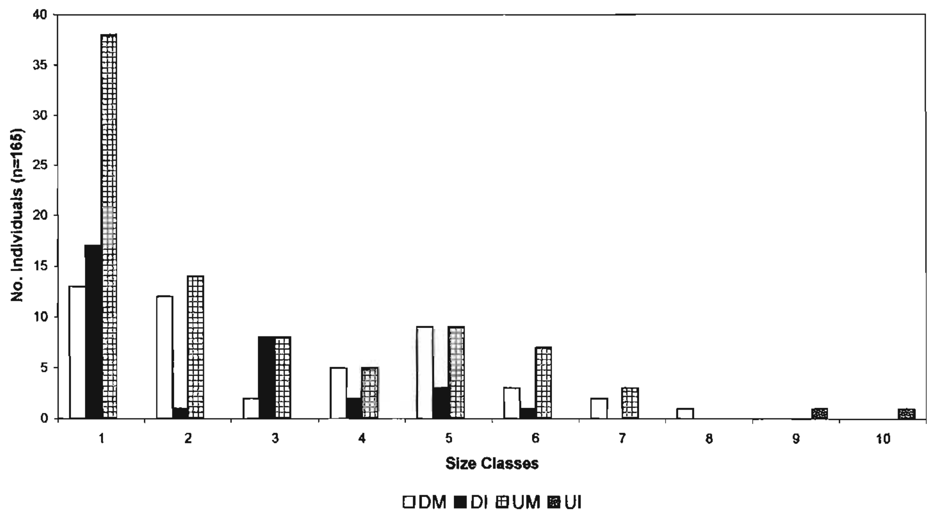

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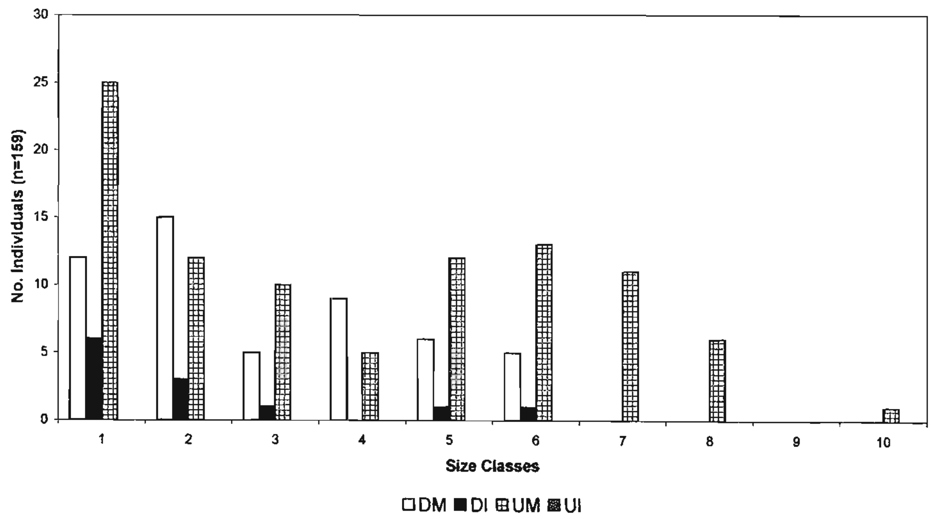

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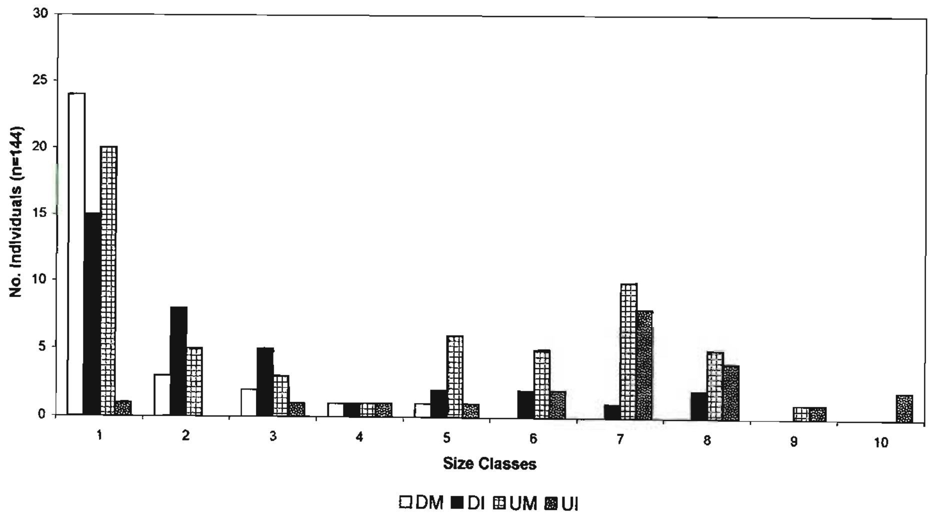
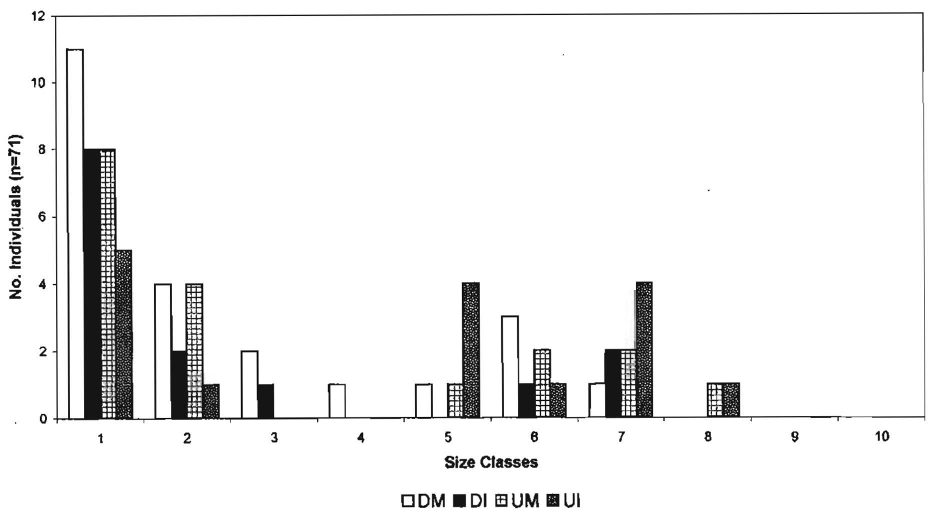


