Effects of pine afforestation on native biota and conservation evaluation of afforestable grasslands in montane areas of South Africa

by

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Pectora roborant cultus recti

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Declaration

I the undersigned hereby declare that the work contained in this dissertation is my own original work and has not previously in its entirety or in part been submitted at any university for a degree.

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Summary

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Pine (*Pinus* spp.) afforestation generally results in a reduction in the species richness of the native biotic assemblages and in the abundance of species of the original habitat. The biotic assemblage changes in the planted area with the aging of the pines, the bird assemblage from one dominated by species of the original habitat to another dominated by those of a wooded habitat. Wooded-habitat specialists, however, are not generally found in pine plantations. Recovery of the animal and plant assemblages after clearfelling may take many years in the fynbos biome.

Vertebrate-mediated pollination appears to be disrupted in pine plantations. Plants pollinated by vertebrates and their bird and rodent pollinators are scarce in, or absent from, mature plantations. The proportion of plant species with seeds dispersed by vertebrates increases under plantations, probably due to the pines providing perches for avian frugivores. Native habitat remnants surrounded by pine plantations should be considered as "islands" in an "inhospitable sea", and managed to maintain their biotic complements and ecological processes.

Large-scale afforestation with pines is occurring in high rainfall montane grasslands. Evaluations of these grasslands for wildlife conservation prior to afforestation have not been done. Grasshoppers, butterflies, birds and small mammals are some key taxa to sample in montane grasslands. Sampling of these four taxa along a gradient of land types was found to be a suitable methodology for a single researcher in conservation evaluations of these grasslands. The land types were defined by altitude, geology and rainfall. Sampling was done at five sites, determined by aspect and topography, on each land type, on four days at each site.

Differences in conservation value between land types and between sampling site types in the Maclear district were demonstrated, but rankings differed according to the criterion used. High-altitude land types and low-altitude *Protea* savanna were most valuable for conserving endemic species. Low-altitude land types with a Molteno sandstone lithology and a high-altitude land type with a Clarens sandstone lithology had the highest conservation values for total numbers of grasshopper genera and species of butterflies and birds.

North slopes and crests were important for grasshoppers, valleys and north slopes for butterflies, and valleys and south slopes for small mammals in the district. Taxon richness "hotspots" were not coincident at both the land type and sampling site scales. Nor were the taxon richness and endemicity "hotspots" coincident at the larger scale.

Adequately-large areas of all the land types are required to protect the complement of species of all taxa in the afforestable part of the Maclear district. However, incidental observations indicated that a set of five land types may be sufficient. Substituting the high-altitude, low rainfall, basalt land type for the low-altitude, high rainfall, Molteno sandstone one in this set would protect all the montane endemic species. Most of the afforested farms

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had high or medium predicted conservation values before afforestation. Nature reserves, necessary for the long-term survival of larger species and some endemics in afforestable regions, should be determined before afforestation begins. Indication of which parts of the Maclear district are most suitable for reservation are given.

Oor die algemeen veroorsaak bebossing met denne (*Pinus* spp.) 'n afname in spesierykheid van die natuurlike biota sowel as 'n afname in die volopheid van spesies van die oorspronklike habitat. Met die veroudering van denne-opstande verander die samestelling van die biotiese groepe binne 'n vak, byvoorbeeld die voëls van die oorspronklike habitat word met dié wat beboste areas oorheers, vervang. Boshabitat-spesialiste kom oor die algemeen egter nie in denneplantasies voor nie. In die fynbosbioom kan die hervestiging van dier- en plantgroepe na kaalkap etlike jare neem.

Bestuiwing deur werweldiere word blykbaar in denneplantasies ontwrig. Plante wat deur werweldiere bestuif word, sowel as hulle voël- en knaagdier-bestuiwers, is òf skaars òf afwesig in volwasse plantasies. Plantspesies met sade wat deur werweldiere versprei word, kom proporsioneel meer in plantasies voor, waarskynlik as gevolg van denneboomtakke wat as sitplekke vir vrugtevretende voëls dien. Oorblyfsels van natuurlike habitat wat deur denneplantasies omring is, behoort as "eilande" in 'n "onherbergsame see" beskou te word. Hulle behoort bestuur te word met die oog op die behoud van hulle biotiese komponente en ekologiese prosesse.

Grootskaalse bebossing met denne geskied tans hoofsaaklik in bergagtige gebiede met hoë reënval. Tot dusver is daar nog geen pogings aangewend om hierdie graslande voor bebossing vir natuurbewaring te evalueer nie. Sprinkane, skoenlappers, voëls en klein soogdiere kan as sleuteltaksa gebruik word om berggraslande te bemonster. Daar is gevind dat bemonstering van dié vier taxa oor 'n gradiënt van landtipes 'n geskikte metode is vir 'n enkele navorser om bewaringsevaluerings in hierdie graslande uit te voer. Die landtipes is volgens hoogte bo seespeël, geologie en reënval gedefinieer. Vyf terreine, bepaal volgens aspek en topografie, is vir vier dae op elke landtipe ondersoek.

Verskille in bewaringsstatus tussen landtipes en tussen mosters van terreintipes in die Maclear distrik is vasgestel, maar die rangordes verskil volgens die kriterium wat gebruik is. Hoogliggende landtipes en laagliggende *Protea*-savanna is die waardevolste vir die bewaring van endemiese spesies. Laagliggende landtipes met Molteno-sandsteen litologie en 'n hoogliggende landtipe met Clarens-sandsteen litologie het die hoogste bewaringswaarde gemeet aan die geheelgetalle van sprinkaangenera en van skoenlapper- en voëlspesies.

In hierdie gebied is noordelike hellings en heuwelkruine belangrik vir sprinkane, valleie en noordelike hellings vir skoenlappers en valleie en suidelike hellings vir klein soogdiere.

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Sentra van taksonrykheid het nie ooreengestem op die skale van sowel landtipes en bemonsteringspersele nie. Sentra van taksonrykheid en van hoë endemisiteit het ook nie ooreengestem op die groter skaal nie.

Areas van voldoende grootte van alle landtipes sal nodig wees om die spesies van alle taksa wat in die bebosbare dele van die Maclear distrik voorkom, te beskerm. Toevallige waarnemings dui daarop dat die reservering van 'n stel van die vyf landtipes voldoende behoort te wees. As die laagliggende, Molteno-sandsteen met hoë reënval-landtipe met die hoogliggende, basalt-landtipe met lae reënval in hierdie stel vervang word, sal alle spesies endemies tot bergagtige gebiede beskerm word. Die studie voorspel dat die meerderheid van die beboste plase in die gebied, 'n hoë tot medium bewaringstatus voor bebossing getoon het. Die plasing van natuurreservate, noodsaaklik vir die langtermyn oorlewing van groter, en van sommige endemiese, spesies in bebosbare gebiede, behoort voor die aanvang van bebossing bepaal te word. Aanduidings word gegee van dié dele in die Macleardistrik wat die mees geskik is vir reservering.

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Introduction

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South Africa had nearly 1.4 million hectares of commercially afforested land in 1994 (Department of Water Affairs and Forestry 1995*a*). The strategic development plan for forestry in South Africa includes the afforestation of approximately 1 million hectares with exotic trees over the next 25 years (van der Zel 1989). Plantations are necessary to supply the forestry product requirements of South Africa since natural forests cannot do so. A minimum of 300 000 ha of new afforestation are required before the year 2010 in order to meet projected demands. Commercial forestry products are major foreign revenue earners for South Africa, earning R 2.6 billion in foreign exchange in 1993, and commercial forestry is a rapidly developing industry (van der Zel 1989; FOA 1994). Just over half the total afforested area is planted with *Pinus* species (softwoods); the hardwoods are predominantly eucalypts (Department of Water Affairs and Forestry 1995*a*).

There has been much concern about the extent of, and continuing expansion of, commercial afforestation in South Africa, as well as the invasion of native habitats by trees from plantations (eg. Jacot Guillardmod 1980; Erskine 1990; Clark 1991). This has led to debate about the impact of commercial afforestation on the environment in the popular media (Johns 1993; Cellier 1994; Meter *et al.* 1994; McAllister 1995; Scotcher 1995). However, few scientific studies have focused on impacts of afforestation on the environment and indigenous biota in South Africa. The impact of commercial forestry on other major foreign currency earning industries is unknown. For example, foreign tourists spent approximately R 7 billion in South Africa in 1994. The top two attractions to visitors were scenery and wildlife (Satour 1995*a*, *b*). Pine afforestation is concentrated in the high rainfall, mountainous, and therefore scenic, areas of South Africa.

Plantations of exotic trees have a negative impact on the species richness and abundance of the indigenous biota present before afforestation (Chapters 1 to 4). Commercial forestry practice and the resulting dominance of the cultivated trees renders plantations unsuitable habitat for many indigenous plants and animals. Part of the strategic development plan is to ensure that the protection of the environment and the creation of nature reserves is not affected adversely by activities within the forestry industry (van der Zel 1989). Promotion of nature conservation and protection of existing indigenous forests and trees are objectives of the plan.

Large-scale afforestation in South Africa has not been preceded by conservation evaluations. Until 1995, there were no legal restrictions on the issuing of afforestation permits that pertained to wildlife conservation. This state of affairs has only recently changed with a directive from the Minister of Water Affairs and Forestry that makes environmental impact assessments mandatory where valid objections to the issuing of an afforestation permit for a particular piece of land are received (Department of Water Affairs and Forestry 1995*b*).

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New afforestation has been concentrated in the Grassland Biome, especially in Afromontane grasslands because of the high rainfall and suitable soils (Rutherford & Westfall 1986; van der Zel 1989; Department of Water Affairs and Forestry 1995*a*). Altogether 2.7% of the biome has been afforested (Kruger *et al.* 1995). There are relatively many plant and animal species endemic to this biome (Dirsh 1956; Hilliard & Burtt 1987; Siegfried 1992; Matthews *et al.* 1993; Pringle *et al.* 1994). Yet many of these grasslands are poorly known biologically and only 2 % of the biome is protected in the nature reserve system (Siegfried 1989).

Nature conservation areas within a potentially afforestable region should be determined before afforestation. Decision-making by provincial conservation authorities on the acceptability of recommendations for the issue of particular afforestation permits by the Department of Environmental Affairs and Forestry has been committee-based without the aid of formal criteria (Bosch & von Gadow 1990). Conservation authorities have little time in which to evaluate recommendations and large areas of land are sometimes involved.

Delays in the issue of afforestation permits, on the other hand, can have far-reaching consequences for both South Africa's economy and the supply of vital wood-based products such as paper. Insufficient timber may mean shortages of paper and fuelwood, with increased harvest of indigenous trees as a consequence.

Therefore, rapid and efficient methods of assessing the conservation value of areas that could be subject to afforestation need to be developed. An optimal combination of land uses is required for the efficient utilization of available land (eg. Thomas 1979). The most important areas for each land use within a designated region should be identified. This would enable optimisation of the division of available land between the various land-uses. The areas that should be set aside for nature conservation can then be decided upon. This will ensure that the nature conservation objectives of the strategic forestry development plan are reached.

The Afromontane region was selected as a priority for conservation attention by the World Wide Fund for Nature (Hamilton 1992). The present study focuses on pine afforestation in Afromontane areas of the Cape for this reason, because pines are the most extensively planted trees in South Africa, and because most new large-scale afforestation is concentrated in Afromontane areas. The study contributes to our knowledge of the impacts of pine afforestation on indigenous biotic assemblages in mountain fynbos, and to the evaluation of afforestable Afromontane grasslands for wildlife conservation.

The aims of this study are to:

(1) review and elucidate some of the effects of afforestation on native biotic assemblages in South Africa;

(2) develop a methodology for the evaluation of montane grasslands for wildlife conservation in a particular region of potential or new commercial afforestation;

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(3) use these methods to determine what features of this afforestable landscape have high conservation value, and;

(4) determine which areas of this region should be incorporated in a nature reserve system.

This thesis is divided into three sections: section 1 addresses aim (1) above, section 2 the next two aims, and section 3 addresses aim (4). It consists of papers that have been published, or accepted for publication, in the scientific literature (Chapters 3 to 7), or that have been submitted for publication (Chapters 1 and 2). Chapters 1, 4 and 6 had appendices which could not be published owing to a lack of space. These are grouped in the Appendices at the end of the thesis.

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Section 1

Effects of pine afforestation on biotic communities and ecological processes

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Chapter 1

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Impacts of Afforestation with Pines on Assemblages of Native Biota in South Africa

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SYNOPSIS

An overview of the impacts of pine afforestation on indigenous biota in South Africa is presented. Changes in the soil, hydrology, habitat structure, microenvironment, food resources and ecological processes of the afforested area occur. These changes influence native organisms and biotic assemblages in various ways. Generally, species richness and numbers of plants and animals indigenous to the native habitat are reduced in plantations. Species may be eliminated from the planted areas.

Woodland and forest species may benefit from pine plantations in terms of food and sites for germination and maturation, nesting, sleeping or resting, and the pines may facilitate the expansion of their local distributions.

Few indigenous species are pests of pines, though some can cause considerable damage and economic expense in plantations. Native species are generally beneficial to the forestry industry through their contribution to the maintenance of ecosystem functioning, pest control and additional revenue generation.

Correct management of unplanted areas, such as rotational mosaic burning within the natural fire regime, can ensure the continuing presence of many native species in forestry areas. These well-managed areas may be important for the persistence of some species in a region, especially where surrounding land use practices are detrimental to their habitats.

INTRODUCTION

Pines are alien to South Africa (Mirov 1967) and commercial afforestation, therefore, would be expected to have detrimental impacts on the native biota. This paper is an overview of work done in South Africa on the effects of pine afforestation on ecosystems and their biotic assemblages. References given are to papers reviewing or synthesizing research and to other key papers where appropriate; other primary references can be found in these.

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NUTRIENT CYCLING AND HYDROLOGY

Nutrient cycling

Afforestation with pines increases the above ground biomass 4 - 25 times or more in South African forestry areas. This will affect the nutrient cycling and hydrology of these areas (Versfeld & van Wilgen 1986). Acidification of the soil occurs. Exchangeable acidity (H^+ and Al^{3+}) increases, whereas organic carbon, organic phosphorous and biological activity decrease, in comparison with native grassland soils. Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) and some reserve cations (Mg^{2+} and K^+) decrease in plantation soils. A decline in soil fertility results, although the nutrient decreases are mainly in the "topsoil" (= upper soil layers) (Morris 1984; Musto 1991, 1992). Some of the above changes were reported in a Swaziland study (Morris 1984). These results are likely to be applicable to some areas of South Africa because Swaziland neighbours an afforestable region of South Africa.

The trend of nutrient decline and soil acidification continued in second rotation plantations in a Swaziland study (Morris 1984). Declines in soil nutrients are to be expected owing to the much greater plant biomass in plantations compared with the indigenous habitats. A decrease in the decomposition of pine litter was found in second rotation plantations compared with first rotation ones, indicating that less nutrients are recycled to the soil through this pathway and that pine litter acts as a nutrient sink (see de Ronde 1993). Nutrients are also removed in harvested logs (Morris 1992). Fertilization can cause acidification of the soil (Good *et al.* 1993).

Watts (1951) found that soils under pine plantations were more acid, had a lower total cation exchange capacity, and had lower concentrations of nitrogen, organic carbon, and exchangeable cations (Ca^{2+} and K^+), in comparison with soils under native forest.

The above changes, together with changes in the water-holding capacity of soils (see below), have an effect on the soil biota, with a proliferation of fungal mycelia evident. The more acidic nature of the pine soils and litter in comparison with forest soils and litter favours fungal decomposition over that by bacteria and soil fauna (Watts 1951; Musto 1992). In some areas there is a lack of soil fauna where fungi are present (de Ronde 1993).

The soil fauna are more numerous and evenly distributed in the "topsoil" under native forest than under pines. Most soil fauna live where there is humus in the soil, the organic material being better mixed with the mineral soil under native forest. Podzolisation of the acid soil occurs under pines, making the soil less suitable for soil fauna. Pine needle litter is less palatable to soil fauna than native forest leaf litter.

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Under pines, the fauna are concentrated in the litter and humus layers; there are fewer of the larger soil fauna than in native forests, and as a consequence there is also less mixing of organic material with the mineral soil (Watts 1951).

These factors result in more rapid decomposition of humus and even mixing of organic matter with mineralized soil under native forest. Native forest soils therefore have a greater partly-decayed and humus organic fraction in comparison to pine soils, and more taxa of soil fauna (Watts 1951).

Aluminium toxicity limits plant growth, and this has consequences for the regeneration of indigenous vegetation after tree-felling. Soils become more water-repellent, especially the "topsoil", in which there are large pores and cracks. Water infiltration rates are modified, and there is a reduced water-holding capacity of the "topsoil" (Musto 1992). It is probable that the soil profile is drier under pines than under native grassland (see Musto 1994). The percentage soil moisture under native forest is greater than that under pine plantations (Watts 1951).

Hydrology

Water use by plantations of pines is greater than that of the original indigenous vegetation: runoff is reduced and apparent evapotranspiration increases when a catchment is afforested with pines. A pine plantation may have a greater total leaf area than the indigenous vegetation it replaced, thereby increasing transpiration and affecting the energy balance. Pines intercept more rainfall than many native plants, and stemflow is lower in the pines. Therefore, more water is lost by evaporation from pines than from the native plant communities they replace. Pines also grow all year round, while the native vegetation they replace may be dormant during part of the year, e.g. grasses in Afromontane areas of South Africa are dormant during the cold, dry winter period. Therefore pine plantations will reduce streamflow relative to native vegetation (Nanni 1970; Bosch & Hewlett 1982; Versfeld & van Wilgen 1986; Versfeld 1993).

In a recent study (Dye & Poulter 1995), the clearing of pines (and wattles) from a riparian zone increased streamflow, and the results demonstrated the importance of transpiration by these trees in the reduction of streamflow. It is possible that pine plantations contribute to the lowering of the water table in specific situations, since in drought conditions they do make use of groundwater (Midgley *et al.* 1994; see Musto 1991).

These hydrological impacts can have an effect on native habitats dependent on runoff from the catchment and their biotic assemblages (Struhsaker *et al.* 1989; Good *et al.* 1993).

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However, stormflow pathways are not altered by pine afforestation, and control of stormflow by a planted catchment approximated that of a grassland catchment that had been protected from fire for just over a decade (Hewlett & Bosch 1984).

Forestry operations may have an impact on the soil. Soil loss during water runoff may be greater from intensively prepared sites supporting young trees than from native grassland (see Boden 1991). Compaction of the soil during logging negatively affects its water-holding capacity (Musto 1992).

IMPACTS ON BIOTA AND BIOTIC ASSEMBLAGES

Protozoa

The number of protozoan species is higher in native forest and coastal scrub soil than in soil under pines, but lower in soil under fynbos. The relationship between protozoan species richness and soil type, however, depends upon the soil layer considered. Where the organic content of the soil is relatively high, species richness is generally high (Watts 1951).

Plants

Plant species richness is reduced in pine plantations when compared with the indigenous habitats in the same areas (Cowling *et al.* 1976; Bigalke 1980*a*; Richardson & van Wilgen 1986; Richardson *et al.* 1989). Species are eliminated from the planted areas. A decrease of approximately 58% in the species richness of indigenous plants over a period of 35 years has been recorded under a plantation of pines (Richardson & van Wilgen 1986). The cover of the native vegetation was reduced from 75 % to 20 %, and mean native plant density was reduced to one third of its former value.

Afforestation may effect a permanent loss of species and alteration of the vegetation communities, even after clear-felling (Richardson & van Wilgen 1986). Recovery of the typical communities of indigenous vegetation in fynbos areas may be slow after clear-felling (Richardson & van Wilgen 1986; Richardson *et al.* 1989). The canopy cover and biomass of indigenous understorey plants in pine plantations decreases with increasing age of the plantations in Jonkershoek, south-western Cape (Bigalke 1980*a*). However, pine plantations in some areas act as nurseries for shade-tolerant forest species and facilitate their local expansion (Geldenhuys *et al.* 1986; Geldenhuys 1993).

Litter fall or below canopy litter mass in pine plantations is greater than that of fynbos, one of the indigenous vegetation types which the pines replace (Versfeld & van Wilgen 1986). Fire is also excluded from plantations, and plantation rotation time is

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often greater than the natural fire frequency (Edwards 1984; Hinze 1993). Therefore smothering of indigenous undergrowth may occur, and species dependent on fire-induced regeneration from seed or underground storage organs may become locally extinct if the latters' longevity in the soil is shorter than the interval between burns (Bond 1980; Tainton & Mentis 1984; Breytenbach 1986; Manders 1989; Porter 1990; van Wilgen & Forsyth 1992).

Manders (1989) found that the known extant populations of the endangered protea *Diastella buekii* occurred in pine plantations or in areas infested with alien trees, and would become extinct in the plantations if the pines were not removed. The *Diastella* plants apparently were killed by the accumulation of pine needle litter on top of them when litter accumulation was more rapid than the growth of the protea's shoots.

Indigenous fungi forming symbiotic mycorrhizae may be eliminated from the planted areas, particularly those with obligate hosts (Stock & Allsopp 1992). Pines rely on introduced fungi for mycorrhizae (Richardson *et al.* 1992).

Food resources and habitat structure

Plant species composition, cover, density, foliage profiles and the physiognomy of the vegetation change with the planting of pines and the ageing of the plantations. Faunal communities will change in response (Breytenbach 1986; Versfeld & van Wilgen 1986).

Pine plantations are usually sited in areas with relatively open vegetation (e.g. grasslands) in South Africa. Presumed shade-intolerant plant species are eliminated from South African plantations and around their edges, as are fauna that are dependent on these plants (e.g. Macdonald & Richardson 1986, cf. Breytenbach 1986; Richardson & van Wilgen 1986; Samways & Moore 1991).

The fast growth of exotic tree species in South Africa (van der Zel 1989) contributes to the change in resource availability. Successional change is rapid with the closed-canopy stage being reached relatively quickly. The resultant large areas of homogeneous habitat created in plantations is not favoured by wildlife.

The active management of plantations means that the availability of essential resources for animals changes within a few years or even from year to year. General forestry practice is to clear vegetation that may compete with the young timber trees for nutrients, light and water, or that may influence the distribution of pests and diseases, until canopy closure (Schumann 1990; Hinze 1993). Thinning, clearing, pruning and clearfelling contribute to changes in overhead and lateral cover, availability of food, and ease of movement (Allen-Rowlandson 1986). The lack of light limits weed growth at the closed canopy stage.

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These actions affect the suitability of the environment for the various species of wildlife. Animal species that are territorial or that have specific food or cover requirements are most affected (Allen-Rowlandson 1986; Breytenbach 1986).

Invertebrates

Soils under pine plantations are generally poor in the number of faunal taxa in comparison to native forest soils. There are many more invertebrate taxa in the litter layer of native forests. Soil invertebrates are more abundant in native forest soils than in soils under pines. However, many more fungivores occur in the organic layers of soils under pine plantations, where fungi thrive (Watts 1951).

Indigenous ants occur in pine plantations in the southwestern Cape, but a plantation ant assemblage has fewer species and fewer ants in comparison to fynbos habitat ones (Donnelly & Giliomee 1985; Manders 1989). Butterflies avoided a double row of exotic plane trees in one study in Natal, probably because the trees were a flight barrier and because of their foreign nature (Wood & Samways 1991). Pine plantations would probably act as barriers to butterfly flight paths. Few or no grasshoppers occurred within the small patches of pines in a Natal grassland area studied by Samways & Moore (1991).

Birds

Winterbottom (1968, 1972) found that only three bird species occurred frequently in pine plantations in the Fynbos Biome. These plantations had fewer bird species compared to indigenous habitats. A young pine plantation had a different bird assemblage to three older pine plantations at Jonkershoek, south-western Cape (Scott 1978). The young plantation still had dense fynbos and the birds recorded there were mainly of the fynbos assemblage.

Bird species richness and abundance were higher in an indigenous wooded habitat than in three small, different-aged pine plantations at Jonkershoek (Armstrong & van Hensbergen 1994). Birds were recorded less frequently in the pine habitats. The 3-year-old pine habitat had higher numbers of species and individuals than the two older, mature pine habitats. The birds in both mature pine habitats were predominantly species of the indigenous riparian assemblage, whereas fynbos species and widespread species predominated in the young pine habitat. The pines had been planted in fynbos.

The diversity of grassland bird species, especially globally threatened species, is negatively correlated with the extent of commercial afforestation in the Eastern Transvaal Province (Allan *et al.* 1995). The endangered blue swallow *Hirundo*

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atrocaerulea, for example, has been eliminated from some of its montane grassland habitat by afforestation (Huggett 1995).

Some woodland and forest birds benefit from the planting of pines. Allan & Tarboton (1985) found that the distribution of some *Accipiter* species has expanded in response to the increased availability of nest sites, afforded by the planting and invasive spread of commercial timber trees. The diversity of woodland and forest species is positively correlated with the extent of afforestation in the Eastern Transvaal Province (Allan *et al.* 1995).

Mammals

Small mammal assemblages change with the replacement of fynbos by pine plantations. Scott (1978) found that species richness and relative abundance of small mammals declined with increasing age of pine plantations at Jonkershoek, southwestern Cape. The occurrence of small mammals in mature plantations is dependent on the presence of sufficient undergrowth. Small mammal granivores that specialize on seeds from specific types of fynbos plants, herbivores, and some insectivores are absent from pine plantations that replace fynbos, except young plantations with sufficient indigenous vegetation (Scott 1978; Breytenbach 1986). Small mammals are absent from relatively old plantations with little undergrowth (Scott 1978; Armstrong & van Hensbergen 1995).

Single-species studies on the Chacma baboon *Papio ursinus*, bushbuck *Tragelaphus scriptus*, common duiker *Sylvicapra grimmia* and bushpig *Potamochoerus porcus* all indicate that these mammals occur in pine plantations, e.g. when foraging or resting, but that, except for baboons, plantations are not their preferred habitat (Odendaal & Bigalke 1979; Allen-Rowlandson 1986; Seydack 1990; Erasmus 1993). However, there is diel and seasonal variation in habitat preferences. Pine plantations are not the preferred habitat of other animals that use them, such as the samango monkey *Cercopithecus mitis*, grysbok *Raphicerus melanotis*, and large-spotted genet *Genetta tigrina* (Seydack 1977).

The avoidance of plantations is probably a result of the lack of food and cover in the plantations. Pine trees have not yet been recorded as providing the major proportion of the diet or the preferred item in the diet of an indigenous mammal or bird in South Africa.

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NATIVE PEST SPECIES AND PEST CONTROL

Native pests

With a few exceptions, indigenous species do not cause considerable damage and economic expense in pine plantations. Indigenous plant species are not the major invaders of these plantations (le Roux 1984). Few indigenous insects are pests of pines (Geertsema & van den Berg 1973; Borthwick & van Rensburg 1993). Frugivorous birds probably disperse the seed of some of the cosmopolitan weeds present in plantations after eating the berries, e.g. *Solanum mauritianum* (Oatley 1984; Dean 1987). These species may therefore cause increased running expenses in plantations through the necessity of more extensive weed control.

Rodents ringbark young trees and in certain areas cause the death of large numbers of pines. The main rodent pest species are the vlei rat *Otomys irroratus* and the striped mouse *Rhabdomys pumilio* (Willan 1984, 1992).

Primates can cause considerable damage in plantations. Samango monkeys at one plantation caused a potential loss in revenue of 2-3 million rand at the processed timber stage (Droomer 1985). The bark-stripping, including ringbarking, by samango monkey groups is opportunistic, the soft tissues (cambium, xylem and phloem) not being a preferred food. The habit is passed on by cultural learning and only certain groups acquire the habit (von dem Bussche & van der Zee 1985). Therefore bark-stripping is only a problem in certain areas. The same is true for baboons, which are estimated to cause damage amounting to several million rand in South Africa (Bigalke & van Hensbergen 1990; Erasmus 1993). Selection of a specific pine species as a food source has been recorded (van Wyk 1979), but this is not usual (Erasmus 1993).

Some species of antelope browse young trees in plantations but the damage is generally of little consequence and insignificant economically (Odendaal 1983; Allen-Rowlandson 1986). However, in certain areas the damage to the trees can be severe (Schutz *et al.* 1978). Grysbok and common duiker browse the terminal shoots and buds of pine seedlings and retard their growth which may result in some economic loss at the processed timber stage (Novellie & Bigalke 1981; Allen-Rowlandson 1986).

Damage to plantation trees by herbivorous animals is most likely to occur when and where their preferred foods are limited. Such limitation occurs in plantations that have had intensive site preparation or that are greater than a few years old, especially in winter and early spring (e.g. Bigalke 1980*b*; Willan 1984; Allen-Rowlandson 1986).

Damage caused by other wildlife species, e.g. breaking off of terminal buds or shoots by raptors when they perch on pine saplings, is infrequent and apparently does not cause major economic loss (Bigalke 1980*b*).

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Pest control and its impacts on native biota

Some of the chemical control methods used for weeds and insect pests are likely to kill non-target species, although this aspect has not been studied in South Africa (Porter 1990; Good *et al.* 1993). Problem animal control is carried out by shooting, trapping, poisoning, fencing and other barrier methods, habitat manipulation and by increasing the availability of suitable conditions for the natural predators of these animals, e.g. provision of raptor perches (Bigalke 1980*b*; Willan 1984; Bigalke & van Hensbergen 1990). Certain of these control measures, e.g. poisoning, may be detrimental to some non-target species, although depending in the case of poisoning on the substance used (e.g. Wirminghaus & Schroder 1994).

Other control measures are harmless and pre-empt the detrimental activities of animals, e.g. browsing antelope. Examples include protecting seedlings with wire or plastic sleeves, and by applying animal repellants (Bigalke 1980*b*). Rodent numbers are controlled by erecting hunting perches for their avian predators or by clearing the ground vegetation cover from around young trees to deter rodents from approaching them (Bigalke 1980*b*). The latter methods are to be preferred from a conservation perspective.

Some of the above factors further emphasize the unsuitability of timber plantations as wildlife habitat. However, because most wildlife species are beneficial, and not pests, on a forestry estate, their presence in an afforestable region should be actively encouraged. This is best done by leaving reserves of indigenous habitat in between plantations.

FRAGMENTATION OF NATIVE HABITATS BY AFFORESTATION

Physical effects

Saunders *et al.* (1991) have reviewed the biological consequences of ecosystem fragmentation. The microclimate in the remnants of indigenous vegetation is changed, which can have important consequences for the indigenous biota. Alteration of wind profiles, water flux and the amount of solar radiation reaching the ground occurs. The amount of radiation reaching the ground has an effect on air temperature and many other variables, such as soil surface temperature, micro-organism activity (and, therefore, nutrient cycling) and soil moisture.

Wind dispersal of pollen, seeds, airborne young invertebrates and adult volant insects are likely to be affected, if not totally disrupted, by the windbreak effect of pine plantations. Persistence of some species in indigenous habitat remnants may depend on successful recruitment from outside the remnant, especially after major disturbance

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(e.g. fire) in the remnant. Some interactions between organisms (e.g. animal-mediated pollination and seed dispersal, other mutual relationships, herbivory and predation) in remnant native habitats also may be disrupted by pine plantations (Breytenbach 1986; Saunders *et al.* 1991).

Pines can have a marked effect on grasshopper assemblages for many metres into surrounding grassland (Samways & Moore 1991). Species richness and abundance may be depressed for several tens of metres from the edge of a plantation, owing to the low ground cover diversity caused by the shading effect of the pines.

Species are likely to be lost eventually from fragmented indigenous habitats, especially species that require large areas of indigenous vegetation for foraging, as territory, etc. However, extinction of populations of long-lived species may not occur for many years on account of their longevity (Saunders *et al.* 1991).

There are also genetic consequences for animal populations isolated by habitat fragmentation, and these are dependent upon whether dispersal occurs between remnant habitats (Templeton *et al.* 1990). Small isolated populations with no immigration are most prone to genetic drift, inbreeding depression, demographic stochasticity and environmentally-mediated local extinction.

Pine plantations may allow invasive alien species, especially the pines themselves, to successfully invade remnants of native vegetation (Geldenhuys *et al.* 1986; Macdonald & Richardson 1986). The five most extensively planted *Pinus* species in South Africa (*P. patula*, *P. elliotti*, *P. taeda*, *P. radiata* and *P. pinaster*) are invasive, some vigorously so (Richardson & Brown 1986; Richardson *et al.* 1990; Richardson & Bond 1991; Richardson *et al.* 1994; Department of Water Affairs and Forestry 1995). Pine invasions are likely to have similar effects to commercial afforestation on the indigenous biota (Macdonald & Richardson 1986).

Impacts related to management of habitat remnants

Regular burning of forestry firebreaks, if too frequent, can have detrimental effects on the indigenous plants there (van Wilgen 1981; Frost 1984; van Wilgen *et al.* 1990). It reduces vegetation height, biomass and cover in fynbos. There are several strategies by which plants escape the effects of fire. However, seed-regenerating plant species may become locally extinct if the interval between successive fires is less than that between seed crops. Some resprouters are also affected or destroyed by repeated burning at short time intervals. If the interval between fires is too short, the mature vegetation structure will not be reached.

However, species richness of plants is greatest in montane grassland that is regularly burnt (Everson & Tainton 1984). Where grassland is seral to scrub or forest, species

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richness of plants is highest in the climax vegetation, which develops where the inter-fire interval is some decades. If the interval between fires is too long in fynbos, species dependent on fire for regeneration may be eliminated from the area through senescence and lack of seedling recruitment (van Wilgen *et al.* 1990).

Animals escape fire by sheltering in fire-protected areas or through dispersal (Bigalke & Willan 1984; Frost 1984). Frequent burning will cause the local extinction of species dependent on the mature stage of the vegetation, for example sugarbirds in fynbos. Burnt areas often attract animals, which come to feed on resprouting plants and dead or dying animals, or which nest there.

Burning of unplanted areas to reduce the fire hazard can have detrimental effects on the indigenous biota if the burning is done at inappropriate times of the year (Tainton & Mentis 1984; Kruger 1984; Little & Bainbridge 1988; van Wilgen *et al.* 1990; van Wilgen *et al.* 1992). Burning at inappropriate times can lead to declines in vegetation density and seedling recruitment and to changes in species composition and vegetation structure. Severe damage to the vegetation, with reduced growth rate during recovery, may occur if the vegetation is burnt during the period of active growth. However, different plant species may not respond in the same way to variation in the season of burn.

If burning is not done in sections on a rotational basis then local extinction and accelerated soil erosion may occur (van Wilgen 1981; Frost 1984; Porter 1990). This applies especially to vleis which have flora and fauna totally dependent on this habitat. There may be no suitable habitat nearby to which animals can flee or from which individuals may immigrate. Vleis may be destroyed through excess siltation if the whole vlei catchment or vlei is burnt (Natal Parks Board 1991).

Rotational mosaic burning of unplanted areas within the optimal fire regime for the area can maintain the diversity of animal and plant species, especially where optimal burning regimes are not maintained on surrounding land. This applies especially to species that are dependent on fire for successful reproduction (e.g. fire-dependent plants, some butterflies) and to species dependent on mature vegetation structures (Brooke 1984; Pringle 1994; Armstrong & Weir 1995). Mowing, instead of burning, of firebreaks can be beneficial for some species on forestry land, such as the reedbuck (Venter 1979).

BENEFITS OF NATIVE SPECIES IN FORESTRY AREAS

Raptors, carnivorous mammals and many snakes found in forestry areas eat small to medium-sized mammals, including forestry pest species (Skinner & Smithers 1990; Willan 1992; Maclean 1993). Insectivores prey on insect pests (Geertsema & van den

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Berg 1973). Several bird and mammal game species occur in forestry areas and can provide additional sources of revenue (Allen-Rowlandson 1986; Mentis & Bigalke 1985; Little & Crowe 1993). These benefits are additional to the other roles that biotic organisms play in the functioning of the ecosystems on which the forest industry depends.

CONCLUSION

The afforestation of indigenous habitats with pines appears to have similar general effects (i.e. reducing the richness and abundances of species) on the native plant, bird and mammal assemblages. However, there may be area-specific differences in the response of the native biota to afforestation.

Forestry companies in South Africa are aware of the environmental effects of large-scale afforestation. Guidelines for the application of conservation practices in commercial forestry have been published and voluntarily accepted by the major companies (Bigalke 1990; Pott 1992; FESA 1995). However, much research remains to be done on the impacts of afforestation in South Africa and how these can be ameliorated. In this regard, studies on the regeneration of native habitats and their biotic assemblages after clearfelling are required urgently, as are studies on the factors affecting the probability of species persistence in native habitats within forestry areas.