Cassipourea gummiflua



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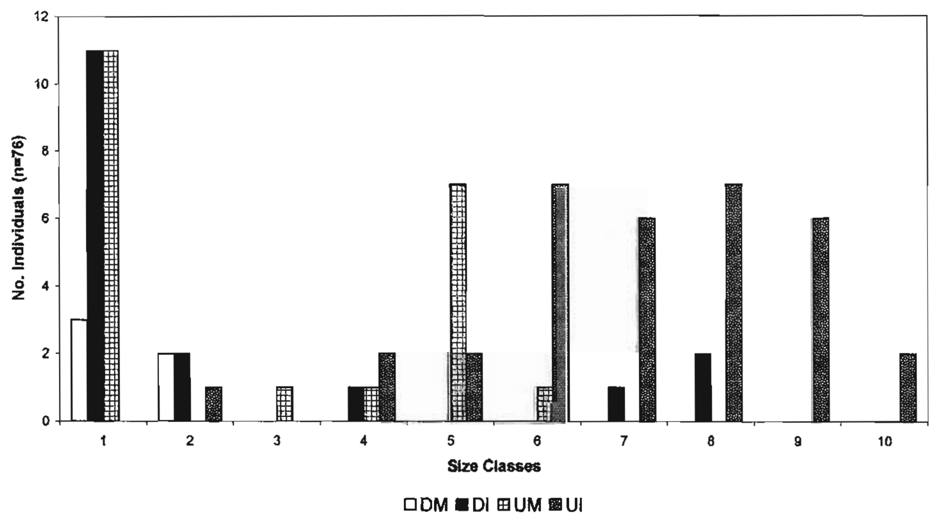

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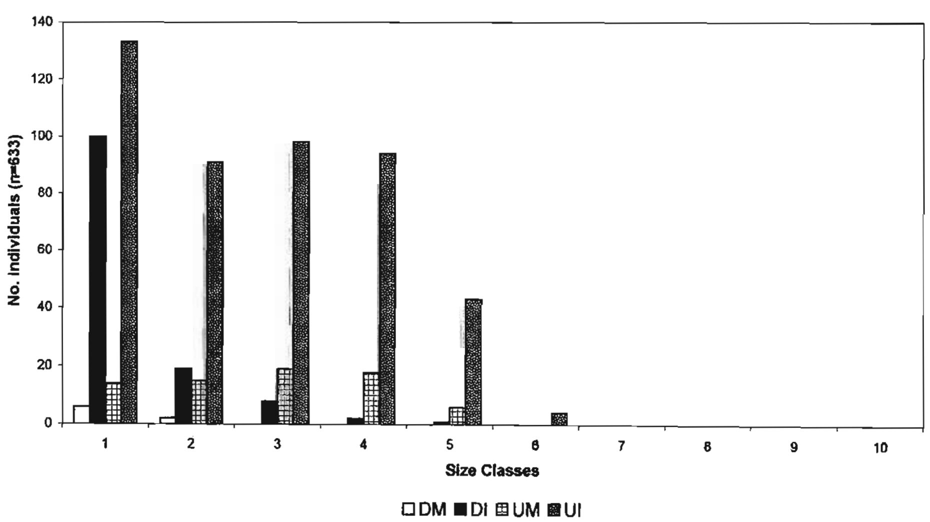

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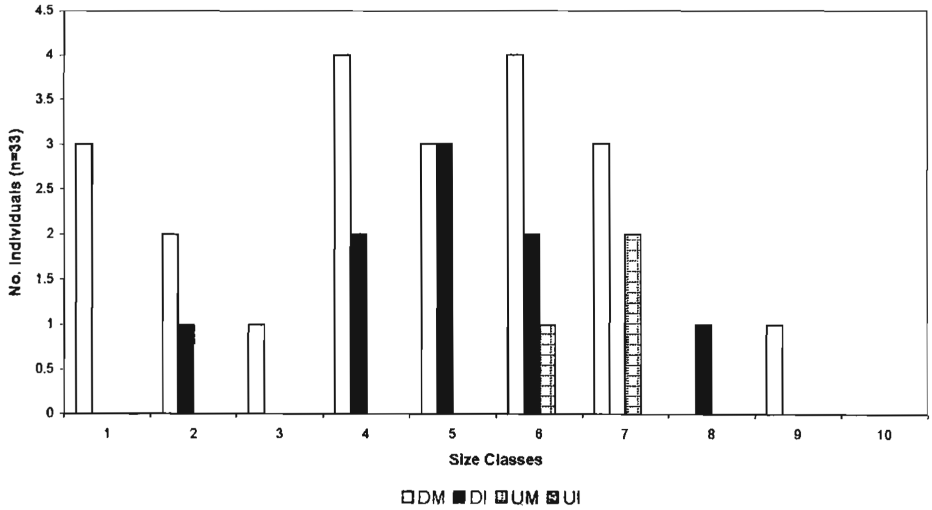
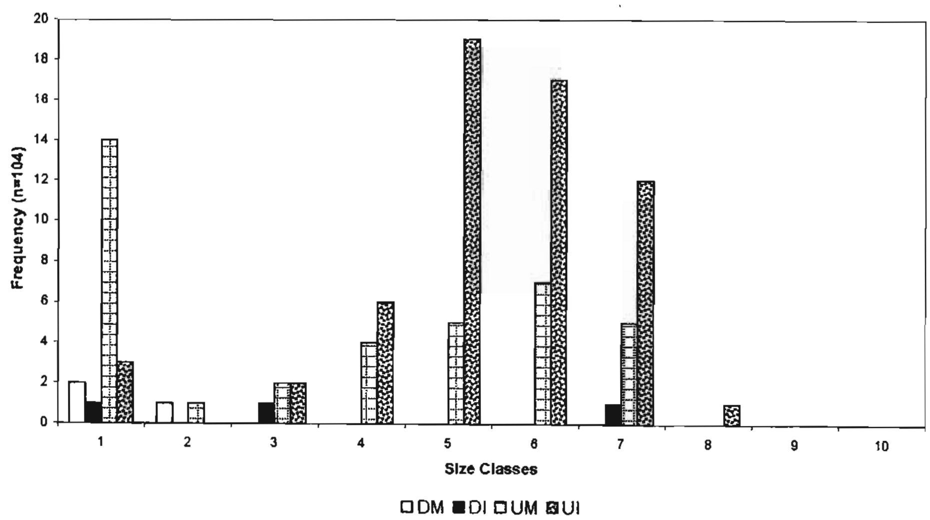
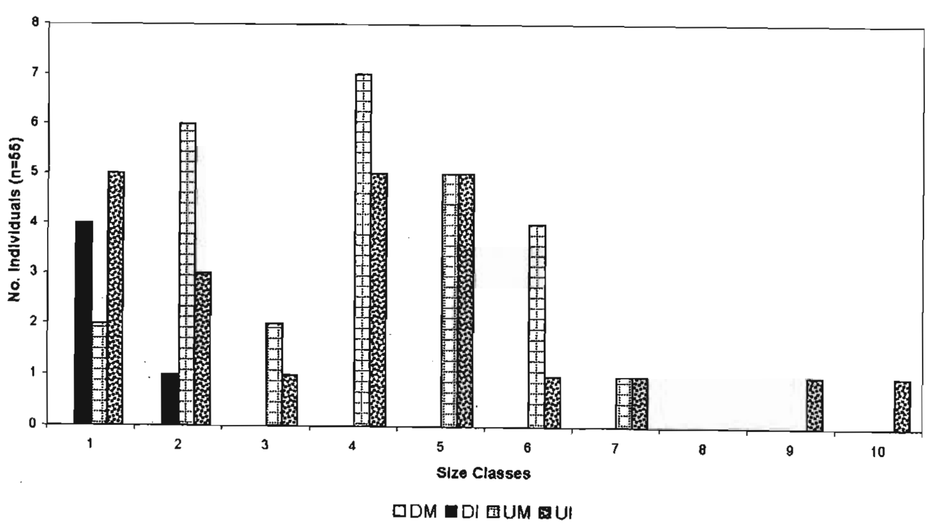