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Chapter 2

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Comparison of avifaunas in *Pinus radiata* habitats and indigenous riparian habitat at Jonkershoek, Stellenbosch

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The bird assemblages of three small, different-aged pine habitats and an indigenous wooded habitat were investigated near Stellenbosch, South Africa. Eight 20-min walk-through counts were done per season (excluding summer) in each habitat. Bird species richness and abundance were higher in the indigenous habitat than in any of the pine habitats during each season. The three-year-old pine habitat had higher numbers of species and individuals than the two mature pine habitats. Birds were recorded more infrequently in the pine habitats compared with the indigenous habitat. The greatest proportion of species recorded in the mature pine habitats were species of the riparian habitat assemblage. Fynbos species and widespread species predominated in the three-year-old pine habitat.

Die voëlgroepe van drie klein denne-habitatte van verskillende ouderdomme en 'n inheemse beboste habitat is ondersoek in die omgewing van Stellenbosch, Suid Afrika. Agt 'deurloop-tellings' van 20 min elk is per seisoen (uitgesluit die somer) in elke habitat gedoen. In die inheemse habitat is meer spesies en individue as in enige van die denne-habitatte in elke seisoen waargeneem. Die drie-jaar-oue denne-habitat het 'n hoër aantaal spesies en individue as die ander denne-habitatte gehad. Voëls is meer sporadies waargeneem in die denne-habitatte as in die inheemse habitat. Verhoudingsgewys is die grootste deel van spesies wat in die volwasse denne-habitatte waargeneem is, spesies geassosieer met 'n oewerhabitat. Fynbos-spesies en wydverspreide spesies het oorheers in die drie-jaar-oue denne-habitat.

Keywords: Bird assemblages, *Pinus radiata* habitats, indigenous riparian habitat

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Introduction

Afforestation and alien tree invasion are two of the eight classes of major land transformations in South Africa that negatively affect the conservation of native biota (Macdonald 1989). The structure and species composition of the natural ecosystems subject to these transformations are altered to a large extent, if not completely. About 1,5% of the Fynbos Biome is afforested with exotic trees, predominantly pines, for commercial purposes (Department of Water Affairs and Forestry 1993; Rutherford & Westfall 1986). At least 19% of the quarter degree squares in the Fynbos Biome have dense stands of pines, greater than 1 ha in extent, that have spread from plantations (Richardson, Macdonald, Holmes & Cowling 1992).

Large, mature plantations of exotic trees have been likened to 'biological deserts', with virtually no birds living in them (e.g. Smith 1974). Small plantations may be exploited by various species for nest sites, shelter and, seasonally, food resources. In this context, a mosaic of small plantations of different ages in a forestry estate may maximize the diversity of birds in the area.

The response of bird species to the transformation of natural habitats by afforestation varies. Bird species disadvantaged by afforestation, such as grassland birds and frugivorous and herbivorous species, disappear (Steyn 1977; Allan & Tarboton 1985). Bird species that can use the trees may appear in the area or increase in numbers. These species are mainly those that nest in tall trees. Allan & Tarboton (1985) documented the range expansion of four *Accipiter* species, facilitated by the planting of commercial trees and the invasive spread of these exotic trees along watercourses. Most of the nests of these *Accipiter* species were found in exotic rather than indigenous trees. Bird species of the original habitat that can adapt to the plantations may remain in the area, perhaps in reduced numbers.

However, few studies have investigated the occurrence of birds in plantations of pines in South Africa. Winterbottom (1968) showed that such plantations in the fynbos biome were depauperate in bird species compared with indigenous habitats in the same region. Only three species were frequently encountered in pine plantations.

A young (5-year-old) *Pinus radiata* plantation supported a different assemblage of birds to that of three older plantations (aged approximately 13, 37, and 39 years old) at Jonkershoek, near Stellenbosch (Scott 1978). Many species recorded in the young pine plantation were characteristic of the original mountain fynbos that persisted among the young pines.

In Australia, a mosaic of different-aged pine plantations supports either similar bird assemblages or fewer species and lower densities compared with indigenous habitats (Cowley 1971; Disney & Stokes 1976; Gepp 1976; Driscoll 1977; Friend 1982). Most of the Australian areas studied, have been afforested with *Pinus radiata*. However, the number of species and the numbers of birds in indigenous eucalypt habitat is greater than that in pine habitat of any particular age (Disney & Stokes 1976; Gepp 1976; Driscoll 1977; Friend 1982). Some species do not occur in pine habitats owing to the lack of specific resources, e.g. holes and snags for breeding, roosting, displaying and foraging, and nectar sources (Cowley

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1971; Disney & Stokes 1976; Gepp 1976; Driscoll 1977; Friend 1982; Caine & Marion 1991). However, birds move into pine plantations if an indigenous understorey of suitable composition and structure is present (Cowley 1971). Curry (1991) found that windrow-related habitat contained significantly more birds than pure pine habitat, but only one third of the birds recorded during winter were in pine trees. Furthermore, several studies found that avian species richness and abundances were greater at the edges than in the interiors of pine habitats (Cowley 1971; Gepp 1976; Friend 1982; Curry 1991). This edge effect was apparent up to 200 m in summer, but less in winter, in one study (Curry 1991).

The present study attempts to answer the following questions in a general way.

(i) How does the bird assemblage change over time in an area within the Fynbos Biome that has been planted with *Pinus radiata*?

(ii) Do these plantations offer an extention of suitable habitat for bird species of an indigenous wooded habitat?

(iii) Is a mosaic of small, different-aged pine plantations effective in retaining the bird species diversity of the area?

(iv) What types of birds are most disadvantaged by afforestation in this area?

The objectives of this study were to compare:

(i) the bird assemblages of small, different-aged pine plantations seasonally to determine how they differ in species composition and relative abundance;

(ii) these plantations with an indigenous wooded habitat patch to find out whether bird assemblages of pine habitats are subsets of the bird assemblage in the indigenous wooded habitat, and;

(iii) particular ecological characteristics of the avifaunas to determine indirectly which resources are lacking in different pine plantations, thereby to elucidate some effects of afforestation on the avifaunas of the indigenous biotopes.

Methods

The study took place in the Jonkershoek State Forest (33°57'S, 18°55'E), 8 km south-east of Stellenbosch in the south-western Cape Province, South Africa. Approximately 800 ha of the 11 053 ha state forest is planted with *Pinus radiata*. The four habitats studied were: (i) a 5,6 ha plantation of 3-year-old pines; (ii) a 5,2 ha plantation of 8-year-old pines that had been pruned to 3 m height at seven years of age; (iii) part of a 52,5 ha plantation of 29-year-old pines, and; (iv) indigenous riparian vegetation in Heuningkloof (Figure 1). The riparian habitat consisted of riparian forest and scrub mixed with some fynbos elements, notably *Protea nitida* (see vegetation description for Swartboskloof, situated across the Jonkershoek valley from Heuningkloof, by Van Wilgen & McDonald 1992). The pine plantations were in their second rotation, except the 29-year-old pine plantation which was a first rotation plantation.

No predominantly fynbos habitat was investigated owing to logistic constraints. However, Scott (1978) found that the bird assemblage in a 5-year-old first-rotation pine plantation next to the present study area was essentially a proteoid fynbos one. Richardson & Fraser (in press) give information on the bird assemblage of proteoid fynbos across the Jonkershoek valley from the present study site.

Figure 1 Relationship of the four habitats sampled. Riparian vegetation is stippled, route walked at Heuningkloof shaded black. Boundaries of pine habitats are indica 'Young' = 3-year-old pines; 'Younger mature' = 8-year-old pines; 'Older mature' = 29-year-old pines. Scale: 83 m.

A 50 m line transect was situated in each habitat along the same bearing to obtain an indication of habitat structure. The starting point of the transect in each habitat was randomly chosen using a random number table, where the numbers represented paces from the south-western corner of each habitat. Vegetation cover was measured to the nearest 5 cm (1 m for mature pine trees) along the line. Only the tallest vegetation layer was measured within any 5 cm length. Cover of the following categories was measured: bare ground and litter; undergrowth (vegetation ≤ 1,5 m tall); shrubs (1,51 –3 m tall); trees (> 3 m tall). In mature pine habitat the understorey was considered separately from the pines. Cover values are reported as a percentage of 50 m (to the nearest per cent) in Table 1.

Each habitat was sampled for birds according to the method of Loyn (1986), slightly modified. The method involves searching a habitat for 20 min by walking slowly through it and stopping at will. Birds seen or heard in a habitat were recorded as present. Records of birds overflying a habitat while in transit were excluded, as were records of

Table 1 Indication of habitat structure from percentage cover values for habitat strata. See text for further details

	Habitat			
	Pine (years)			Indigenous Riparian
Stratum	3	8	29	
Bare ground/litter	30	61	40	27
Undergrowth	57	24	35	37
Shrubs	11	15	13	6
Trees	3	–	13	30
Mature pines	–	54	72	–

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audibly-detected birds where reasonable doubt existed that the birds were in the habitat concerned. Birds on road edges within a habitat or flying into the habitat were recorded. Indices of relative abundance are obtained using this method. The method makes no attempt to correct for differences in detectability between habitats. Equal detectability over habitats implies similar habitat structures (e.g. Bibby & Buckland 1987). If the detectability of a species is similar over all habitats, the relative abundance of the species can be compared across habitats, but not with another species in any habitat unless they are equally easy to detect.

Although the structure of the habitats differed (Table 1), the method used, was considered suitable, for the following reasons: (i) all habitats were wooded, and so there was a heavy reliance on calls or song for the detection of birds. Differences in the habitat structures should affect audible detections less than visual ones; (ii) no cryptic or generally silent species were encountered in any habitat; (iii) the areas of the habitats sampled were small and walk-through counts were done; (iv) gross differences between habitats in total bird abundance should be detectable.

For the riparian habitat counts a road was always followed owing to the steepness of the terrain and the denseness of the vegetation. The possibility of inflated counts from the relatively large area of riparian habitat was countered in two ways. The distance walked along the road above the riparian habitat was limited (as indicated in Figure 1) and (except for the autumn counts) the overall area sampled was restricted to approximately 4,2 ha on one side of the road (calculated from an aerial photograph). The counts in the 29-year-old pine habitat were restricted to a certain section of the plantation (totalling about 5,2 ha in autumn, 4,5 ha in winter and spring [to exclude the small section below the road], calculated from an aerial photograph). Draglines and other relatively open pathways were often followed in the plantations to ease movement and reduce noise caused by stepping on pine trash from prunings.

The plantations were not divided into edge or interior because they were considered too small for such a division (see Curry 1991). Counts were done during the autumn, winter and spring of 1992. Most counts were done on fine days with slight or no wind. Counts were not done under conditions of rain or consistently strong wind. Eight counts were done per habitat each season. All habitats were usually visited on each sampling occasion. All counts were completed before 11h00 to standardize for time of day (see Siegfried & Crowe 1983; Koen 1988a). The sequence in which the habitats were visited was reversed for consecutive bird count days. Unidentified birds were recorded as such. Identification of a few individuals to species was based on locality and habitat.

Recorded species were classified according to diet, foraging substratum, nest site and indigenous habitat assemblage. A species was assigned to the class of each given characteristic that was predominant in its life history or ecology (Broekhuysen 1951; Rowan 1967; Skead 1967; Rowan 1969; Liversidge 1970; Milewski 1978; Steyn 1982; Cody 1983; Langley 1983; Rowan 1983; Harris & Arnott 1988; Knight 1988; Koen 1988b; Maclean 1993; Richardson & Fraser in press; pers. obs). A species was classified into a combination of two classes if adequate information on the required aspect of its life history or ecology was lacking. The classification of the species recorded with respect to life history and ecological characteristics is given in Table 2.

Table 2 Classification of the bird species recorded in the four habitats with respect to life history and ecological attributes

Species	DC	FS	NS	IH
Rock kestrel *Falco tinnunculus*	R	G	R	F
Rameron pigeon *Columba arquatrix*	F	C	C	R
Red-eyed dove *Streptopelia semitorquata*	G	G	C	R
Cape turtle dove *Streptopelia capicola*	G	G	C	R
Red-chested cuckoo *Cuculus solitarius**	I	C	–	R
Speckled mousebird *Colius striatus*	H	S	S	R
Olive woodpecker *Mesopicos griseocephalus*	I	B	H	R
Black saw-wing swallow *Psalidoprocne holomelas*	I	A	G	F/R
Cape bulbul *Pycnonotus capensis*	F	C	S	F/R
Sombre bulbul *Andropadus importunus*	F	C	S	R
Olive thrush *Turdus olivaceus*	O	G	C	R
Cape robin *Cossypha cafra*	I	U	U	F/R
Bar-throated apalis *Apalis thoracica*	I	M	S	R
Grassbird *Sphenoeacus afer*	I	U	U	F/R
Neddicky *Cisticola fulvicapilla*	I	U	U	F
Spotted prinia *Prinia maculosa*	I	U	U	F
Dusky flycatcher *Muscicapa adusta*	I	C	H	R
Fiscal flycatcher *Sigelus silens*	I	G	S	F
Cape batis *Batis capensis*	I	S	C	R
Paradise flycatcher *Terpsiphone viridis**	I	C	C	R
Southern boubou *Laniarius ferrugineus*	I	M	S	R
Bokmakierie *Telophorus zeylonus*	R	G	U	F/R
Red-winged starling *Onychognathus morio*	O	M	R	F
Malachite sunbird *Nectarinia famosa*	N	S	S	F/R
Orange-breasted sunbird *Nectarinia violacea*	N	S	S	F
Lesser double-collared sunbird *Nectarinia chalybea*	N	C	S	R
Cape white-eye *Zosterops pallidus*	O	M	C	R
Yellow-rumped widow *Euplectes capensis*	M	U	U	F
Cape canary *Serinus canicollis*	G	U	C	F/R
Cape siskin *Pseudochloroptila totta*	G	M	R	F

Diet class (DC): F = frugivore; G = granivore; H = herbivore[a]; I = insectivore[b]; M = granivore/insectivore; N = nectarivore[c]; O = insectivore/frugivore; Q = insectivore/herbivore; R = raptor/insectivore

Foraging substratum (FS): G = ground; U = undergrowth (including low shrubs ≤ 1,5 m height); S = shrubs; B = bole; C = canopy (smaller branches, twigs etc.); A = aerial; M = most substrata

Nest site (NS): G = ground or ground-hole; R = rock ledge or rock cavity; U = undergrowth; S = shrubs; H = tree-hole; C = canopy (fork of branch or twigs etc.)

Indigenous habitat (IH): F = fynbos; R = riparian forest and scrub

[a] Combinations of fruit, leaves, seeds, flower parts, nectar

[b] 'Insectivore' diet includes other invertebrate prey

[c] All nectarivores eat invertebrates as well

*Migrant

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All statistical tests were carried out using BMDP statistical software (Dixon 1988). Log likelihood ratio tests were used to detect significant associations between variables. Resultant tables of adjusted residuals (d_{ij}) were scanned to detect associations between classes of the variables that deviated significantly from expectation (Everitt 1977). A significance level of 5% was used unless otherwise stated.

Results

Species richness

The species recorded (and the mean number of each species recorded per count) in the four habitats over the three seasons are listed in Table 3. The number of species recorded was greater in the indigenous riparian habitat than in any of the pine habitats (Figure 2). The species richness of the indigenous riparian habitat was similar to that of the combined pine habitats (23 *vs* 24 species, respectively). More species were recorded in the young pine habitat than in either of the mature pine habitats during each season. The latter had similar numbers of species.

Numbers of birds

Birds were more abundant in the indigenous riparian habitat

Table 3 Birds recorded during 20-min counts in the four habitats during autumn (AUT), winter (WIN) and spring (SPR). Pine habitats are identified by age (years); RV = riparian habitat. Figures not corrected for differences in detectability

Habitat	Species	Mean number count [1]		
		AUT	WIN	SPR
3	Rock kestrel	–	–	0.25
	Speckled mousebird	0.50	0.63	1.00
	Black saw-wing swallow	–	–	0,13
	Cape bulbul	–	–	0,13
	Olive thrush	–	0.13	0,75
	Cape robin	1.88*	1,13*	2.00*
	Grassbird	0,13	0,13	0,13
	Neddicky	0,50	1.25*	1.50*
	Spotted prinia	1,63*	1,75*	2.25*
	Fiscal flycatcher	0,13	–	–
	Boubou shrike	–	–	0,13
	Bokmakierie	–	0,13	0,25
	Malachite sunbird	–	0,75*	0,13
	Orange-breasted sunbird	0.25	0,25	0,63
	Lesser double-collared sunbird	0.38	–	–
	Cape white-eye	0.13	–	1,25*
	Yellow-rumped widow	1.50	–	0,50
	Cape canary	–	–	0,13
	Cape siskin	–	0,25	–
	Unidentified	–	0.13	0.38
8	Rameron pigeon	–	–	0,13
	Cape turtledove	0,13	–	0,13
	Cape bulbul	–	–	0,13
	Olive thrush	–	–	0,38
	Cape robin	0,63*	0,63*	0,13
	Grassbird	0,13	–	–
	Neddicky	–	0,25	–
	Cape batis	0,38	0,25	0,38
	Boubou shrike	–	0,13	–
	Malachite sunbird	–	0,50*	–
	Orange-breasted sunbird	0,13	0,13	–
	Cape white-eye	–	0,50	0,38
	Cape canary	–	–	0,38
29	Rameron pigeon	–	0,13	–
	Cape turtledove	–	0,25	0,13
	Red-chested cuckoo	0,25	–	0,13
	Olive thrush	0,50	–	0,13
	Cape robin	0,13	–	0,25
	Neddicky	0,13	0,13	–
	Dusky flycatcher	–	–	0,63
	Cape batis	0,13	–	0,25
	Malachite sunbird	–	0,13	–
	Cape white-eye	0,13	0,50	1,13*
	Cape canary	–	–	1,50*
	Cape siskin	0,75	0,75	0,88*
	Unidentified	0,13	–	–
RV	Rameron pigeon	0.25	0,13	–
	Red-eyed dove	–	–	0,13
	Cape turtledove	0.63	–	0,63*
	Speckled mousebird	0,75	0,25	0,50
	Olive woodpecker	0,13	0,25	–
	Cape bulbul	3,63*	2,13*	2,63*
	Sombre bulbul	2,38*	2,50*	2,50*
	Olive thrush	1,38*	0,88*	0,38
	Cape robin	2,13*	0,50*	1,50*
	Bar-throated apalis	1,63*	1,13*	2,50*
	Grassbird	0,13	–	–
	Spotted prinia	0,50	0,25	0,38
	Dusky flycatcher	2,63*	–	1,75*
	Cape batis	1,75*	0,38	0,50
	Paradise flycatcher	0,13	–	–
	Boubou shrike	1,00*	0,38	0,63
	Red-winged starling	–	–	0.25
	Malachite sunbird	0,63	0,50	0,63
	Orange-breasted sunbird	1,50*	2,38*	1,00*
	Lesser double-collared sunbird	2,75*	–	–
	Cape white-eye	10,38*	5,38*	4,50*
	Cape canary	–	–	0,13
	Cape siskin	–	0,13	–
	Unidentified	–	1,00	1,63

*Recorded on ≥ 50% of counts

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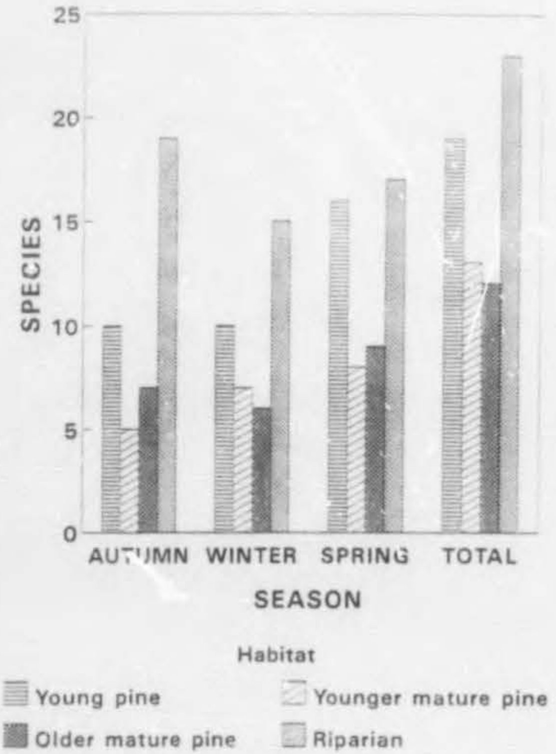

Figure 2 Numbers of bird species recorded in each habitat (see Figure 1) during each season and for all seasons combined.