Ochna natalitia



Strychnos henningsii



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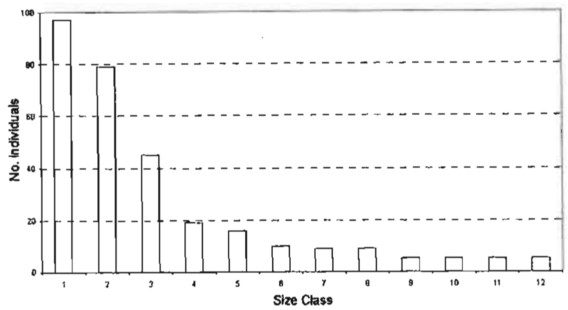

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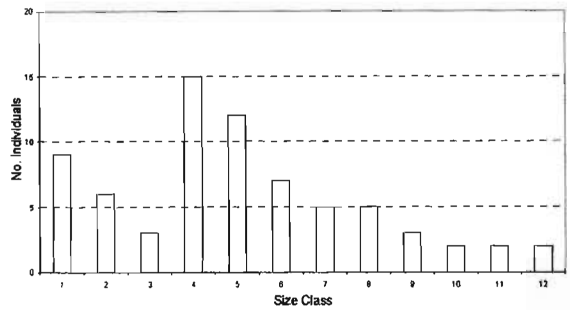

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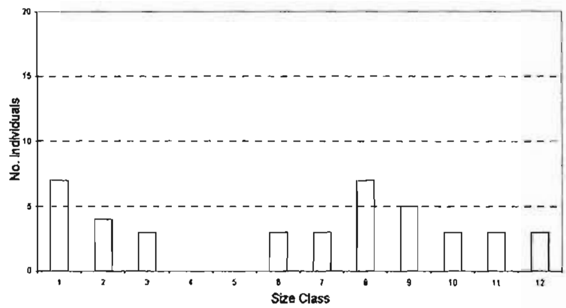

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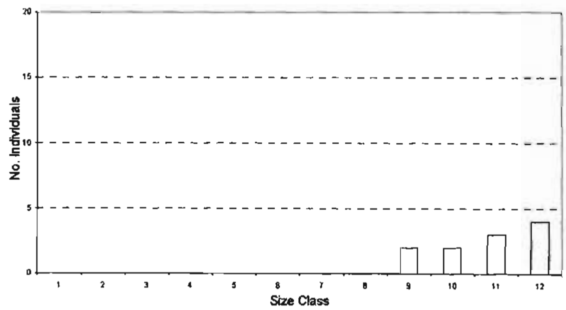

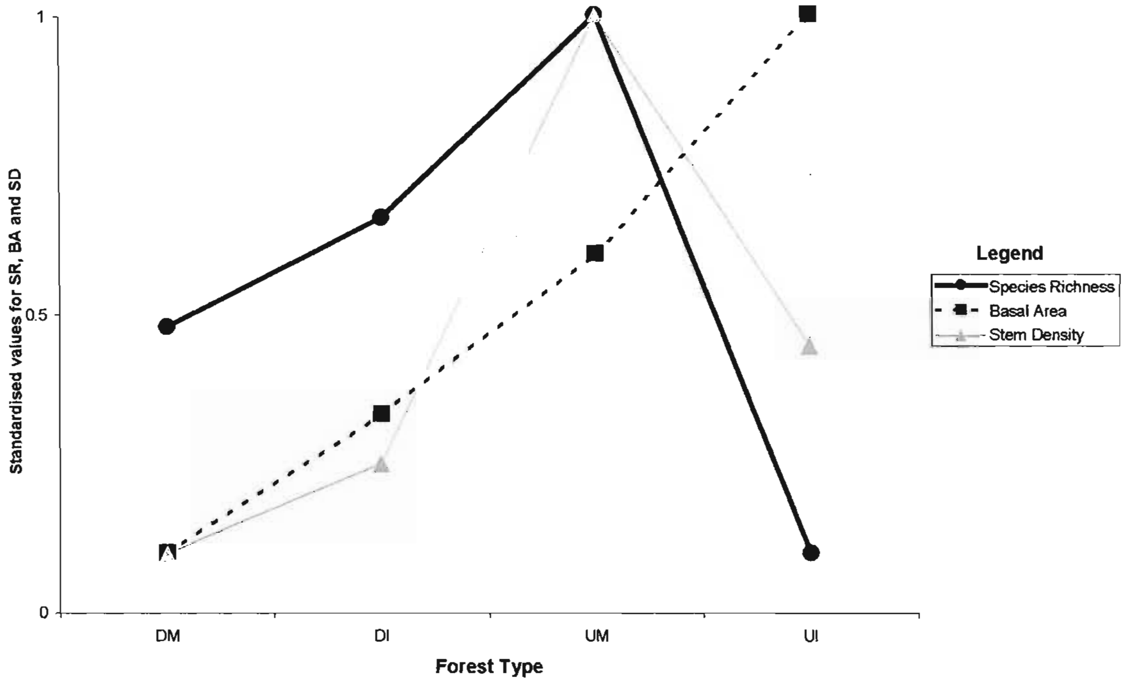

1
0.5
0
Standardised values for SR, BA and SD
DM
DI
UM
UI
Forest Type
Legend
Species Richness
Basal Area
Stem Density

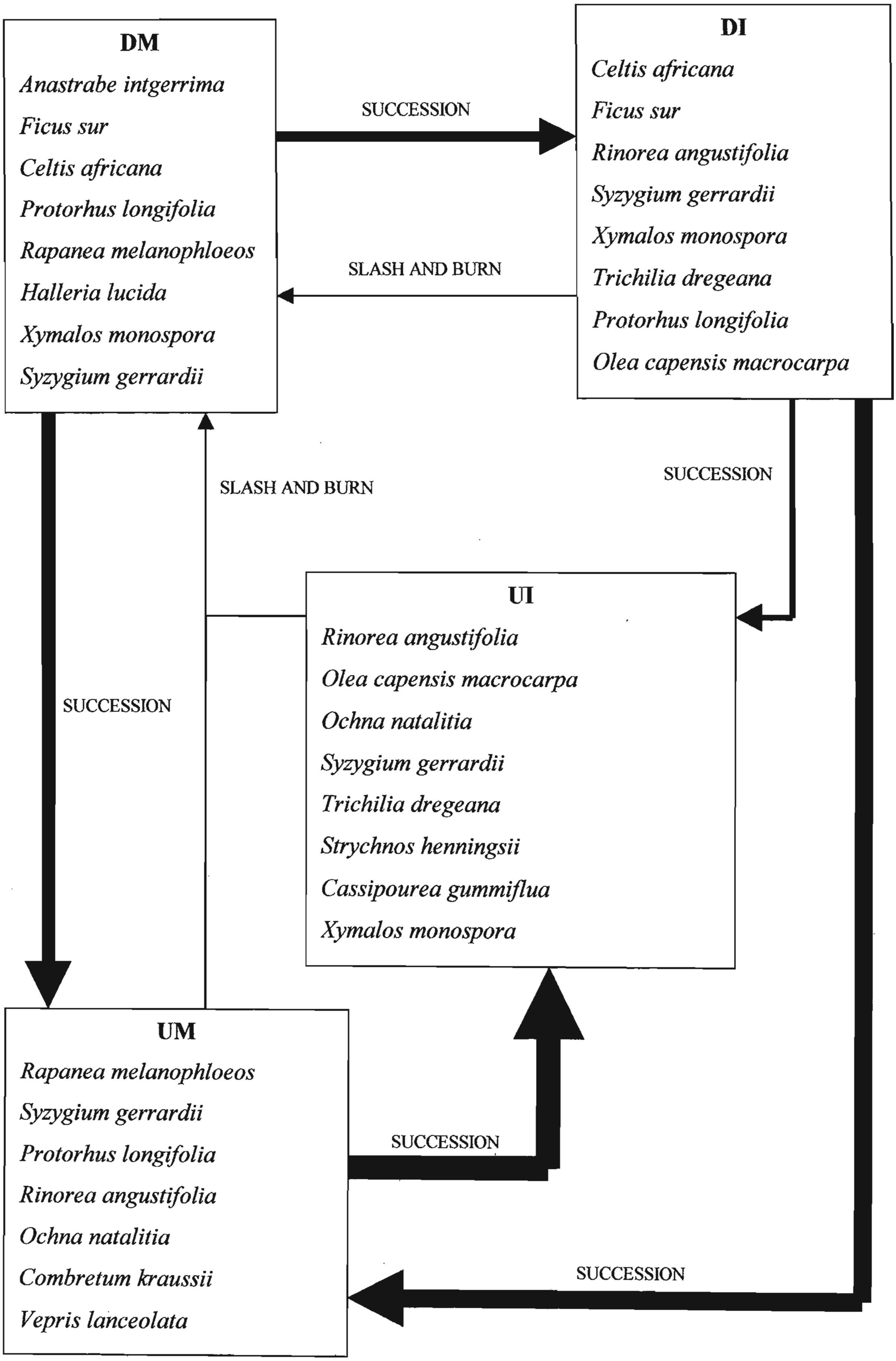
DM
Anastrabe intgerrima
Ficus sur
Celtis africana
Protorhus longifolia
Rapanea melanophloeos
Halleria lucida
Xymalos monospora
Syzygium gerrardii
SUCCESSION
SLASH AND BURN
DI
Celtis africana
Ficus sur
Rinorea angustifolia
Syzygium gerrardii
Xymalos monospora
Trichilia dregeana
Protorhus longifolia
Olea capensis macrocarpa
SLASH AND BURN
SUCCESSION
SUCCESSION
UI
Rinorea angustifolia
Olea capensis macrocarpa
Ochna natalitia
Syzygium gerrardii
Trichilia dregeana
Strychnos henningsii
Cassipourea gummiflua
Xymalos monospora
UM
Rapanea melanophloeos
Syzygium gerrardii
Protorhus longifolia
Rinorea angustifolia
Ochna natalitia
Combretum kraussii
Vepris lanceolata
SUCCESSION
SUCCESSION

Table 2.1 Species richness and diversity measures for the four different forest types sampled in the Nkandla forest complex.

	DM	DI	UM	UI
Species Richness				
n	17	13	10	8
Cumulative species no.	89	85	73	49
Jacknife-1	112	103	91	63
% Sampled	79	83	80	78
Diversity Indices				
N2	13.5	13.5	10.4	2.9
N1	15.3	16.1	16.1	5.8
Pielou's Evenness J'	0.89	0.89	0.84	0.63
Vegetative Character				
Species richness (mean/plot)	$21.6 \pm 3.9^{a,b}$	$23.8 \pm 5.3^{b,c}$	27.9 ± 6.5^{c}	17.0 ± 4.0^{a}
Basal Area (m^2/ha)	14.3 ± 6.3^{a}	$22.9 \pm 11.4^{a,b}$	$32.7 \pm 11.4^{b,c}$	47.4 ± 15.6^{c}
Stem Density (stems/ha)	2536 ± 821^{a}	2895 ± 1545^{a}	4684 ± 1006^{b}	$3368 \pm 703^{a,b}$
Canopy Cover (%)	84.7 ± 7.2^{a}	$90.0 \pm 6.1^{a,b}$	83.0 ± 6.0^{a}	96.0 ± 3.9^{b}
Canopy Height (m)	8.7 ± 1.3^{a}	$9.6 \pm 2.8^{a,b}$	10.0 ± 1.5^{b}	12.1 ± 1.3^{c}

DM = disturbed margin forest, DI = disturbed interior forest, UM = undisturbed margin forest, UI = undisturbed interior forest.
Means with letters in common are not significantly different ($P > 0.05$)

Table 2.2 Jaccard measures of association for the four forest types sampled in the Nkandla forest complex.

	DM	DI	UM	UI
DM	*	0.72	0.47	0.36
DI	*	*	0.57	0.46
UM	*	*	*	0.60
UI	*	*	*	*

DM = disturbed margin, DI = disturbed interior, UM = undisturbed margin, UI = undisturbed interior

Table 2.3 Species abundance values for the four different forest types sampled in the Nkandla forest complex.