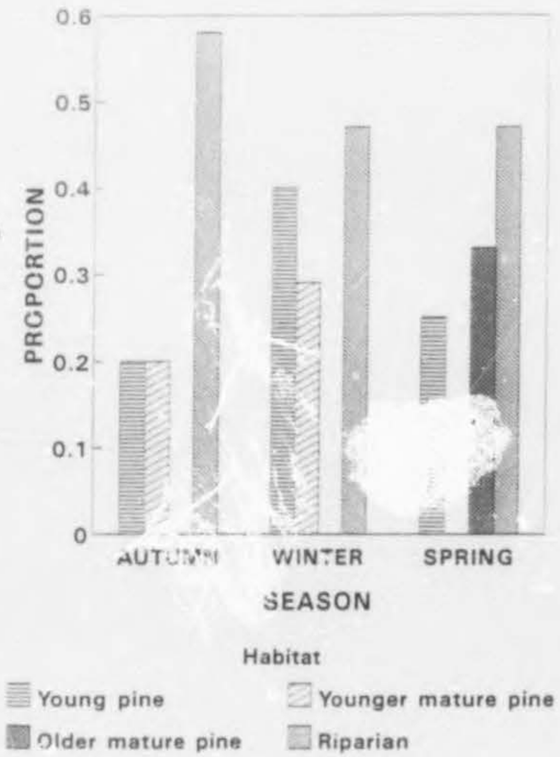

Figure 3 Proportion of bird species recorded in each habitat present on ≥ 50% of the counts.

than in any of the pine habitats during each season [Brown-Forsythe test or ANOVA (spring)]: autumn $F_{1,13} = 73,02$; $p < 0,001$; winter $F_{1,17} = 35,21$; $p < 0,001$; spring $F_{1,28} = 25,67$; $p < 0,001$. All pairwise t tests between riparian habitat and each pine habitat: $t \geq |4,27|$; $p < 0,01$). Mean avian abundance in the riparian habitat was approximately three times greater than that of the young pine habitat (Table 4). It was approximately ten times greater than that of the 29-year-old pine habitat. Birds were more abundant in the young pine habitat than in either the 8-year-old pine habitat (significantly during spring: $t = 3,82$; $p < 0,01$) or the 29-year-old pine habitat. Birds were least abundant in the 8-year-old pine habitat.

Consistency of occurrence

The numbers of species recorded in 50% or more of the counts as a proportion of the total number recorded in each habitat during each season is given in Figure 3. Table 3 shows which species were consistently found in a particular habitat. Consistency of occurrence of species was highest in the riparian habitat and lowest (except for spring) in the 29-year-old pine habitat.

Table 4 Mean number of birds per count in each of the four habitats during each season (s = ± 1 standard deviation)

Habitat	Age (yr)	Mean number birds count^{-1}		
		Autumn (s)	Winter (s)	Spring (s)
Pine	3	7,00 (4,87)	6,50 (4,04)	11,50 (7,15)
	8	1,38 (0,74)	2,38 (1,30)	2,00 (1,41)
	29	2,13 (2,80)	1,88 (2,23)	5,00 (4,41)
Riparian		34,25 (8,62)	18,13 (5,38)	22,13 (5,14)

Association between habitat type and the various avifaunal characteristics

There were no significant associations between habitat type and the various avifaunal characteristics in any season. However, significant associations between classes of habitat type and avifaunal characteristics are reported. The number of species in each class combination is given in Table 5.

Diet class

There was a significant association between granivorous species and the 29-year-old pine habitat in winter ($d_{ij} = 2$; $p < 0,05$). The raptor/insectivore diet class was significantly associated with the young pine habitat in spring ($d_{ij} = 2,1$; $p < 0,05$). Most species recorded in pine habitats are insectivores or else invertebrates make up most of their diets (18 species). Only six species are not insectivorous. Frugivores were rarely encountered in the pine habitats. The range in diet of the species recorded in the riparian habitat was wide and covered most diet classes. The insectivorous diet class (nine species) was the most frequent, with the granivorous diet class second

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Table 5 Numbers of species in each combination of habitat type and life history or ecological characteristic

		Habitat			
		Pine (years)			Indigenous
Characteristic	Class	3	8	29	Riparian
Diet	Frugivore	1	2	1	3
	Frugivore/insectivore	1	1	1	2
	Granivore	2	2	3	4
	Granivore/insectivore	1	–	–	–
	Herbivore	1	–	–	1
	Herbivore/insectivore	1	1	1	1
	Insectivore	7	5	5	9
	Nectarivore	3	2	1	3
	Raptor/insectivore	2	–	–	–
Foraging substrate	Ground	4	2	2	3
	Undergrowth	6	4	3	4
	Shrubs	3	3	2	4
	Tree bole	–	–	–	1
	Tree canopy	2	2	3	6
	Aerial	1	–	–	–
	Most substrata	3	2	2	5
Nest site (spring)	Ground	1	–	–	–
	Rock	1	–	1	1
	Undergrowth	6	1	1	2
	Shrub	5	1	–	7
	Tree cavity	–	–	1	1
	Tree canopy	3	6	5	6
Indigenous habitat assemblage	Fynbos	7	2	2	4
	Riparian	5	6	7	14
	Both	7	5	3	5

(four species). The frugivore and nectarivore classes were well represented (three species each).

Foraging substratum

Avian species that forage in the lower vegetation strata predominated in the pine habitats. Species that forage on the boles and larger branches of trees were absent from these habitats, and canopy-foragers were relatively few. Canopy-foragers and species that forage in shrubs were the most frequent classes of birds recorded in the riparian habitat. Species that forage in the undergrowth were also well represented in this habitat.

Nest site

Most of the recorded species breed in spring (Maclean 1993). Only results for this season were analysed. The following significant associations were found: species nesting in undergrowth with the young pine habitat ($d_{ij} = 2{,}1$; $p < 0{,}05$), and canopy-nesting species with the 8-year-old pine habitat ($d_{ij} = 2{,}2$; $p < 0{,}05$). As expected, there was a significant lack of canopy-nesting species in the young pine habitat ($d_{ij} = -2{,}2$; $p < 0{,}05$). Species that nest in the canopy predominated in both mature pine habitats. Species that nest in shrubs and species that nest in the canopy predominated in the riparian habitat. Species nesting in tree cavities were present in the riparian habitat during spring and at other times of the year, but were absent from most of the pine habitats. One species that nests in pre-formed tree cavities was present on three counts in the 29-year-old pine habitat.

Indigenous habitat assemblage

There was a significant association between the young pine habitat and species of fynbos origin in autumn ($d_{ij} = 2{,}2$; $p < 0{,}05$). There were fewer species of riparian habitat origin than expected during spring in the young pine habitat ($d_{ij} = -2{,}4$; $p < 0{,}05$). The largest proportion of the species recorded in the young pine habitat was part of the fynbos bird assemblage (autumn) or were widespread species (spring). The bird assemblage in the 8-year-old pine habitat consisted mainly of species from the riparian bird assemblage and widespread species. The bird assemblage in the 29-year-old pine habitat was predominantly of riparian origin.

Use of mature pines by bird species

The activities of birds recorded directly using cone-bearing pines (i.e. 8-year-old and 29-year-old pines) during the counts are given in Table 6. In general, insectivores foraged on mature pines while frugivores, granivores and nectarivores used mature pines as perches for singing and calling or for daytime roosting. The only granivore observed feeding on mature pines was the Cape siskin.

Table 6 Recorded activities of species directly using pines during counts in the mature pine habitats (F = foraging, P = perching/roosting, C = calling/singing)

Species	F	P	C
Rameron pigeon		X	
Cape turtle dove		X	X
Red-chested cuckoo		X	
Dusky flycatcher	X		
Cape batis	X		
Malachite sunbird	X		X
Cape white-eye	X		
Cape canary			X
Cape siskin	X		X

Discussion

The young pine plantation contained a greater number of species and individuals than a 29-year-old or an 8-year-old plantation probably because the young plantation had plant species in common with, and a similar structure to, the indigenous habitat that it replaced. A first rotation plantation is expected to hold greater numbers of species and individuals than a second rotation plantation of similar age. This would

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be due to the effects of the preceding dominance of the pines, the harvesting of the pines and the site preparation on the ability of the indigenous vegetation to regenerate in the plantation area.

Gepp (1976) found that different-aged pine plantations in Australia did not have different numbers of species but had different species compositions. He also found that species richness increased with greater vegetation diversity. Driscoll (1977) found that a 20-year-old pine habitat and a 40-year-old pine habitat had the same species composition. However, the older pine habitat had a greater abundance of birds.

Bird species richness and bird densities are lower in small plantations of *Pinus radiata* than in indigenous riparian habitat at Jonkershoek. These results are similar to those from Australian studies (Disney & Stokes 1976; Gepp 1976; Driscoll 1977; Friend 1982).

The bird community changed from one dominated by fynbos species to one dominated by 'riparian' (i.e. forest/scrub) species with increasing age of the pine trees at Jonkershoek. The fynbos species are most at risk from afforestation. The bird communities of the pine habitats, however, lacked the abundance of birds and the specialist species of the indigenous wooded habitat. Occupation of pine plantations by birds is sporadic.

The value of patches of indigenous vegetation among plantations is clearly seen in this study. Even a mosaic of small plantations does not provide adequate habitat for some species of birds occurring at Jonkershoek. Indigenous habitat patches are apparently required to ensure that some species will continue to occur in the plantation area at Jonkershoek (e.g. olive woodpecker, Cape bulbul, sombre bulbul, paradise flycatcher). It is likely that no species could live exclusively in pine plantations at Jonkershoek. None of the five ubiquitous species were regularly recorded in all pine habitats.

Curry (1991) found that most species recorded in a 15-year-old pine plantation in Australia were insectivores. Fruit or nectar was commonly consumed by only 17% of the species, and the species including fruit in their diets were also insectivorous. Disney & Stokes (1976) recorded only insectivorous birds in a thinned, 19-year-old pine plantation. Nectarivores and frugivores were frequent in indigenous eucalypt forest habitats in the same region. Insectivorous birds were predominant in pine plantations of different ages in the study of Friend (1982). The same trend is apparent at Jonkershoek in the south-western Cape, where insectivores predominate in the pine habitats and frugivores and nectarivores are under-represented. Frugivores and nectarivores used the pine trees in the mature plantations as perches (for roosting, calling or song, or while in transit), and, with one exception, were not seen to forage there during counts. A malachite sunbird was only once observed foraging off pines during the counts. All but one of the other species noticed foraging off pines were insectivorous.

Insectivorous species also predominate in the indigenous riparian habitat. It is rather the absence or scarcity of birds of several of the other diet classes that distinguishes pine habitats from indigenous habitats. Plants with bird-dispersed seeds have been recorded in pine plantations at Jonkershoek (Milton 1976; Richardson & van Wilgen 1986; Armstrong 1993). This may be the result of frugivorous bird species depositing seeds while using pine trees as perches (Dean 1987). Frugivorous birds were probably scarce in the pine habitats because fleshy fruits are scarce. There is apparently an adequate supply of fruit from bird-dispersed plants in riparian habitats at Jonkershoek. For example, fruiting of *Olea europaea africana* occurred for an extended period during the study (see Manders, Richardson & Masson 1992).

Driscoll (1977) found in Australia that several species of ground and undergrowth foragers were more abundant in pine habitats than in indigenous eucalypt habitats. Most of the species of eucalypt forest habitats missing from pine habitats were canopy species. Bole-foragers were scarce in the pine habitats although relatively common in the eucalypt forest habitats. Canopy foragers were scarce in, and bole-foragers absent from, pine habitats at Jonkershoek. Undergrowth foragers were more abundant in the young pine habitat than in the indigenous riparian habitat. Ground-foragers were more abundant in the indigenous riparian habitat than in any of the pine habitats at Jonkershoek.

Some of the regularly recorded undergrowth-nesting species probably bred in the young pine habitat during the spring because breeding-related behaviour was observed. The canopy-nesting species recorded in the 8-year-old pine habitat, however, may not have nested there. These species were only infrequently recorded during spring.

The near-absence of species that nest in tree cavities from the pine habitats was expected. Cavities do not form in pines until the trees are much older than the age at which they are harvested in South Africa. When snags and nest boxes were added to plots in young *Pinus elliottii* plantations in Florida the number of species and the number of birds found on the treatment plots were significantly higher than the number found on the control plots (Caine & Marion 1991). Some hole-nesting species enlarged or modified their territories to move onto the treatment plots, and some nested in the nest-boxes and bred in greater numbers on treatment plots than control plots (Caine & Marion 1991). South African hole-nesting species like the olive woodpecker that construct their own nests might not move into pine plantations at all because of the apparent lack of suitable nesting and foraging substrata.

Edge effects were subjectively apparent in the small plantations studied at Jonkershoek where there were adjacent riparian strips. This aspect is worth study in South African pine plantations.

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Chapter 3

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Research Note

Effects of Afforestation and Clearfelling on birds and small Mammals at Grootvadersbosch, South Africa

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SYNOPSIS

Results from a short-term study of birds and small mammals in pine plantations, regenerating clear-felled sites and indigenous forest and fynbos habitats at Grootvadersbosch, southern Cape, indicate that the pine faunal assemblages are pauperised in relation to those of the original habitat. The pine bird assemblage is largely composed of forest species which are not habitat specialists. Small mammal occurrence in pine habitat is dependent on the presence of sufficient undergrowth, and these small mammals are of fynbos origin. Recovery of the fynbos plant and animal assemblages after clear-felling may take many years.

Key words: Commercial afforestation. Afromontane forest, fynbos, birds, small mammals.

INTRODUCTION

The effect of commercial afforestation on wildlife and their habitats and the subsequent regeneration and recolonisation of these habitats after timber harvesting has seldom been studied in South Africa. Relevant literature for South Africa has been reviewed by Armstrong (1993), Armstrong and van Hensbergen (1994) and Allan *et al.* (1995). Large areas of land are being afforested without prior conservation evaluations and with little knowledge of the long-term effects on the ecosystems.

Basic information relating to some of these issues was gathered during a short-term study to test a conservation evaluation methodology for afforestable Afromontane areas, and is presented here.

STUDY AREA AND METHODS

The data presented here were collected at Grootvadersbosch State Forest (34°00'21"S, 20°49'43"E), Heidelberg District, southern Cape. The climate is temperate and rainfall occurs in all months (*Figure 1*). Plantations of about 250 ha were established in the fynbos surrounding the 292 ha Afromontane forest. However, removal of the pines was begun in 1987 because the area is not optimal for commercial tree growth. Sampling was done during October and November 1991, under similar environmental conditions.

Habitats

Six habitats were included in the study. Vegetation was sampled by the point-centred quarter method and/or quadrats to give an indication of the common species in each habitat (Mueller-Dombois and Ellenberg, 1974). The size of area sampled for plants varied between the habitats. Only mature plants were sampled. Brief habitat descriptions, including relatively common plant species (in decending order of abundance) found in each, follow.