Species RA	DM		DI		UM		UI	
	N	%	N	%	N	%	N	%
Infrequent, <1%	55	19	50	21	50	20	35	12
Occasional, 1.1 – 3%	25	49	28	45	13	22	11	20
Uncommon, 3.1 – 5%	7	20	6	24	6	22	1	4
Common, 5.1 – 7%	2	12	0	0	1	6	0	0
Abundant, 7.1 – 9%	0	0	0	0	1	8	1	7
Very Abundant, >9%	0	0	1	10	2	21	1	56
Total Species	89		85		73		49	
Total Individuals	933		840		872		825	

N= number of species, % = percentage of total number of individuals in the specified population
DM = disturbed margin, DI = disturbed interior, UM = undisturbed margin, UI = undisturbed interior

Table 3.1 Results of canonical correspondence analysis (CCA) for Nkandla forest complex species abundance data.

	Axis 1	**Axis 2**	**Axis 3**	**Axis 4**
Eigenvalues	0.507	0.195	0.148	0.083
Species environment correlations	0.969	0.880	0.850	0.828
Cumulative % variance species data	15.5	21.5	26.0	28.5
Cumulative % variance species-environment data	47.5	65.8	79.7	87.5

Table 3.2 Explained variance, Monte Carlo test statistics and inter-set correlations for the environmental variables of the Nkandla forest complex using canonical correspondence analysis.

Environmental Variable	Variance	F-ratio	p-value	Axis I*
Disturbance	0.43	6.98	0.005	0.863
Litter Cover	0.19	3.26	0.005	-0.811
Age*Disturbance	0.15	2.59	0.005	0.460
Herb Cover	0.09	1.70	0.005	0.791
Age	0.08	1.47	0.025	-0.610
Slope	0.07	1.20	0.095	0.552
Aspect	0.05	1.00	0.395	-0.675

*Inter set correlations with CCA axis I.

Table 3.3 Species response patterns along the disturbance gradient extracted using canonical correspondence analysis (CCA) for the Nkandla forest complex.

Pattern Type	**1**	**2a**	**2b**	**3**
Species				
Anastrabe intgerrima	*			
Celtis africana	*			
Ficus sur	*			
Maesa lanceolata	*			
Ochna natalitia		*		
Olea capensis macrocarpa		*		
Protorhus longifolia				*
Rapanea melanophloeos				*
Rinorea angustifolia		*		
Strychnos henningsii			*	
Syzygium gerrardii				*

Notes:

Pattern 1: High abundance in disturbed areas decreasing to nil in undisturbed areas.

Pattern 2a: Low abundance in disturbed areas increasing continually towards undisturbed areas.

Patterns2b: Low abundance in disturbed areas increasing towards undisturbed areas and stabilising.

Pattern 3: Unimodal, with a maximum occurring towards the midpoint of the disturbance axis.

Table 3.4 Site preference of selected species based on canonical correspondence analysis (CCA) for the Nkandla forest complex.

Disturbed sites	**Undisturbed sites**
Anastrabe intgerrima	*Olea capensis* subsp. *macrocarpa*
Ficus sur	*Ochna natalitia*
Celtis africana	*Ochna arborea*
Maesa lanceolata	*Strychnos henningsii*
Halleria lucida	*Rinorea angustifolia*
Grewia occidentalis	

Table 3.5 Composition and density of seedlings recorded in the forest types surveyed in the Nkandla forest complex. Table values are stems/ha per plot. Shrubs and climbers were excluded.

Forest Type	DM	DI	UM	UI	Notes*
Allophylus dregeanus	48	48	25	50	
Anastrabe intgerrima	25	0	0	0	1
Andrachne ovalis	75	25	0	0	
Atalaya natalensis	100	50	138	332	
Bersama tysonii	50	25	25	38	
Brachylaena discolor	25	25	50	38	
Burchellia bubalina	25	0	0	0	
Canthium inerme	50	55	75	91	
Cassipourea gerrardii	0	100	81	136	
C. gummiflua	50	55	25	42	4
Celtis africana	152	116	75	25	1,2
Clausena anisata	30	31	100	25	
Combretum kraussii	29	25	38	0	1,3,4
Croton sylvaticus	25	25	0	0	1,2
Cryptocarya myrtifolia	33	275	89	125	
Curtisia dentata	25	38	0	0	1
Cussonia sphaerocephala	50	0	0	0	
Dais cotinifolia	58	50	0	0	
Dombeya tiliacea	156	50	0	100	
Drypetes gerrardii	44	95	38	54	
Duvernoia adhatodoides	0	42	0	100	2
Ekebergia capensis	54	29	0	0	
Englerophytum natalense	178	283	50	56	
Eugenia zuluensis	0	0	0	75	
Faurea saligna	0	0	25	0	
Ficus sur	75	142	0	0	1,2
Grewia occidentalis	108	25	0	0	
Halleria lucida	25	0	0	0	1
Harpephyllum caffrum	25	0	0	0	2
Heteropyxis natalensis	100	25	0	0	
Kiggelaria africana	0	25	0	0	
Macaranga capensis	25	0	0	0	
Mackaya bella	133	75	105	100	
Maesa lanceolata	50	25	25	0	
Micrococca capensis	0	0	50	0	
Mimusops obovata	25	25	0	25	
Ochna arborea	0	50	30	50	
O. natalitia	42	150	172	106	3,4
Olea capensis subsp. *macrocarpa*	30	125	135	110	4
Oricia bachmannii	25	131	75	63	

Oxyanthus speciosus subsp. *gerrardii*	0	38	0	163	
Peddiea africana	109	50	139	100	3
Podocarpus henkelii	25	0	0	0	
P. latifolus	0	0	25	0	
Protorhus longifolia	61	63	225	63	1,3
Ptaeroxylon obliquum	118	25	25	250	
Rapanea melanophloeos	159	55	168	25	1,3
Rauvolfia caffra	25	0	0	0	
Rhus chirindensis	25	50	0	0	
Rinorea angustifolia	75	539	917	1846	2,3,4
Rothmannia globosa	42	113	69	429	3
Scolopia mundii	25	33	0	0	
S. zeyheri	0	50	33	25	
Senna pendula	163	25	0	0	
Strychnos henningsii	25	25	35	0	3,4
Syzygium cordatum	38	25	0	0	
S. gerrardii	136	53	145	38	2,3,4
Tricalysia lanceolata	133	25	0	0	
T. sonderiana	0	50	33	169	2
Trichilia dregeana	33	25	0	0	2,4
Trimeria grandifolia	50	25	0	0	
Vepris lanceolata	50	50	42	25	3
Xymalos monospora	157	54	0	0	2
Zanthoxylum davyi	25	25	150	25	
Density of seedlings stems/ha	2153	2177	2581	4680	
Number of species	53	52	34	34	

Notes:

* Numbers reflect dominance as a tree in forest types 1=DM, 2=DI, 3=UM and 4=UI based on top 10 trees in each forest type by importance values (Appendix 3).