1. A 23-year old, 17 ha, plantation of *Pinus radiata* (D.Don) with a relatively dense understorey of indigenous vegetation. It was situated on a fairly steep westerly-facing slope adjacent to 3-year-old fynbos. *Restio inconspicuus* Esterhuysen, *Ficinia ?bergiana, Tetraria ?fimbriolata, Ficinia macowanii* C.B. Cl., *P. radiata, Diospyros glabra* (L.) De Winter, *Erica cordata* Andr..
2. A section with relatively very little indigenous undergrowth of a 25/26-year old, 14,6 ha, *P. radiata/P. pinaster* plantation situated on a slight southerly slope adjacent to 3-4-year-old fynbos. *P. radiata, Ficinia macowanii, Ehrharta setacea* spp *scabra* Stapf.
3. Regenerating mountain fynbos on a 13 ha *P. radiata* plantation that had been clear-felled in 1989. It was situated on a slight south-easterly slope adjacent to a forest ecotone and to 17-year-old fynbos. *Ehrharta dura* Nees ex. Trin, *Senecio paniculatus* Berg., *Lanaria lanata* (L.) Dur. & Schinz., *?Bobartia* sp., *Senecio crenatus* Thunb., *Erica gracilis* Wendl. (cf. *Hypodiscus aristatus – Leucadendron eucalyptifolium* shrubland; McDonald 1993).
4. Regenerating mountain fynbos on a 6,5 ha *P. radiata* plantation that had been clear-felled during 1987 and 1988. It was situated on flat ground adjacent to a forest ecotone. *Erica melanthera* L., *Diospyros glabra,*

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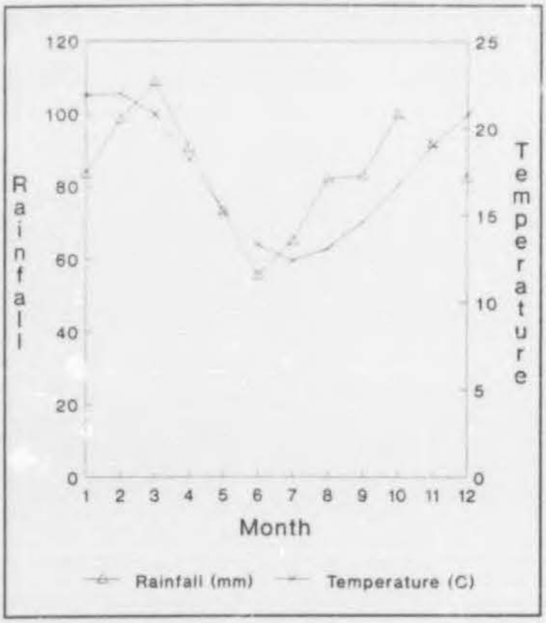

FIGURE 1. Mean monthly rainfall and temperature for study area (Strawberry Hill; Weather Bureau, Pretoria).

Ehrharta setacea spp *scabra*, *Pentaschistis malouinensis* (Steud.) Clayton, *Pentaschistis colorata* (Steud.) Stapf, *Restio inconspicuus* Esterhuysen, *Erica versicolor* Wendl., *Ficinia macowanii*, *Tetraria ?capillacea; Epischoenus* sp.; *Ficinia trichodes* (Schrad.) Benth. & Hook. F. (cf. *Berzelia intermedia* – *Erica melanthera* shrubland; McDonald 1993).

5. 17-year-old post-burn mountain fynbos. It was on a fairly steep northeast-facing slope. *Erica grata* Guth. & Bol., *Tetraria cuspidata-bolusii* complex, *T. microstachys* (Yahl) Pfeiffer, *Osteospermum pyrifolium* T. Norl., *Hypodiscus alboaristatus* (Nees) Mast., *Tetraria capillacea* (Thunb.) C.B. Cl., *Leucadendron eucalyptifolium* Buek ex Meisn., *Psoralea monophylla* (L.) C.H. Stirton, Restionaceae sp. 1, *Tetraria crassa* Levyns, *Elegia fistulosa* Kunth, *Hypodiscus argenteus* (Thunb.) Mast., *Protea neriifolia* R. Br., *Centella virgata* (L.F.) Drude, *Erica cerinthoides* L., *E. copiosa* Wendl., *E. hispidula* L. (cf. *Hypodiscus aristatus* – *Leucadendron eucalyptifolium* shrubland; McDonald 1993).
6. Dry Afromontane forest. The site was relatively flat. *Schoenoxiphium lehmannii* (Nees) Steudel, *Dietes iridioides* (L.) Sweet ex Klatt, *Ficinia sylvatica* Kunth, *Podocarpus latifolius* (Thunb.) R.Br. ex Mirb., *Rapanea melanophloeos* (L.) Mez, *Hartogiella schinoides* (Spreng.) Codd, *Maytenus acuminata* (L.F.) Loes., *Olea capensis* L., *Cassine peragua* L., *Apodytes dimidiata* E. May. ex

TABLE 1: Mean number per count of each avian species recorded in each habitat over the three sampling days

Habitat	Species	Mean no.
25 yr pines	Dusky Flycatcher *Musicapa adusta*	0,67
	Paradise Flycatcher *Terpsiphone viridis*	0,33
	Cape Batis *Batis capensis*	1,33
	Cape White-eye *Zosterops pallidus*	1,67
	Cape Siskin *Pseudochloroptila totta*	0,33
2 yr fynbos	Neddicky *Cisticola fulvicapilla*	0.33
3-4 yr fynbos	Greater Striped Swallow *Hirundo cucullata*	0,33
	Neddicky *C. fulvicapilla*	0,67
	Spotted Prinia *Prinia maculosa*	1,33
	Orangebreasted Sunbird *Nectarinia violacea*	0,67
	Black Sunbird *N. amethystina*	0,33
17 yr fynbos Forest	Greater Striped Swallow *Hirundo cucullata*	0,67
	Rock Martin *H. fuligula*	0,33
	Victorin's Warbler *Bradypterus victorini*	0,67
	Spotted Prinia *Prinia maculosa*	0,67
	Redwinged Starling *Onychognathus morio*	0,67
	Cape Sugarbird *Promerops cafer*	2,33
	Orangebreasted Sunbird *Nectarinia violacea*	0,33
Forest	Olive Woodpecker *Mesopicos griseocephalus*	0,33
	Sombre Bulbul *Andropadus importunus*	0,33
	Dusky Flycatcher *Muscicapa adusta*	0,33
	Cape Batis *Batis capensis*	0,33
	Cape White-eye *Zosterops pallidus*	1,00

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Arn., *Scolopia mundii* (Eckl. & Zeyh.) Warb., *Carissa bispinosa* (L.) Desf. ex Brenan, *Psydrax obovata* (Eckl. & Zeyh.) Bridson (cf. dry Afromontane forest type *sensu* Taylor 1955; McDonald 1993).

Birds

Birds were sampled on a fixed circular plot of 50 m radius in each habitat on three mornings (modified from Koen, 1988). Each count was ten minutes in duration. The bird sampling of the two indigenous habitats was extended to both the morning and the afternoon over seven days (13 sampling occasions) to determine what proportion of the bird assemblage present in the plot area was actually sampled over the first three mornings.

Mammals

Small mammals were sampled along two parallel traplines per habitat. Trapping points were ten paces (*ca* 10 m) apart with the pair of traplines five paces (*ca* 5 m) apart. There were twenty trapping points per habitat. One Sherman live trap was set at each trapping point, baited with a mixture of oats, peanut butter, lard and candle wax. Small carnivores were sampled using two carnivore traps, baited with cat food, per habitat, placed at least ten paces away from each end of the traplines on a path or other suitable spot. All trapping was for four days and nights. Small mammals caught were fur clipped, while carnivores were uniquely identified with dye spots or by their coat patterns.

RESULTS

Birds

The species recorded, and their mean numbers, are given in *Table 1* for the first three sampling occasions in each habitat. As many species of birds were recorded in the pine plantation as on the regenerating 3-4-year-old fynbos plot. There were no species in common, however. The 17-year-old fynbos habitat had the greatest avian diversity (*Table 2*). The plot with 2-year-old fynbos vegetation was the least diverse, with only one individual recorded on it.

The majority of the bird species recorded in the pine plantation were forest species, although a fynbos species (siskin) was also recorded (*Tables 1 and 3*). The avifauna of the regenerating 3-4-year-old fynbos [illegible] more similar to that of the mature, 17-year-old fynbos, but still lacks species dependent on a tall, mature vegetation structure (eg. Cape sugarbird, Victorin's warbler; *Tables 1 and 3*).

Mammals

The mammals captured in the different habitats are given in *Table 4*. The abundance of small mammals was greater in the fynbos habitats than in the pine plantations. No mammals were trapped in the pine plantation with a sparse understorey. The small mammals recorded in the pine plantation with a relatively dense understorey were fynbos species. The large-spotted genet, however, is associated with well-wooded vegetation rather than mountain fynbos, through which, nevertheless, it may range while foraging.

DISCUSSION

The majority of avian species recorded in the pine plantation were forest species. This is probably due to the close proximity of the Afromontane forest to the pine plantation and the more similar vegetation structure between these two habitats than between the pine plantation and mountain fynbos. Nectarivorous species, relatively common in fynbos, and hole-nesting forest insectivores were not recorded in the pine plantation. The findings of Armstrong and van Hensbergen (1994) for the bird assemblages of mature pine plantations at Jonkershoek, southwestern Cape, were similar. The common species recorded on the fynbos plot and forest plot at Grootvadersbosch are characteristic of tall sparse shrubland and tall forest/closed woodland, respectively, at Jonkershoek (Fraser, 1989).

The planting of pines in the fynbos habitat therefore replaced the fynbos assemblage of birds with another, relatively pauperised, forest assemblage. Clearfelling of the pine plantations in turn eliminates many of the species found previously in the pine community, but there is apparently a long time lag before some of the species of birds of the fynbos assemblage are re-established in the area.

The extent of afforestation of the Afromontane grasslands in the Eastern Transvaal Province is significantly and negatively correlated with the species diversity of grassland birds, especially with globally threatened grassland species (Allan *et al.*, 1995). Species that benefit from afforestation and spread of alien trees are significantly and positively correlated with the extent of afforestation in the same region, and these birds are woodland and forest species. Therefore, the effect of afforestation on bird communities is similar in the fynbos and the grassland biomes, the original assemblage of species being replaced by a pauperised woodland or forest bird assemblage.

Forty-two avian species are regarded as resident or common migrants in the Grootvadersbosch Forest. Only 8 species, however, were recorded on the dry forest plot during the 13 counts. Some of the other species are generally found in other parts of the habitat gradient and so would not be expected on the plot. All the common fynbos and forest species present on the respective plots were recorded during the first three days of sampling, indicating that the three-day sampling period was sufficient to identify major differences between the habitats (cf. *Tables 1 and 3*).

An unknown factor in this study is whether the 3-4-year-old fynbos will ever have the same bird assemblage as the 17-year-old fynbos, if the mature plant community on this regenerating site is *Berzelia intermedia – Erica melanthera* shrubland. The structure of the *Berzelia intermedia – Erica melanthera* shrubland differs from that

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of the *Hypodiscus aristatus – Leucadendron eucalyptifolium* shrubland (McDonald 1993). The Cape Sugarbird, for example, is associated with tall, mature proteas, which are absent from the *Berzelia intermedia – Erica melanthera* community (Fraser 1989; McDonald 1993).

The presence of indigenous vegetation is apparently vital for the survival of small mammals in the pine plantations at Grootvadersbosch. No small mammals were trapped in the pine plantation that was almost devoid of indigenous vegetation. Even in the pine plantation where there was some indigenous vegetation, the

TABLE 2. Bird diversity calculated as the Shannon index (H') for each habitat

Habitat	H'
Pine with little understorey (25 years old)	1,41
2-year-old regenerating fynbos	-
3-4-year-old regenerating fynbos	1,47
17-year-old fynbos	1,71
Forest	1,48

TABLE 3. Mean number per count of each avian species recorded in the 17-year-old fynbos and in the forest over the 13 sampling occasions

Habitat	Species	Mean no.
Fynbos	Alpine Swift *Apus melba*	0,08
	Greater Striped Swallow *Hirundo cucullata*	0,38
	Rock Martin *H. fuligula*	0,31
	Victorin's Warbler *Bradypterus victorini*	1,08
	Grassbird *Sphenoeacus afer*	0,38
	Spotted Prinia *Prinia maculosa*	0,62
	Redwinged Starling *Onychognathus morio*	0,15
	Cape Sugarbird *Promerops cafer*	1,00
	Orangebreasted Sunbird *Nectarinia violacea*	0,54
Forest	Olive Woodpecker *Mesopicos griseocephalus*	0,31
	Knysna Woodpecker *Campethera notata*	0,08
	Sombre Bulbul *Andropadus importunus*	0,15
	Olive Thrush *Turdus olivaceus*	0,15
	Dusky Flycatcher *Muscicapa adusta*	0,23
	Cape Batis *Batis capensis*	0,46
	Greater Doublecollared Sunbird *N. afra*	0,15
	Cape White-eye *Zosterops pallidus*	0,92

TABLE 4. Number of each mammalian species captured in each habitat over the four sampling days

Habitat	Species	No.
25 yr pines	–	–
23 yr pines	Forest shrew *Myosorex varius*	2
	Verreaux's mouse *Myomyscus verreauxii*	1
	Largespotted genet *Genetta tigrina*	2
2 yr fynbos	Striped mouse *Rhabdomys pumilio*	4[a]
	Forest shrew *Myosorex varius*	2
	Largespotted genet *Genetta tigrina*	1
3-4 yr fynbos	Forest shrew *Myosorex varius*	5
	Striped mouse *Rhabdomys pumilio*	1
17 yr fynbos	Forest shrew *Myosorex varius*	3
	Greater musk shrew *Crocidura flavescens*	1
	Striped mouse *Rhabdomys pumilio*	1
	Water mongoose *Atilax paludinosus*	1
Forest	Largespotted genet *Genetta tigrina*	1

[a] Minimum number

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total number of individuals trapped was always less than that in the regenerating fynbos habitats. *Mysorex varius* occurred both in the pine habitat with an indigenous understorey and in the two regenerating fynbos habitats, but was less abundant in the pine habitat. Circumstantial evidence for the importance of an understorey for the small mammals occurring at Grootvadersbosch comes from the 17-year-old fynbos habitat and the dry forest habitat. No small mammals were caught in the dry forest habitat with its paucity of undenstorey species and sparse understorey, while three small mammal species were trapped in the dense 17-year-old vegetation, which therefore had the greatest species richness of all the habitats sampled.

In contrast to the avifauna, the small mammal species captured in the pine plantation were fynbos species, which indicates that the small mammal community present in the area before afforestation is not replaced by a forest community. However, some fynbos small mammal species do not frequent the pine plantations. No small fynbos carnivores were recorded in the pine plantations, but a small forest carnivore was trapped in the pine plantation with a relatively dense understorey.

The successional changes which occur in the plant, bird and animal assemblages after the clear-felling should be investigated further. This preliminary study suggests that more detailed studies on the effects of afforestation and clear-felling on biotic communities in South Africa are required.

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Chapter 4

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Are pine plantations "inhospitable seas" around remnant native habitat within southwestern Cape forestry areas?

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SYNOPSIS

Some areas of forestry estates, including unplantable ones, may be zoned and managed for nature conservation. This paper is an analysis of the results of studies of plants, birds and small mammals at Jonkershoek, Stellenbosch, to determine whether pine plantations are "inhospitable" to ecological and demographic processes required for the persistence of these biota in native habitat "islands" within forestry areas. The present study indicates that pine plantations are not unqualified "inhospitable seas". However, the human-assisted dominance of the pines over the indigenous vegetation eliminates many species of the original habitat and reduces the numbers, or the frequency of occurrence, of the remaining species. There were significantly fewer vertebrate-pollinated, indigenous, plant species in the plantation sample than in the mountain fynbos one, and significantly more vertebrate-dispersed, native, plant species. Vertebrate pollinators were infrequently recorded in, or absent from, mature pine plantations. These factors are likely to affect some ecological and demographic processes in the pine plantations, such as vertebrate-mediated pollination, and perhaps the continuity of these processes between large areas of original habitat and indigenous habitat patches in the forestry area. Therefore we suggest that areas of fynbos and riparian forest surrounded by plantations should be considered as "islands" in an "inhospitable sea" when considering the zonation and management of indigenous habitat for conservation on forestry estates.

Key words: Pine plantations, plants, birds, small mammals, ecological processes

INTRODUCTION

The equilibrium theory of island biogeography has been used to suggest designs for nature reserves. The theory, however, has been criticized by, *inter alia*, Gilbert (1980)

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who reviewed the evidence from studies relating to the theory and found almost no empirical support for the theory. No mainland insular studies provided unequivocal support for the theory. More recently the approach to the study of the fragmentation of habitats and the resultant proposition of measures to counteract these effects has changed from using the theory to studying each situation separately (eg. Bennett 1987; Bond *et al.* 1988).

Bond *et al.* (1988) found that fynbos "islands" in a "sea" of Afrotropical forest had fewer species than comparably-sized areas of the fynbos "mainland" studied. The "sea" was inhospitable to fynbos plants because virtually no species were found common to both habitats. Fire is necessary for the regeneration of certain fynbos plants, but rarely occurs in the forest "sea". Therefore, the "islands" had fewer fires than the "mainland" and as a consequence apparently lost species dependent on frequent fires for regeneration. The forest is also an "inhospitable sea" for the rodent species, but not to all the ant species, recorded in the fynbos "islands" (Midgley & Bond 1990). However, there appeared to be no major effects of insularization on the ant and rodent faunas (Midgley & Bond 1990). This is remarkable owing to the apparent long time since fragmentation of the fynbos occurred.

Cowling & Bond (1991) studied fynbos plants occurring on limestone outcrop "islands" in a "sea" of acid-sand fynbos. In contrast to the fynbos/forest situation reported in Bond *et al.* (1988), the "sea" was not inhospitable to the ecosystem processes occurring on the "islands" because myrmecochory, fire, ornithophilous pollination, etc., also occurred in the "sea". Some species on the "islands" were recruited from the "sea". Only small "islands" (<4ha) had the expected reduced species richness when compared to comparable "mainland" areas. In general, the distribution of the species traits studied (eg. substrate specificity, dispersal method, and pollination syndrome) did not differ significantly between the "islands" and the comparable "mainland" areas. Local endemic fynbos species were significantly underrepresented on small "islands", and so the critical factor is the amount of required habitat available for these habitat specialists rather than the total size of the "island".

Patches of indigenous vegetation in commercial timber plantations have been likened to habitat "islands" in an "inhospitable sea", i.e. the area planted to exotic timber trees. The species richness and abundance of plants, birds and small mammals are much greater in indigenous habitat than mature pine plantations of similar area at Jonkershoek, near Stellenbosch (Scott 1978; Richardson & van Wilgen 1986; Armstrong & van Hensbergen 1994). Some species present in the native habitat before afforestation are eliminated from the planted areas. There was approximately a 58 % reduction in the number of indigenous plant species over 35 years in the area planted to pines studied by Richardson & van Wilgen (1986). The mean cover of the native

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vegetation was reduced from 75 % to 20 %, and mean native plant density was reduced to one third of its former value. Therefore remnant patches of native habitat are important for maintaining the presence of these species in forestry areas.

The question of whether ecological processes are disrupted by afforestation with pines should be asked when considering how best to manage remnant native habitat within plantations. Continuity of specific ecological processes between remnants and other nearby areas of the same habitat may be necessary for the persistence of some of the biota of the patches.

Are pine plantations inhospitable "seas" around indigenous habitat patches in the sense that ecological and demographic processes are disrupted in the plantations? Is the reduction in plant species richness and biomass with pine afforestation and with increasing age of pine plantations partly due to the disruption of important ecological processes or is it due solely to the human-assisted dominance of the pine trees when competing for light, water, nutrients and rooting space? Also, are certain avifaunal and mammalian guilds disproportionately affected by pine afforestation, thereby adversely affecting vertebrate-mediated ecological processes, and reducing or disrupting immigration to, and dispersal from, indigenous habitat patches?

This paper presents some analyses of the results of studies of plants, birds and small mammals in pine plantations and indigenous habitats at Jonkershoek, to provide some answers to these questions.

STUDY AREA

The Jonkershoek State Forest is in the south-western Cape region of South Africa (33°57' S, 18°15' E; *Figure 1*). The climate is mediterranean. By Köppen's (1931) system, the climate may be classified as mesothermal (Csb) with a warm dry summer (mean temperature of the hottest month $\leq$ 22°C) and a relatively wet winter. More than 80% of the rain falls between April and October (Wicht *et al.* 1969) usually in long duration, low intensity, frontal events.

The indigenous vegetation of the area is fynbos, a sclerophyllous scrub dominated by species of Proteaceae, Ericaceae and Restionaceae, and along stream courses there are belts of native riparian forest. A total of 800 ha has been afforested with *Pinus radiata* which is managed as a saw-timber crop on a 35 - 40 year rotation.

The Peninsula Sandstone Formation of the Table Mountain Group underlies most of the Jonkershoek valley and outcrops as cliffs in the upper elevations. It is highly folded and faulted and contains occasional shale lenses. Beneath the sandstone, and outcropping occasionally in the lower parts of the valley, is deeply weathered Cape Granite which allows deep penetration of roots and water. Weathering, soil creep and colluviation have resulted in a complex and varied distribution pattern of soil parent

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materials derived from the two geological formations. The soils are mainly sandy loams (Versfeld 1981).

METHODS

Plants

Fynbos data were collected from Biesievlei (Rycroft 1950) and plantation data from Bosboukloof (Milton 1976), situated along the southwesterly-facing side of the Jonkershoek Valley within two kilometres of each other (*Figure 1*). The elevation at Biesievlei ranges from 290 to 580m (Richardson & van Wilgen 1986). Therefore only plant data collected within the elevation range of approximately 300 to 580m by Milton (1976) at Bosboukloof were used in the comparison. The pine plantations studied by Milton (1976) were approximately 37 years old. Only the plants that were identified to species level in the studies of Rycroft (1950) and Milton (1976) were used in the analyses. Only one species was considered where two species on a list are subspecies of the same species.

Plants were classified according to the pollination system (Rebelo 1987), the seed dispersal system (Bond & Slingsby 1983; Knight 1988; le Maitre & Midgley 1992), and the persistence group of vital attributes (van der Merwe 1966; Knight 1988; van Wilgen & Forsyth 1992). The classes of these three characteristics are as follows.

Pollination system - wind, insect, insect & bird, bird, mammal.

Seed dispersal system - water, wind, other (gravity, ballistic, rodent, unknown), ant, vertebrate.

Method of persistence - dispersed propagules, dispersed propagules and vegetative regrowth, retained propagules, retained propagules and vegetative regrowth. These classes were modified from the scheme of Noble & Slatyer (1980).

Information was obtained from specimens at the Stellenbosch herbarium (STE) and from some field observations to supplement that in the literature. Plants were classified as having dispersed propagules if the possibility exists for the regular dispersal of the seeds more than a few metres from the parent plant. Plants classified into this category had wind-dispersed seeds, water-dispersed seeds or vertebrate-dispersed seeds (ectocochory and endocochory). Other dispersal systems, eg. myrmechochory or ballisitic mechanisms, possibly do not result in seed dispersal in fynbos of more than a

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few metres from the parent plant (eg. Bond & Slingsby 1983; Yeo 1984). Plants falling into the latter group of dispersal systems have a restricted seed dispersal and were grouped with the plants with non-dispersed seeds. Seed dispersal systems are not mutually exclusive (eg. Dean *et al*. 1990) and so seeds were classified according to their actual, or suspected, primary dispersal system.

Birds

The avifaunal data were obtained from four adjacent wooded habitats between Lambrechtsboskloof and Heuningkloof: three pine plantations (three, eight and 29 years old) and a riparian habitat (*Figure 1*; Armstrong & van Hensbergen 1994). All pine habitats were adjacent or close to riparian habitat corridors.

Birds were classified according to diet, foraging substratum, nest site and indigenous habitat. The classes of these four characteristics are as follows.

Diet - frugivore, granivore, herbivore, nectarivore, raptor, insectivore, insectivore & frugivore, insectivore & granivore, insectivore & herbivore, raptor & insectivore.

Foraging substratum - ground (includes still-hunting from a perch to the ground), "undergrowth" (including shrubs ≤1.5m high), shrubs, bole and larger branches of trees, tree canopy, most or all substrata.

Nest site - ground (including ground holes), rock ledges and cavities, undergrowth, shrubs, tree-hole, tree canopy (forks of branches etc.).

Indigenous habitat - fynbos, riparian forest & scrub, both habitats.

Results were taken from Armstrong & van Hensbergen (1994).

Mammals

The species lists for pine plantations were collected at Bosboukloof (Scott 1978), and the lists for the indigenous habitats were collected across the valley on the northeasterly-facing side at the Assegaaibosch Nature Reserve (*Figure 1*; Stuart 1971). *Acomys subspinosus* was not recorded by Stuart (1971) but was captured by Toes (1974) in fynbos in nearby Swartboskloof. This species therefore was added to the fynbos list. The young pine plantation studied by Scott (1978) was approximately four years old and the middle aged plantation approximately 13 years old.

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Mammals were classified according to diet, foraging microhabitat and resting site. The classes of the characteristics are as follows.

Diet - "frugivore" (fruit, flowers, fungal fruiting bodies), granivore, "folivore" (herbivorous on vegetative parts of plants), herbivorous on underground organs of plants, generalist herbivore (combination of two or more of the above diet categories), insectivore (includes any invertebrates), carnivore, omnivore.

Foraging microhabitat - subterranean or ground surface in several microhabitats, amongst herbaceous growth, terrestrially amongst shrubby cover, water, most or all microhabitats.

Resting site - underground or on "bare" ground, among rocks in rocky open areas or on rock ledges, in rock hole or crevace, amongst herbaceous growth, among shrubs in shrubland or in thicket, in tree-hole.

Classification method

Each species was assigned to the class of each characteristic that was predominant in the life history or the ecology of the species. A species was classified into a composite class if information enabling classification of the species into a predominant class was lacking.

Sampling intensity

Sampling intensity differed between the two plant studies and between the three mammal studies. This will not effect an analysis of the ratios between guild classes, on the assumption that the sampling methods used in these studies were not biased against the species of particular guilds. Similar results from other studies (plants: Richardson & van Wilgen 1986; small mammals: Breytenbach 1986; Armstrong & van Hensbergen 1995) give support to the validity of this assumption for the present study.

Statistical analysis

All statistical testing was done using BMDP statistical software (Dixon 1988). *Chi*-square tests of association between habitat type and the different plant and animal guilds were done using species presence/absence data only, under the null hypothesis of no association. The resultant tables of adjusted standardized residuals were used to

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determine the significant associations ($d_{ij} > 1.96$; $p < 0.05$) between specific habitat and guild classes (Everitt 1977).

RESULTS

Plants

(a) Pollination system

The plantation and fynbos habitats did not differ in the relative number of species in the different pollination classes ($X^2 = 5.831$; df=4; p=0.212; *Table 1*). There were no bird-pollinated or rodent-pollinated plants in the plantation sample, although these plants made up a small proportion of the species in the fynbos sample (2.6 and 0.4 % of the species, respectively). However, when the vertebrate classes were combined (including the insect & bird class), pollination system and habitat type were associated (G = 6.648; df=2; p=0.036; *Table 1*). Vertebrate-pollinated plants were associated with the indigenous habitat and there was a lack of these species in the plantation habitat ($d_{ij} = 2.0$; $p < 0.05$).

(b) Seed dispersal system

Seed dispersal system and habitat type were associated ($X^2 = 14.19$; df=4; p=0.007; *Table 2*). The plantation habitat had a significantly greater proportion of vertebrate-dispersed plants than the fynbos habitat (26.1 and 11.7% of the species, respectively; $d_{ij} = 3.5$; $p < 0.05$).

(c) Potential mode of persistence

The plantation and fynbos habitats did not differ in the relative number of species in the different persistence mode classes ($X^2 = 1.632$; df=3; p=0.652; *Table 3*).

Birds

(a) Consistency of habitat occupation

Birds were more regularly present in the indigenous riparian habitat than in any of the pine habitats. Birds were infrequently recorded in mature pine plantations.

(b) Diet, foraging site and nest site

There was no significant association between habitat type and diet, foraging site or nest site guilds (*Table 4*). However, there was a significant association between undergrowth-nesting species and the young pine habitat. Species nesting in the canopy

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were significantly associated with the younger mature (eight year old) pine habitat, and predominated in the older mature pine habitat, but behaviour associated with nesting was not recorded.

Insectivorous species predominated in pine plantations. Avian pollinators, the malachite (*Nectarinia famosa*), orange-breasted (*N. violacea*) and lesser double-collared (*N. chalybea*) sunbirds, and some seed dispersers, the speckled mousebird (*Colius striatus*), Cape (*Pycnonotus capensis*) and sombre (*Andropadus importunus*) bulbuls, and red-winged starling (*Onychognathus morio*), were absent, or virtually so, from mature pine plantations. All the sunbirds and the mousebird and Cape bulbul were recorded in the young pine plantation. Birds that forage in the lower vegetation strata predominated in the pine habitats. Bole-foragers were only encountered in the riparian habitat.

(c) Indigenous habitat assemblage

Indigenous habitat bird assemblage and habitat type were not associated (*Table 4*). Fynbos and widespread birds predominated in the young pine habitat, whereas riparian and widespread birds predominated in the younger mature pine habitat and riparian birds in the older one.

Mammals

There were no significant associations between diet guild, foraging site or resting site and habitat type ($X^2 = 9.421$; df=21; p=0.985; *Table 5*; $X^2 = 13.565$; df=12; p=0.329; *Table 6*; $X^2 = 10.053$; df=15; p=0.816; *Table 7*; respectively). The only rodent pollinator recorded in the middle-aged (mature) pine plantation was the striped mouse (*Rhabdomys pumilio*). The other rodent pollinators, the Cape spiny mouse (*Acomys subspinosus*), namaqua rock mouse (*Aethomys namaquensis*) and Verreaux's mouse (*Myomyscus verreauxii*), were either not recorded in pine plantations or were found in the young plantation.

DISCUSSION

Pine plantations are not unqualified "inhospitable seas". Ecological processes such as pollination and seed dispersal are apparently not disrupted totally. The absence or scarcity of rodent and avian pollinators (Rebelo 1987) and vertebrate-pollinated plants in mature pine plantations, however, may lead to disruption of vertebrate-mediated pollination in indigenous habitat patches isolated by these plantations. There may also be some disruption of wind-mediated and insect-mediated pollination. Plantations act as wind-breaks and perhaps flight barriers to insects (Saunders *et al.* 1991; Wood & Samways 1991). This subject requires further study.

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Vertebrate-dispersed plants proportionately increased in pine plantations, perhaps because avian frugivores utilize pines as roosts and some mammalian species forage for mushrooms and insects in plantations, with the consequent opportunity for the deposition of seed there (Geertsema & van den Berg 1973; Oatley 1984; Allen-Rowlandson 1986; Dean 1987). However, there is a danger that dispersal of indigenous fruits by birds to and from patches of native vegetation may be disrupted if the fruits of invasive plants growing in, or along the borders of, plantations become the preferred food of frugivores. This has happened in the case of the bugweed *Solanum mauritianum* and rameron pigeons *Columba arquatrix* in parts of Natal (Oatley 1984).

The presence of plants with ant-dispersed seeds suggests that myrmecochory still occurs in pine plantations, but at considerably reduced rates. Ant species known to disperse seeds of fynbos plants were found in a *Pinus radiata* plantation at Jonkershoek (Slingsby & Bond 1981; Donnelly & Giliomee 1985). Ants were more scarce, and the ant diversity low, in the pine plantation in comparison with three fynbos vegetation sites (Donnelly & Giliomee 1985).

Similarly, Richardson & van Wilgen (1986) found that the proportion of bird-dispersed, larged-leaved sprouters had increased relative to the other reproductive and growth form guilds in a pine plantation at Jonkershoek over 35 years, owing to the pines providing perches for frugivorous birds. Serotinous non-sprouters, woody small-leaved sprouters, and woody small-leaved myrmecochorous species were eliminated. These authors suggested that myrmecochorous shrubs may re-establish from soil-stored seed after clear-felling or fire.

Wind dispersal of seeds to and from native remnants may be disrupted by the windbreak effect of the pines (Saunders *et al.* 1991).

The replacement of mountain fynbos with pines changed the composition of the bird assemblage from predominantly fynbos species to an assemblage dominated by species of the riparian habitat, but of lower abundance and which lacked the specialist wooded-habitat species (olive woodpecker *Mesopicos griseocephalus*, sombre bulbul, paradise flycatcher *Terpsiphone viridis*). The fragmentation of the populations of fynbos species by the afforestation is expected to have increased the probability of extinction of the sub-populations in the fynbos remnants (Merriam 1991).

Avian frugivores and nectarivores, although consistently present in riparian habitats, were present infrequently in middle-aged and old plantations, and apparently used pines mainly for roosting and as song posts. Some of these species, and some habitat specialist birds which do not use pine plantations, e.g. sugarbirds and woodpeckers, may be prevented from dispersing to, or from, native habitat "islands", although nectarivores are known to disperse widely (Fraser *et al.* 1989).

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There was no statistically discernible impact of pine afforestation on the relative proportions of the different mammalian guilds. The negative impact of afforestation on the species richness and biomass of indigenous plants (Cowling *et al.* 1976; Bigalke 1980; Richardson & van Wilgen 1986; Richardson *et al.* 1989), and therefore on the microhabitats, in pine plantations, appears to affect the different mammalian guilds similarly.

The results suggest that vertebrate seed-dispersers are able to move between patches of indigenous habitats separated by relatively small pine plantations, although some vertebrate pollinators may not. However, vertebrate-mediated pollination and seed dispersal should not be totally disrupted. The results of Midgely and Bond (1990) suggest that if these habitat "islands" are managed well, rodent-mediated pollination (Wiens & Rourke 1978), rodent-mediated seed dispersal (Vlok 1995), and myrmecochory will continue because small mammals and ants should persist in the "islands". For example, burning of a native habitat patch should be done within the natural fire regime, and only one section of the patch at a time to prevent the elimination of species which do not disperse readily through pine plantations. Also, patches of riparian forest and scrub should be kept free of self-seeded plantation trees and other invader plants.

It appears that a contributing factor to the "inhospitable" nature of pine plantations is the management of them (removal of competing vegetation; Hinze 1993), as opposed to the physical effects of the pines alone. Some small mammals survive in plantations where there is adequate undergrowth of indigenous plants. Such plantations are often, but not necessarily, young, and their small mammal inhabitants may include some species that feed on and disperse the seeds of fynbos plants, such as the Cape spiny mouse and Verreaux's mouse (Scott 1978; Breytenbach 1986; Armstrong & van Hensbergen 1995; Vlok 1995).

Corridors between native vegetation remnants and other areas of native vegetation should provide flight pathways for insects, movement pathways for birds and mammals, and perhaps pathways for wind-blown pollen and seeds (e.g. Bennett 1987; Newbey & Newbey 1987; Merriam 1991; Saunders & de Rebeira 1991). Corridors would also act as habitat for certain species. Continuity of ecological and demographic processes should thereby be ensured. For some species, patches of native habitat close to each other and to more extensive areas of the same habitat may act as "stepping stones", allowing movement between the areas of native vegetation (Date *et al.* 1991). Young pine plantations could be considered as "stepping stones" between areas of native vegetation due to the presence of native plants which attract nectar-feeding and fruit-eating birds.

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When considering the zonation and management of indigenous habitat for conservation on forestry estates, should areas of fynbos and riparian forest surrounded by plantations be considered as "islands" in an "inhospitable sea"? The following all indicate that pine plantations are to varying degrees "inhospitable" to at least some indigenous plants, animals and ecological processes: the large negative impact of afforestation with pines on the indigenous flora and fauna in terms of their abundance and species richness; the scarcity or absence of vertebrate pollinators in old plantations; the infrequent and non-permanent occupancy of pine plantations by birds, and; the change in the composition of bird assemblages with time as the pines mature. Therefore it is suggested that fynbos remnants should be managed as if they were "islands" in an "inhospitable sea", and cognisence of this is important when zoning areas of indigenous vegetation for conservation in new forestry regions.