Table 3.6 Composition and density of saplings recorded in the forest types surveyed in the Nkandla forest complex. Table values are stems/ha per plot. Shrubs and climbers were excluded.

Forest Type	DM	DI	UM	UI	Notes*
Species					
Allophylus dregeanus	43	15	12	0	
Anastrabe intgerrima	31	10	0	0	1
Andrachne ovalis	1	2	0	0	
Atalaya natalensis	1	6	8	0	
Baphia racemosa	1	0	0	0	
Bersama tysonii	0	0	49	8	
Brachylaena discolor	1	2	5	0	
Bridelia micrantha	3	6	0	0	1
Burchellia bubalina	0	2	0	0	
Canthium inerme	35	19	29	0	
Casearia gladiiformis	0	0	0	3	
Cassipourea gerrardii	0	6	35	13	
C. gummiflua	22	19	54	15	4
Celtis africana	38	13	0	0	1,2
Chrysophyllum viridifolium	0	6	0	0	
Clausena anisata	3	2	12	0	
Combretum kraussii	19	6	40	0	1,2,4
Commiphora woodii	13	4	0	0	
Croton sylvaticus	6	8	11	0	1,2
Cryptocarya myrtifolia	18	8	28	3	
Curtisia dentata	7	2	0	0	1
Cussonia sphaerocephala	4	0	0	0	
C. spicata	0	2	0	0	
Dais cotinifolia	4	4	13	0	
Dombeya tiliacea	25	23	0	0	
Drypetes gerrardii	1	10	11	10	
Duvernoia adhatodoides	0	48	13	3	2
Ekebergia capensis	6	10	0	0	
Englerophytum natalense	9	60	11	15	
Faurea saligna	0	0	5	0	
Ficus ingens	1	0	0	0	
Ficus sur	3	6	0	0	1,2
Grewia occidentalis	15	21	6	0	
Halleria lucida	1	6	0	0	1
Harpephyllum caffrum	3	6	0	0	2
Heteropyxis natalensis	6	4	0	0	
Homalium dentatum	0	0	6	0	4
Macaranga capensis	4	0	0	0	
Mackaya bella	22	6	23	0	

Maesa lanceolata	6	12	0	0	
Micrococca capensis	0	13	39	5	
Mimusops obovata	4	6	0	0	
Ochna arborea	0	0	0	3	
O. natalitia	4	2	44	8	3,4
Olea capensis subsp. *macrocarpa*	7	23	16	3	4
Oricia bachmannii	4	12	6	0	
Oxyanthus speciosus subsp. *gerrardii*	4	6	5	5	
Peddiea africana	13	4	70	0	3
Podocarpus henkelii	1	2	0	0	
P. latifolus	0	0	7	0	
Protorhus longifolia	29	35	60	0	1,3
Ptaeroxylon obliquum	6	2	10	0	
Rapanea melanophloeos	31	15	65	0	1,3
Rhus chirindensis	3	13	15	0	
Rhus pyroides	3	0	0	0	
Rinorea angustifolia	10	148	45	560	2,3,4
Rothmannia globosa	12	40	36	0	3
Scolopia mundii	10	13	0	0	
Scolopia zeyheri	0	0	22	0	
Senna pendula	7	2	0	0	
Strychnos henningsii	0	10	37	20	2,4
Syzygium cordatum	4	2	0	0	
S. gerrardii	40	42	59	3	2,3,4
Tricalysia capensis	0	0	7	0	
T. lanceolata	12	0	5	0	
T. sonderiana	3	13	35	5	2
Trichilia dregeana	3	8	0	0	2,4
Trimeria grandifolia	9	19	13	0	
Vepris lanceolata	1	0	37	0	3
Xymalos monospora	46	31	3	0	2
Zanthoxylum davyi	1	0	9	0	
Density of saplings stems/ha	810	987	1379	740	
Number of species	56	55	42	17	

Notes:
* Numbers reflect dominance as a tree in forest types 1=DM, 2=DI, 3=UM and 4=UI based on top 10 trees in each forest type by importance values (Appendix 3).

Table 4.1 Change in population numbers, homesteads and homestead densities from 1937 to 1996 in the Nkandla Magisterial District, unless otherwise stated.

Year	1936	1996
Total population[1]	44 420	134 308
Homesteads[2]	196	266
Area[3] (km²)	114	114
Density (homesteads/km²)	1.72	2.33
Change (%)		36

[1] Source: Statistics South Africa
[2] Total number of homesteads within 2km of the Nkandla forest complex.
[3] Area enclosed by 2km buffer surrounding Nkandla forest complex.

Table 4.2 Commonly harvested woody species of the Nkandla forest complex and their Zulu names and uses

Species	Zulu Name[1]	Use[2]
Ochna natalitia	umBovane	BM
Ochna arborea	umThelelo	BM
Strychnos henningsii	umQalothi	BM/CW
Drypetes gerrardii	umHlwakela	BM/CW
Harpephyllum caffrum	umGwenya	MP/CW
Rapanea melanophloeos	umaPhipha	MP
Curtisia dentata	Gejalibomvu	MP
Protorhus longifolia	isiFico	MP
Cassipourea gummiflua	umHlalamagwababa	MP
Olea capensis macrocarpa	umZimane	MP
Croton sylvaticus	amaHlabakufeni	MP
Cryptocarya myrtifolia	umNqabe	MP
Ptaeroxylon obliquum	umThathe	MP
Cassipourea gerrardii	uMemezi	MP

[1]Zulu names used by field assistants at Nkandla forest complex during data collection.
[2]Uses based on interviews with field assistants, local inhabitants and KZNNCS field rangers
BM = building material, CW = craftwork, MP = medicinal plant

Appendix 1: Plot details for each of the 48 sample plots showing forest type, physical attributes and disturbance history surveyed in the Nkandla forest complex.