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TABLE 1. Number of plant species in each pollination class in the plantation and fynbos samples

Pollination system	Plantation	Fynbos
Vertebrate classes separate		
Bird & insect	1	7
Bird	0	7
Insect	82	212
Rodent	0	1
Wind	25	46
Vertebrate classes combined		
Vertebrate	1	15
Insect	82	212
Wind	25	46

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TABLE 2. Number of plant species in each seed dispersal class in the plantation and fynbos samples

Seed dispersal system	Plantation	Fynbos
Ant	16	40
Other	34	101
Vertebrate	29	33
Water	1	9
Wind	31	99

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TABLE 3. Number of plant species in each potential persistence class in the plantation and fynbos samples

Persistence mode	Plantation	Fynbos
Dispersed propagule	12	36
Retained propagule	49	105
Resprouting & dispersed propagule	11	32
Resprouting & retained propagule	39	109

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TABLE 4. Number of bird species in each class of the various characteristics in the plantation and riparian habitat samples (from Armstrong & van Hensbergen 1994)

Characteristic	Class	Habitat			
		Pine (years)			Riparian
		3	8	29	
Diet	Frugivore	1	2	1	3
	Frugivore/insectivore	1	1	1	2
	Granivore	2	2	3	4
	Granivore/insectivore	1	-	-	-
	Herbivore/insectivore	1	1	1	1
	Herbivore	1	-	-	1
	Insectivore	7	5	5	9
	Nectarivore	3	2	1	3
	Raptor/insectivore	2	-	-	-
Foraging substrate	Ground	4	2	2	3
	Undergrowth	6	4	3	4
	Shrubs	3	3	2	4
	Tree bole	-	-	-	1
	Tree canopy	2	2	3	6
	Aerial	1	-	-	-
	Most substrata	3	2	2	5
Nest site	Ground	1	-	-	-
	Rock	1	-	1	1
	Undergrowth	6	1	1	2
	Shrub	5	1	-	7
	Tree cavity	-	-	1	1
	Tree canopy	3	6	5	6
Indigenous habitat assemblage	Fynbos	7	2	2	4
	Riparian	5	6	7	14
	Both	7	5	3	5

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TABLE 5. Number of mammal species in each diet class in the plantation and native habitat samples

Diet	Young plantation	Mature plantation	Fynbos	Riparian habitat
Carnivore	2	1	5	3
Folivore	1	1	4	0
Frugivore	1	0	1	1
Granivore	1	0	1	1
Herbivore	1	1	5	2
Insectivore	2	1	2	3
Omnivore	0	0	0	1
Herbivore (subterranean plant parts)	1	0	3	2

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TABLE 6. Number of mammal species in each foraging microhabitat class in the plantation and native habitat samples

Foraging microhabitat	Young plantation	Mature plantation	Fynbos	Riparian habitat
Ground	1	0	5	4
Among herbs	5	2	8	4
Among shrubs	2	1	8	2
Water	0	0	0	2
Most microhabitats	1	1	0	1

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TABLE 7. Number of mammal species in each resting site class in the plantation and native habitat samples

Resting site	Young plantation	Mature plantation	Fynbos	Riparian habitat
Ground	3	1	7	4
Open rocky area	0	0	2	1
Rock crevace	1	0	3	1
Among herbs	3	1	5	6
Among shrubs	1	1	4	0
Tree hole	1	1	0	1

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Caption for Figure

FIGURE 1 Location of Jonkershoek and the study areas.

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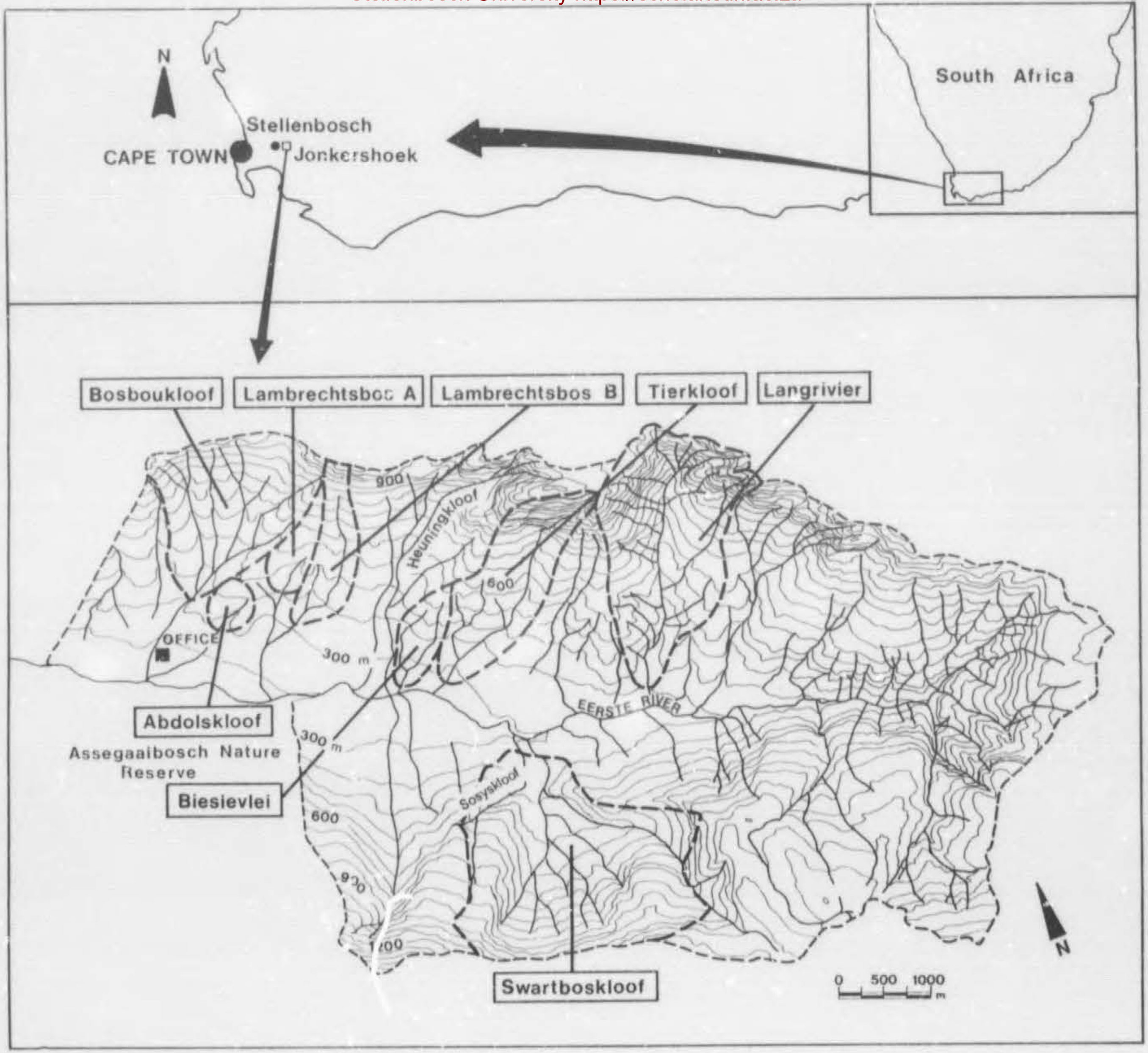

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Section 2

Evaluation of afforestable montane grasslands for wildlife conservation

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Chapter 5

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Scientific Paper

Evaluation of Afforestable Montane Grasslands for Wildlife Conservation in the North-Eastern Cape, South Africa. Part 1. Methods

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SYNOPSIS

Wildlife conservation evaluations of afforestable Afromontane grasslands are required. The methodology given is for rapid evaluation by a single person with minimal equipment. Grasshoppers, butterflies, birds and small mammals are key taxa for sampling. A survey of these taxa in different environments using an obligatory design and gradient-directed transect sampling is suitable. Sampling sites within an environment cover the variability in topography and aspect. Sampling at a site covers variability in the habitat. A visual description or the step-point method can be used to give an indication of habitat composition. Grasshoppers, butterflies and birds are adequately sampled by timed walk-through counts, and small mammals by trapping on a grid. The survey should be done between November and March.

INTRODUCTION

The strategic development plan for forestry in South Africa includes the afforestation of more than one million hectares with exotic tree species over 30 years (Van der Zel, 1989). Plantations of exotic trees have a negative effect on the diversity of indigenous animals (Bigalke, 1980; Armstrong, 1993). Nature conservation personnel have limited time to make recommendations from a wildlife conservation perspective about specific afforestation permits. Therefore, rapid and efficient methods of assessing the conservation value of afforestable areas need to be developed.

Most current large-scale afforestation in South Africa is in montane grasslands. One such area, the Maclear district of the north-eastern Cape, situated at the southern end of the Drakensberg, South Africa, is presently being afforested on a large scale (Department of Water Affairs and Forestry, 1993). Wildlife conservation evaluations are required, but no formal evaluation methodology has been developed for these grasslands.

A survey of all the major taxa present in the montane ecosystem is not possible due to financial and time costs. It is necessary, therefore, to choose key taxa for sampling. Simple, standardised sampling methods should be used to obtain species richness and relative abundance for each key taxon. However, literature on the suitability of different sampling methods for specific wildlife groups in montane grasslands in South Africa is limited.

The aim of this study was to develop a methodology for the wildlife conservation evaluation of afforestable montane grasslands in South Africa. Specific aims were to determine:

1. which taxa should be sampled,
2. the methods of sampling that should be used, and
3. a suitable survey design.

A prerequisite is that the methodology must be suitable for a single person, not necessarily an expert on any of the taxa sampled, who will undertake the full conservation evaluation.

MATERIALS AND METHODS

Choice of taxa to sample

Animals most at threat from land conversion are species that occur only in the environments typical of that area. These endemic species are therefore of special concern, as are animal taxa that have a large number of species in the ecosystem. The integrity of an ecosystem depends on its unimpaired functioning. Different land uses may have different impacts on organisms that are important contributors to the functioning of the ecosystem. These organisms must remain in the area.

The costs of external identifications and curation of specimens in three surveys in Western Australia made up between 1 % and 10 % of the total project budget (Burbidge, 1991). Therefore, it is best to sample well-known taxa which are easily recognized in the field. Taxa should be sampled using reliable, relatively easy, standardised sampling techniques. If one or two taxonomic groups contribute inordinately to species richness or biomass of a higher taxon, the

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lower taxonomic level only need be sampled. On the other hand, it is plausible that richness at a higher taxonomic level can be used to predict species richness (Gaston and Williams, 1993). Sampling at higher taxonomic levels may be cost-efficient where species identification is difficult.

It is necessary to include taxa with extremes in space requirements in the survey, i.e. mobile taxa, with wide individual space requirements, and sedentary taxa, with small individual space requirements. The former need larger areas of land for conservation.

Therefore it is suggested that taxa or groups to be sampled should:

1. have relatively high percentages of species endemic to the montane grassland ecosystem;
2. have relatively high species richness in the montane grassland ecosystem;
3. be important contributors to ecosystem functioning;
4. occur in all or most habitats in the montane grassland ecosystem;
5. be amenable to sampling by simple, relatively unbiased, standardised methods;
6. be taxonomically well-known and easy to identify; and
7. cover, between them, a wide range in spatial requirements.

These criteria are ordered in descending importance for this study. A search was made of relevant literature to determine potentially suitable taxa in South African montane grasslands. Potentially suitable taxa (based on available knowledge) are listed in *Table 1*. The four groups chosen for sampling during the survey were grasshoppers, butterflies, birds and small mammals.

Habitat description

An indication of the habitat composition at each sampling site was obtained using the step-point method (Bond, Ferguson and Forsyth, 1980; Mentis, 1981; Everson and Clarke, 1987). At least 100 points were taken at each site, generally in the bird plot (see later; cf. Hardy and Walker, 1991). A point was taken every second step along two perpendicular diameters of the plot. Occasionally guesses had to be made as to

TABLE 1. Potentially suitable taxa for sampling in the montane ecosystem. Criterion numbers correspond to those given in the text in the Methods section. An "" indicates that the taxon fulfills the criterion.*

Taxon	Criterion						Reference[a]
	(1)	(2)	(3)	(4)	(5)	(6)	
Annelids:							
Earthworms	*	*	*	*	*		1
Arachnids:							
Spiders	*	*	*	*			2
Insects:							
Grasshoppers	*	*	*	*	*	*	3,4
Butterflies	*	*	*	*	*	*	5
Moths		*	*	*			6
Beetles	*	*	*	*	*		7
Reptiles:							
Lizards	*	*	*	*		*	8
Birds	*	*	*	*	*	*	9,10
Mammals:							
Small mammals		*	*	*	*	*	11,12

[a] 1 Sims, 1978; 2 Newlands, 1978; 3 Samways, 1990; 4 Gandar, 1982; 5 Carcasson, 1964; 6 H. Geertsema, pers. comm.; 7 Endrödy-Younga, 1978; 8 Branch, 1988; 9 Dowsett, 1986; 10 Willan, 1992; 11 Lynch, 1989; 12 Rowe-Rowe, 1986.

TABLE 2. Environments defined by combinations of variables. Environment designation: first digit = altitude class (1=1 300-1 500 m; 2=1 500-1 700 m; 3=1 700-1 900 m); first letter = first letter of geological formation (B[asalt]; C[larens]; E[lliot]; M[olteno]; second letter = mean annual rainfall class (L[ower] = < 900 mm; H[igher] = ≥ 900 mm)

Altitude (x 1 000 m)	Lithology (formation)	Mean annual rainfall	Environment designation
1,7 - 1,9	Basalt	≥ 900 mm	3BH
1,7 - 1,9	Clarens	< 900 mm	3CL
		≥ 900 mm	3CH
1,7 - 1,9	Elliot	< 900 mm	3EL
		≥ 900 mm	3EH
1,5 - 1,7	Elliot	< 900 mm	2EL
		≥ 900 mm	2EH
1,3 - 1,5	Elliot	< 900 mm	1EL
		≥ 900 mm	1EH
1,3 - 1,5	Molteno	< 900 mm	1ML
		≥ 900 mm	1MH

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the situation of points where there were insurmountable obstacles, eg. sheer rock faces.

The habitat features measured are indicated in *Table 3*. Grass and sedges were grouped together, and divided into two classes according to height. The class cutpoint was at 300 mm height. *Themeda triandra* is the dominant grass in the region and when mature is at least 300 mm tall (Gibbs-Russel *et al.*, 1990). A 300 mm long spike, placed at the point, enabled the rough classification of the vegetation in front of it into a height class.

Only the highest stratum was considered at any point. Plants were considered to be solid to their canopy edges. Dead standing plants were classified with living plants; felled plants, branches etc. were classified as litter. Bare soil, stones smaller than boot size, and termite and molerat mounds were classified into the bare ground class. Photographic slides were taken of the habitats.

Sampling methods for the key taxa

Data were collected between April and September 1993. Each wildlife group was sampled on four days (or the equivalent number of samples taken) at a site. Factors affecting the detectability or catchability of animals include time of day and climate conditions such as rain, mist and wind (Pollard, Hall and Bibby, 1986; Samways, 1990; Bibby *et al.*, 1992; van Hensbergen and Martin, 1993). Sampling (except small mammal trapping) was not done under conditions of rain, mist or consistently strong wind.

Grasshoppers

Grasshoppers were sampled by flushing and by sweeping in each environment on each sampling occasion. Sampling was done, where possible, perpendicular to the bird plot radii coinciding roughly with the major bearings. The sweep samples and flush samples were taken along parallel bearings, at least 10 paces apart to minimise bias from fleeing individuals.

One hundred sweeps were done per day in units of 10 sweeps. A sweep consisted of moving a standard (*ca* 380 mm diameter) insect net through the top of the vegetation in a 180° arc at each step along the bearing (modified from Evans, Rogers and Opfermann, 1983). After 10 sweeps any grasshoppers captured were removed from the net and placed in a killing jar containing ethyl acetate.

TABLE 3. Habitat descriptions for sites in different environments. Shannon indices (H') are for habitat diversity

Environment	Site	No of points	Percent composition (to nearest percent)								Habitat designation	H '	Last fire (yrs)	Last grazing (months)
			Grass >300 mm	Grass <300 mm	Woody plants	Herbs	Litter	Rock	Soil etc.	Water				
1ML	Ridge	165	13	38	3	1	5	30	10	-	Short grassland, pavement rock	1,53	3	36
1MH	Valley	169	66	17	5	2	6	1	3	1	Tall grassland	1,17	4+	48+
1EL	Ridge	163	2	90	-	1	3	-	4	-	Short grassland	0,45	2	5
1EL	East slope	170	28	67	-	4	1	-	1	-	Short grassland	0,85	2	6
1EL	Vlei	150	51	49	-	-	-	-	-	-	Tall grassland	0,69	3	24
1EH	West slope	175	19	39	-	2	2	29	9	-	Short grassland, pavement rock	1,41	4+	48+
1EH	North slope	121	25	60	11	2	-	1	2	-	Short grass *Protea* savanna, boulder slope	1,10	4+	48+
2EL	Ridge	148	7	56	14	2	8	7	9	-	Short grass *Protea* savanna, pavement rock	1,47	1	8
2EL	North slope	167	28	38	5	2	1	22	4	-	Short grass *Protea* savanna, boulder slope	1,46	1	8
2EL	North slope	152	13	69	-	-	1	14	4	-	Short grassland, pavement rock	0,97	1	8
2EL	South slope	145	65	16	18	-	-	1	-	-	Tall grass *Protea* savanna	0,93	1	8
3BH	South slope	144	36	56	1	3	3	1	1	-	Short grassland	1,04	2	3

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Flush counts consisted of walking along the bearing for one minute. When a grasshopper was flushed, the timer was stopped and an attempt was made to capture the individual. The same line was then regained at or slightly ahead of the flushing point and the flushing resumed.

Only adult grasshoppers were recorded. Grasshoppers caught were classified into different morphotypes (not identified species). Sampling was done between 10:00 and 15:30.

Butterflies

Butterflies were sampled on 10-minute walk-through counts. The counts were confined to the bird plots, except at two sites where the counts were not confined to a specific area. The sampling method involved slowly walking through the habitat searching for butterflies, and stopping at will. When an individual that could not be identified was sighted during a count, the timer was stopped and an attempt was made to capture the individual. Unidentified butterflies were recorded as such, unless obviously different from species already recorded at the site. Sampling was done between 10h00 and 15h15.

Birds

Birds were sampled on timed walk-through counts (Loyn, 1986; Koen, 1988; Fraser, 1989). Counting was done in fixed circular plots of 50 m and 75 m radius (modified from Koen, 1988). Counts were also done at the same sites without regard to the area sampled (after Loyn, 1986). The sites were searched for birds by walking through the habitat, stopping at will.

The smaller circular plot was centred at the middle of the larger circular plot. Counting began from outside the plots if birds began to move away on approach. Counts were 10 minutes long. Counting was done mainly on the smaller plot for the first five minutes, and only in the area of the larger plot outside the smaller plot for the final five minutes.

Timed counts of unbounded area were commenced immediately before and/or after the plot counts and were continued for 20 minutes. These unbounded-area counts were begun or ended some distance away from the plots to minimise bias from flushed birds. Data from the first 10 minutes of a count were considered separately from the full 20-minute count to enable comparison with counts from the large circular plot. The plot method was considered as the standard in comparisons because the area sampled was known and searching of plots could be fairly thorough within the time limit.

Birds seen or heard were recorded. Unidentified birds were recorded as such. Birds overflying the habitat that were assumed only to be in transit were excluded. All other birds were recorded, including those displaying or obtaining lift over the habitat. Morning counts began at least half an hour after sunrise and ended before 11:00. Afternoon counts began after 15:30. Species occurring in South Africa which are endemic or near-endemic to montane regions in Africa were obtained from Dowsett (1986) and Maclean (1993). The term endemic is used in this sense.