Plot No.	Location	Forest	Dist Edge	Slope	Aspect	Clear cut	Cultivated
1	1	DM	5	25	S	Y	N
2	1	DI	80	45	S	Y	N
3	1	DM	5	25	S	Y	N
4	1	DM	10	30	E	Y	N
5	1	DM	10	30	E	Y	N
6	1	DI	180	35	S	Y	N
7	2	DM	5	45	W	Y	N
8	2	DM	30	30	W	Y	N
9	2	DI	150	25	S	Y	N
10	2	DI	250	30	E	Y	N
11	2	DI	150	30	S	Y	N
12	2	DM	10	45	S	Y	N
13	3	DM	40	30	S	Y	Y
14	3	DI	120	30	S	Y	Y
15	3	DM	50	45	S	Y	Y
16	3	DM	10	30	S	Y	Y
17	3	DI	60	30	S	Y	Y
18	4	DI	100	30	S	Y	Y
19	4	DI	150	45	S	Y	Y
20	4	DI	250	45	S	Y	Y
21	4	DI	400	45	S	Y	N
22	4	DM	10	3	S	Y	Y
23	4	DM	40	15	S	Y	Y
24	4	DM	10	15	S	Y	Y
25	4	DM	20	45	S	Y	Y
26	4	DI	125	30	S	Y	Y
27	4	DM	10	20	S	Y	Y
28	4	DM	10	20	S	Y	Y
29	5	DM	10	30	S	Y	N
30	5	DI	100	25	S	Y	N
31	5	UI	200	10	S	N	N
32	6	UI	180	0	S	N	N
33	6	UI	250	0	S	N	N
34	6	UI	300	0	S	N	N
35	6	UI	300	5	E	N	N
36	7	UI	100	10	E	N	N
37	7	UI	150	20	E	N	N
38	7	UI	200	20	W	N	N
39	7	UI	400	2	W	N	N
40	7	UI	400	5	N	N	N
41	7	UM	20	10	W	N	N
42	7	UM	10	15	S	N	N
43	7	UM	10	10	S	N	N
44	7	UM	10	35	N	N	N
45	7	UM	10	10	N	N	N
46	8	UM	10	5	N	N	N
47	9	UM	10	5	W	N	N
48	10	UM	10	20	E	N	N

Appendix 2: Species list for all woody species sampled in the four forest types in the Nkandla forest complex.

SA No.	Scientific Name	English Name	Zulu Name
160	*Acacia ataxacantha*	Flame thorn	uBobe
0	*Acridocarpus natalitius*	Moth-fruit	umaBhopa
424	*Allophylus dregeanus*	Forest False Currant	
671	*Anastrabe intgerrima*	Pambati Tree	isiPhampatho
305	*Andrachne ovalis*	False Lightning Bush	
429	*Atalaya natalensis*	Natal Krantz Ash	uSimanaye
121	*Bachmannia woodii*	Four-finger Bush	
224	*Baphia racemosa*	Natal Camwood	isiFithi
443	*Bersama tysonii*	Common White Ash	iNdiyaza
724	*Brachylaena discolor*	Coast Silver Oak	iPhahla
324	*Bridelia micrantha*	Coastal Goldenleaf	umHlahle
688	*Burchellia bubalina*	Wild Pomegranate	
219	*Calpurnia aurea*	Natal Laburnum	umPhekembhetu
709	*Canthium ciliatum*	Dwarf Turkey-berry	
708	*C. inerme*	Common Turkey-berry	
640.1	*Carissa bispinosa*	Forest Num-num	iMambaeluhlaza
512	*Casearia gladiiformis*	Sword-leaf	umLolo
415	*Cassine papillosa*	Common Saffron	isiNama
414	*C. peragua*	Cape Saffron	iKhukhuza
529	*Cassipourea gerrardii*	Common Onionwood	uQongqo
530	*C. gummiflua*	Large-leaved Onionwood	umHlalamagwababa
39	*Celtis africana*	White Stinkwood	umVuvu
43	*Chaetachme aristata*	Thorny Elm	
580	*Chrysophyllum viridifolium*	Fluted Milkwood	uMemezi
0	*Citrus limon*	Lemon	
265	*Clausena anisata*	Horsewood	umSanka
667	*Clerodendrum glabrum*	Tinderwood	umQaqonqo
0	*Clutia pulchella*	Warty-fruited Clutia	
147.1	*Cnestis polyphylla*	Itch-Pod	iHlozi
540	*Combretum kraussii*	Forest Bushwillow	umDubu
291	*Commiphora woodii*	Forest Corkwood	uMumbu
330	*Croton sylvaticus*	Forest Fever-berry	amaHlabakufeni
115	*Cryptocarya myrtifolia*	Myrtle Quince	umNqabe
570	*Curtisia dentata*	Assegaai	Gejalibomvu
564.2	*Cussonia sphaerocephala*	Natal Forest Cabbage Tree	umSenge wehlati
564	*C. spicata*	Common Cabbage Tree	umSenge
521	*Dais cotinifolia*	Pompon Tree	Uzi

SA No.	Scientific Name	English Name	Zulu Name
231	*Dalbergia armata*	Thorny Rope	umHluhluwe
235	*Dalbergia obovata*	Climbing Flat-bean	umZungulu
609	*Diospyros simii*	Climbing Star-apple	umNqandane
611	*D. whyteana*	Bladder-nut	
472	*Dombeya tiliacea*	Wild Pear	iBunda
509	*Dovyalis rhamnoides*	Common Sourberry	umNyuswa
314	*Drypetes gerrardii*	Forest Ironplum	umHlwakela
681	*Duvernoia adhatodoides*	Pistol Bush	uZilwayo
298	*Ekebergia capensis*	Cape Ash	umNyamathi
582	*Englerophytum natalense*	Natal Milkplum	umThongwane
245	*Erythrina lysistemon*	Common Coral Tree	umSinsi
250	*Erythroxylum pictum*	Forest Coca Tree	
553.2	*Eugenia natalitia*	Common Forest Myrtle	
554	*E. zuluensis*	Paper-bark Myrtle	umThintane
75	*Faurea saligna*	Transvaal Beech	isiSefu
55	*Ficus ingens*	Red-leaved Rock Fig	umGonswane
50	*F. sur*	Broom Cluster Fig	umKhiwane
463	*Grewia occidentalis*	Cross-berry	iKlolo
670	*Halleria lucida*	Tree Fuchsia	Nondomela
361	*Harpephyllum caffrum*	Wild Plum	umGwenya
455	*Heteropyxis natalensis*	Lavender Tree	mKluzwa
501	*Homalium dentatum*	Brown Ironwood	inDlulamithi
690	*Hyperacanthus amoenus*	Spiny Gardenia	uBhembhetu
225.6	*Indigofera natalensis*	Forest Indigo	iNsiphane
494	*Kiggelaria africana*	Wild Peach	uSahlulamanye
335	*Macaranga capensis*	Wild Poplar	umPhumelele
681.1	*Mackaya bella*	River Bells	uZwathi
577	*Maesa lanceolata*	False Assegai	iNdende
399	*Maytenus heterophylla*	Common Spike-thorn	uSala
399.2	*M. mossambicensis*	Black Forest Spike-thorn	iNgqwangane-yehlati
401	*M. peduncularis*	Cape Blackwood	umNqayi
332.2	*Micrococca capensis*	Common Bead-string	
584	*Mimusops obovata*	Red Milkwood	aMasethole
107.1	*Monanthotaxis caffra*	Dwaba-berry	uMazwenda
633	*Nuxia congesta*	Common Wild Elder	isiPhofane
479	*Ochna arborea*	Cape Plane	umThelelo
481	*O. natalitia*	Natal Plane	umBovane
618.2	*Olea capensis macrocarpa*	Ironwood	umZimane
257	*Oricia bachmannii*	Twin-berry Tree	umBozane
696	*Oxyanthus speciosus gerrardii*	Wild Loquat	isiBinda

SA No.	Scientific Name	English Name	Zulu Name
718	*Pavetta inandensis*	Forest Bride's Bush	
719	*P. natalensis*	Natal Bride's Bush	
517	*Peddiea africana*	Poison Olive	imBondwe
715	*Plectroniella armata*	False Turkey-berry	
17	*Podocarpus henkelii*	Henkel's Yellowwood	umKhoba
18	*P. latifolus*	Real Yellowwood	umSonti
364	*Protorhus longifolia*	Red Beech	isiFico
147	*Prunus africana*	Red Stinkwood	unYazangoma
292	*Ptaeroxylon obliquum*	Sneezewood	umThathe
578	*Rapanea melanophloeos*	Cape Beech	umaPhipha
647	*Rauvolfia caffra*	Quinine Tree	umHlambamanzi
491	*Rawsonia lucida*	Forest Peach	umGudlangulube
456.4	*Rhoicissus rhomboidea*	Glossy Forest Grape	umThwazi
380	*Rhus chirindensis*	Red currant	umDwendwelencuba
392	*R. pyroides*	Common Wild Currant	iNhlokoshiyane
489	*Rinorea angustifolia*	White Violet-bush	iThwakela
695	*Rothmannia globosa*	September Bells	isiGcatha-inkobe
496	*Scolopia mundii*	Red Pear	iHlambahlale
498	*S. zeyheri*	Thorn Pear	umQokolo
451	*Scutia myrtina*	Cat-thorn	
0	*Senna pendula*		iKhohlokhohlo
367	*Smodingium argutum*	African Poison Oak	umHlalamvubu
0	*Solanum mauritianum*	Bugweed	Bhongabhonga
625	*Strychnos henningsii*	Natal Teak	umQalothi
555	*Syzygium cordatum*	Water Berry	umDoni
556	*S. gerrardii*	Forest Water Berry	umDoni-wehlati
42	*Trema orientalis*	Pigeonwood	umBhangazi
699	*Tricalysia lanceolata*	Jackal-coffee	
700	*T. sonderiana*	Coast Coffee	iSanwane
300	*Trichilia dregeana*	Forest Mahogany	umKhuhlu
503	*Trimeria grandifolia*	Wild Mulberry	iDlebelendlovu
261	*Vepris lanceolata*	White Ironwood	
111	*Xymalos monospora*	Lemonwood	uHlwehlwe
254	*Zanthoxylum davyi*	Forest Knobwood	umNungumabele
447	*Ziziphus mucronata*	Buffalo-thorn	umPhafa
0	Species A		umSulumbuzi
0	Species B		isiBangamlotha
0	Species C		
0	Species D		
0	Species E		

Appendix 3: Contrasting dominance of the major species in each of the four forest types in the Nkandla forest complex by importance values.

DM		DI		UM		UI	
Species Name	**IV**	**Species Name**	**IV**	**Species Name**	**IV**	**Species Name**	**IV**
Anastrabe intgerrima	15.72	*Celtis africana*	21.98	*Rapanea melanophloeos*	30.32	*Rinorea angustifolia*	80.93
Ficus sur	15.03	*Ficus sur*	15.23	*Syzygium gerrardii*	21.51	*Olea capensis macrocarpa*	22.42
Bridelia micrantha	13.28	*Rinorea angustifolia*	13.86	*Protorhus longifolia*	17.32	*Ochna natalitia*	17.83
Celtis africana	13.25	*Harpephyllum caffrum*	11.86	*Combretum kraussii*	14.38	*Syzygium gerrardii*	14.66
Protorhus longifolia	11.54	*Croton sylvaticus*	11.26	*Rinorea angustifolia*	14.09	*Trichilia dregeana*	13.24
Combretum kraussii	10.27	*Trichilia dregeana*	10.90	*Ochna natalitia*	12.19	*Homalium dentatum*	12.82
Rapanea melanophloeos	10.15	*Syzygium gerrardii*	8.86	*Vepris lanceolata*	11.52	*Strychnos henningsii*	11.41
Curtisia dentata	9.32	*Duvernoia adhatodoides*	8.79	*Peddiea africana*	8.85	*Cassipourea gummiflua*	8.39
Halleria lucida	8.96	*Tricalysia sonderiana*	8.34	*Strychnos henningsii*	8.31	*Hyperacanthus amoenus*	8.21
Croton sylvaticus	7.8	*Xymalos monospora*	8.31	*Rothmannia globosa*	7.96	*Combretum kraussii*	7.84
Allophylus dregeanus	7.62	*Protorhus longifolia*	7.09	*Cassipourea gummiflua*	7.48	*Cassipourea gerrardii*	7.61
Cassipourea gummiflua	7.54	*Englerophytum natalense*	7.02	*Scolopia zeyheri*	6.3	*Ochna arborea*	6.38
Xymalos monospora	7.34	*Allophylus dregeanus*	6.77	*Hyperacanthus amoenus*	6.14	*Xymalos monospora*	6.24
Canthium inerme	7.18	*Olea capensis macrocarpa*	6.08	*Olea capensis macrocarpa*	6.11	*Rothmannia globosa*	6.05
Acacia ataxacantha	7.15	*Trimeria grandifolia*	5.20	*Nuxia congesta*	5.28	*Brachylaena discolor*	5.65
Macaranga capensis	6.9	*Clerodendrum glabrum*	5.07	*Cryptocarya myrtifolia*	5.26	*Nuxia congesta*	4.93
Dalbergia armata	6.66	*Dalbergia obovata*	4.95	*Atalaya natalensis*	5.17	*Vepris lanceolata*	4.34
Harpephyllum caffrum	6.61	*Rothmannia globosa*	4.76	*Croton sylvaticus*	5.08	*Englerophytum natalense*	4.23
Syzygium gerrardii	5.6	*Grewia occidentalis*	4.56	*Canthium inerme*	4.8	*Protorhus longifolia*	4.14
Prunus africana	5.58	*Canthium inerme*	4.49	*Mackaya bella*	4.59	*Atalaya natalensis*	4.06