Small mammals

A grid of 100 trap points was set up at each site. Trapping points were in 10-by-10 arrangement, each point being 10 m apart. One Sherman live trap was placed within 1 m of each point. Traps were baited with a mixture of peanut butter, oats, lard, candle wax and raisins/currants (modified from Willan, 1986). At some sites, traps on alternate grid lines were baited with a mixture of oats, sunflower oil and currants to increase the probability of capture of herbivorous species (Willan, 1986). A shortage of traps precluded setting two traps per point, each trap with a different bait, as suggested by Willan (1986).

Sampling on two grids was split (i.e. some traps were placed/removed before the others) owing to human disturbance of traps and a shortage of set-up time. The first grid line at two sites had two traps, set 1 m apart, per trapping point. A capture in the second trap at a trapping point was excluded from the results if there was a simultaneous capture in the first trap.

Small mammals were marked by fur-clipping, and most were individually marked by nail-clipping (Twigg, 1975). Identification of species was confirmed where necessary through hair characters (Keogh, 1985). Traps were checked once a day. Ether was used to anaesthetise rodents to facilitate marking and examination. Information in Rowe-Rowe (1986) was used to classify small mammals into diet class.

The fewest consecutive gridlines that would have captured all species recorded at a site was obtained from the data. A computer program was also written to randomly select sets of traps, and square grids of traps, of specified sizes from each 10-by-10 grid. Each time a set of traps was selected, the species caught in that set were recorded. Each set size was selected 1 000 times. In this way an average occurrence of each species in the specified set size could be obtained. The size of the set of traps was initially small and was increased until the rarest species occurred in the set at least 50 % of the time. The same procedure was carried out for the random selection of square grids of traps.

Survey design

Gradient-directed transect sampling, using an obligatory survey design, was considered appropriate for the study region. The relatively large area involved, time costs, and the limited previous survey work in the region were the main reasons for this choice (Collinson, 1985; Austin and Heyligers, 1989). Sampling sites were within 1 km of an access track or road.

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The variables chosen to delimit the environments in this area were altitude, rainfall and geology (*Table 2*). The altitude ranges from around 1 300 m upwards in the Ugie-Maclear area (South Africa 1: 50 000 sheets 3028CD, 3128AA, 3128AB, Surveys and Mapping, Cape Town). Intervals of 200 m were chosen between 1 300 m and 1 900 m to encompass the afforestable altitudinal range. Temperature is negatively correlated with altitude in the study region and environs (Weather Bureau, Pretoria; Department of Agricultural Engineering, University of Natal). Mean annual precipitation data (calculated on a 1° x 1° grid for the region) were used (Dent, Lynch and Schulze, 1987; Computing Centre for Water Research, University of Natal). Two classes were used so as to divide equally the range in mean annual precipitation: < 900 mm and ≥ 900 mm. The major geological formations present in the study region were used (1:250 000 Geological Series Maps, Geological Survey, Pretoria). Those of limited areal extent, eg. dolerite, were not sampled.

Altitude and rainfall influence the distributions of some grasshoppers (Evans, Rogers and Opfermann, 1983), butterflies (Carcasson, 1964), birds (Dowsett, 1986, Maclean, 1993) and small mammals (Lynch, 1989). The distribution or abundance of some animal species is influenced by the distribution of various vegetation types (eg. Rowe-Rowe and Meester, 1982a; Lynch, 1989). Plant distributions, and therefore vegetation types, are influenced indirectly by geological formation through the distribution of soils derived from these formations (eg. McDonald, 1985; Hilliard and Burtt, 1987).

The variables defining the environments should ideally be independent. This is not the case since rainfall increases with elevation (Dent, Lynch and Schulze, 1987) and geological formation tends to change predictably with altitude (1:250 000 Geological Series Maps, Geological Survey, Pretoria). All three were used to define the environment owing to the lack of information on which are the primary variables influencing the distribution and abundance of the animals.

Sampling in a full conservation evaluation should be done on a crest/ridge, an exposed slope, a sheltered slope, a slope of intermediate exposure, and a bottomland in each environment (Austin and Heylighers, 1989). Topography and aspect are known to influence the distribution and abundance of grasshoppers and small mammals in South African montane regions (Samways, 1990; Bowland and Perrin, 1993). Since topography and aspect influence plant distribution and physiognomy in South African montane regions (eg. Killick, 1963), they are likely to influence other animal distributions (see Evans, 1988 for an example of grasshoppers elsewhere).

Fire and grazing effects

Fire frequency has an effect on grasshopper and small mammal communities in grassland (eg. Rowe-Rowe and Lowry, 1982; Evans, 1988; Chambers, 1992). Mowing influenced the composition of grasshopper communities in tall grassland at a site in South Africa (Chambers, 1992). Grazing is likely to have similar effects since the removal of vegetation biomass is involved. Time since the last fire (years) and time since the last grazing (months) were therefore recorded.

Time of survey

Temperature data for place in the NE Cape were obtained from the Weather Bureau, Pretoria. Predicted monthly rainfall data were obtained from the models of Zucchini and Adamson (1984), using 1 000 years of generated rainfall.

Common butterfly species expected to occur in the montane grasslands of the afforestable region of the NE Cape were obtained from the distribution maps in Migdoll (1987). Their flight periods were obtained from the same source.

Birds recorded in the study region were obtained from unpublished lists (A.J.F.K. Craig, pers. comm.; Cape Nature Conservation). Only grassland, *Protea* savanna, montane scrub and vlei species were considered. Breeding seasons for these species, in the Eastern Cape Province (or Natal) where available, and months during which migrants are present in South Africa were obtained from Maclean (1993). Breeding seasons of small mammals in montane grasslands were obtained from Rowe-Rowe and Meester (1982b), Smithers (1983), and Lynch (1989).

RESULTS

Habitat description

Table 3 gives an indication of the habitat compositions. Rocky habitats were the most diverse.

Grasshoppers

The results of the sampling trials are given in *Table 4*. There was no significant difference between the flush and the sweep methods in the mean number of morphotypes and individuals recorded (morphotypes: $t_{0,025} = 0,161$; df = 20; N/S; individuals: $t_{0,025} = 0,245$; df = 20; N/S). Four morphotypes were recorded during flush counts, and 10 morphotypes during sweep counts. However, the flush method was far more efficient in terms of time (mean time per daily sample; flush: $\bar{X} = 6,2$ minutes; s = 7,24, n = 37; sweep: $\bar{X} = 14,5$ minutes; s = 4,626; n = 36). This difference is significant ($t_{0,025} = 5,85$; df = [illegible]1; $p < 0,001$).

Forty flushed individuals were unidentified (because they could not be [illegible]ught within a reasonable search pe[illegible] with two escapees during the swee[illegible]ree quarters of the unidentified in [illegible] at the three sites with the highest [illegible] A third of the morphotypes (all "rare [illegible] only on the fourth day of sampling. A[illegible]ur days sampling are required

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for grasshoppers.

The highest number of morphotypes and individuals were recorded from an east slope in the lowest altitude class (*Table 4*). A vlei at the lowest altitude and a south slope at the middle altitude had the fewest morphotypes and individuals.

Butterflies

The number of species and individuals at the sampled sites were low. Butterflies appeared to be fairly uniformly distributed over the study area in winter. Rocky sites tended to support more species and individuals than other sites (*Table 5*).

TABLE 4. Results for two grasshopper sampling methods in different environments and at different sites

Environment	Site	Habitat	Count type	Morphotypes	Total individuals
1ML	Ridge	Short grassland, pavement rock	Flush Sweep	1 2	3 2
1MH	Valley	Tall grassland	Flush Sweep	4 2	41 29
1EL	Ridge	Short grassland	Flush Sweep	2 1	4 1
1EL	East slope	Short grassland	Flush Sweep	2 6	46 31
1EL	Vlei	Tall grassland	Flush Sweep	1 0	1 0
1EH	West slope	Short grassland, pavement rock	Flush Sweep	3 4	20 12
1EH	North slope	Short grass *Protea* savanna, boulder slope	Flush Sweep	3 3	11 13
2EL	North slope	Short grass *Protea* savanna, boulder slope	Flush Sweep	3 2	5 3
2EL	North slope	Short grassland, pavement rock	Flush Sweep	3 4	6 19
2EL	Ridge	Short grass *Protea* savanna, pavement rock	Flush Sweep	1 3	2 12
2EL	South slope	Tall grass *Protea* savanna	Flush Sweep	0 1	0 1

*TABLE 5. Results of butterfly sampling in different environments and at different sites. * = counts not confined to plot*

Environment	Site	Habitat	Species	Mean No. individuals per count
1ML	Ridge	Short grassland, pavement rock	3	1,75
1MH	Valley	Tall grassland	1	0,5
1EL	Ridge	Short grassland	1	0,25
1EL	East slope	Short grassland	0	0
1EL	Vlei	Tall grassland	2	6,5
1EH	West slope	Short grassland, pavement rock	2	1
1EH	North slope	Short grass *Protea* savanna, boulder slope	6	3,25
2EL	North slope	Short grass *Protea* savanna, boulder slope	1*	1,5
2EL	North slope	Short grassland, pavement rock	3*	2
2EL	Ridge	Short grass *Protea* savanna, pavement rock	2	1
2EL	South slope	Tall grass *Protea* savanna	1	0,75

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TABLE 6. Presence of bird species at different sites and environments during plot counts (p), 10-minute walk-through counts (w), or both counts (b), mornings only. E = African montane endemic; North = north-facing slope, South = south-facing slope, West = west-facing slope, East = east-facing slope.

Species	E?	Site	North			South	West	East	Ridge		Vlei	Valley
		Environment	1EH	2EL	2EL	2EL	1EH	1EL	1ML	1EL	1EL	1MH
Buteo rufofuscus							p					
Falco tinnunculus							p					
Francolinus levaillantii	E				p							
Columba guinea					w	w						
Streptopelia capicola												w
Apus melba												w
Apus barbatus			p									b
Apus caffer			p									
Colius striatus												w
Geocolaptes olivaceus			w									
Hirundo cucullata			w					b				b
Hirundo fuligula					b							w
Riparia cincta								w				
Dicrurus adsimilis									w			
Corvus capensis						w						
Pycnonotus barbatus				w								b
Turdus olivaceus	E				w							
Monticola rupestris			w	w			b					w
Oenanthe monticola							b					
Oenanthe bifasciata	E		w				b					w
Cercomela familiaris			w						w			b
Myrmecocichla formicivora								w				
Saxicola torquata							b				w	b
Cossypha caffra	E											w
Sphenoeacus afer			w			b						
Cisticola juncidis												w
Cisticola ayresii	E						b	b		w		
Cisticola lais	E		b	w	w	p	b					
Cisticola tinniens							w					b
Cisticola fulvicapilla					w							
Prinia maculosa			w		w							
Motacilla capensis					w							
Anthus cinnamomeus							p		w	w		
Macronyx capensis					p		w	w		w		
Lanius collaris			p									w
Telophorus zeylonus							b					
Onychognathus morio				b			w					b
Promerops guerneyi	E		w	w								
Nectarinia famosa	E		b									
Passer griseus												w
Euplectes progne							w					p
Euplectes ardens							w					p
Euplectes capensis							w					w
Estrilda astrild												b
Ortygospiza atricollis								b			w	p
Vidua macroura												w
Serinus canicollis	E						w					
Emberiza capensis					b							

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Birds

Data from plots are given below as the mean (± 1SD) for species, and the mean of means (± 1SD) for birds, in comparisons between plot counts only. Five (±4,5) and 7,2 (±4,4) species were recorded on the 50 m and the 75 m radius plots, respectively (afternoon counts included; n = 6; three sites sampled). There were 7,9 (±11,6) and 11,6 (±12,4) birds per count on the 50 m and the 75 m radius plots, respectively (afternoon counts included; n = 6; three sites sampled). Two of the three 50 m radius plots had few species and individuals. Data collected at the end of the prior summer also indicated that 50 m plots were too small to adequately sample birds in montane grasslands (4,3 [±1,8] species; n = 10) Therefore 75 m radius plots (= "plots") were used in further comparisons.

There was no significant difference between the number of species recorded on the same plot in the morning and the afternoon at the three sites sampled (*Table 7*; paired samples $t_{0,025}$ = 0,671; df = 2; N/S). This indicates that sampling of birds can be done either before 10:00 or after 15:30.

Fewer species and individuals were usually recorded during counts on plots than during 10-minute unbounded-area counts at the same sites. There was a significant linear relationship between the number of species recorded on plots and during 10-minute counts (*figure 1*; morning counts only):

Ten-minute count =
1,46 x plot count + 2,35
r = 0.962; df = 8; $p < 0,001$ (1)

There was also a significant linear relationship between the number of species recorded on plots and during 20-minute counts:

*TABLE 7. Results for bird sampling methods in different environments and different sites. **Brackets indicate afternoon counts. Shannon indices (H') are for bird diversity (BI; plots: morning counts) and habitat diversity (HA)***

Environment	Site	Habitat	Count type	Species	Endemics	Mean No. per count	H' (BI)	H' (H)
1ML	Ridge	Short grassland, pavement rock	Plot 10 min 20 min	0 3 7	0 0 0	0 1,75 3,75	–	1,53
1MH	Valley	Tall grassland	Plot 10 min	11 (12) 21 (15)	0 (1) 2 (2)	31,5 (22) 20,75 (8,75)	1,72	1,17
1EL	Ridge	Short grassland	Plot 10 min 20 min	0 3 3	0 1 1	0 1,25 4,25	0	0,45
1EL	East slope	Short grassland	Plot 10 min	3 (2) 6 (8)	1 (1) 1 (1)	2,25 (1,25) 6,75 (5,25)	0,85	0,85
1EL	Vlei	Tall grassland	Plot 10 min 20 min	0 2 4	0 0 0	0 1,25 2,75	–	0,69
1EH	West slope	Short grassland, pavement rock	Plot 10 min 20 min	10 14 17	3 4 4	5 18,25 27,5	2,20	1,41
1EH	North slope	Short grass *Protea savanna*, boulder slope	Plot 10 min	5 (10) 11 (8)	2 (5) 4 (4)	3,25 (9,25) 7,25 (3,5)	1,26	1,10
2EL	Ridge	Short grass *Protea* savanna, pavement rock	Plot 20 min	3 12	0 1	1,75 9,5	0,96	1,47
2EL	North slope	Short grass *Protea* savanna, boulder slope	Plot 10 min 20 min	1 5 9	0 2 3	0,5 2,25 5	–	1,46
2EL	North slope	Short grassland, pavement rock	Plot 10 min 20 min	4 8 9	1 2 2	2 3,75 4,75	1,21	0,97
2EL	South slope	Tall grass *Protea* savanna	Plot 10 min 20 min	2 3 5	1 0 0	1 1,75 2,25	0,69	0,93

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Twenty-minute count =
1,2 x plot count + 5,25
$r = 0{,}877$; df = 6; $p < 0{,}005$ (2)

Ten-minute unbounded-area counts were more efficient than the other counts in terms of the number of species recorded per unit time taken (10 minutes).

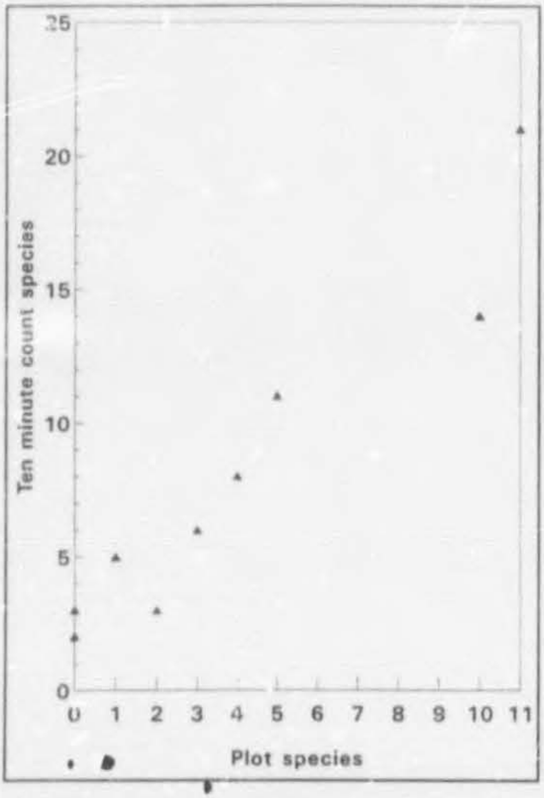

FIGURE 1. Number of avian species recorded on 75 m radius plots and during 10-minute unbounded-area counts in the same habitat.

Bird species recorded on plots were usually recorded during walk-through counts at the same site (*Table 6*).

The relationship between the mean number of individuals per day recorded on plots and on 10-minute counts was (morning counts only):

Ten-minute count =
0,6 x plot count + 3,77
$r = 0.799$; df = 8; $p < 0{,}01$ (3)

Unbounded-area counts were generally more efficient than plot counts in term of numbers of individuals recorded per unit time.

Topography and aspect influenced bird distributions (*Table 6*). High bird diversity was apparently associated with high habitat diversity, and conversely (*Table 7*). North rocky slopes supported relatively high numbers of endemic montane species.

Small mammals

TABLE 9. Bait preferences of small mammals (Peanut butter and lard = oats and raisins / currants plus peanut butter, lard and candle wax; Sunflower oil = oats and currants plus sunflower oil)

Species	Diet class	Total number captures	
		Peanut butter and lard	Sunflower oil
Rhabdomys pumilio	Granivore	37	30
Myosorex varius	Insectivore	31	15
Otomys irroratus	Herbivore	3	19
Mus minutoides	Granivore	6	6
Dendromus spp	Granivore	2	0
Graphiurus murinus	Insectivore/ granivore	0	1

TABLE 8. The numbers of consecutive gridlines, randomly selected traps (on average over 1 000 runs) and the smallest square grid (on average over 1 000 runs) required to sample all species recorded at each site. Percentages indicate the chance of capture of the rarest species at the given number of traps

Environment	Site	Number of gridlines	Number of traps (50% chance)	Square grid size (50 % chance)
1ML	South slope	1	25	7 x 7
1EL	Ridge	-	-	-
1EL	East slope	1	72	10 x 10
1EL	Vlei	2	65	6 x 6
1EH	North slope	6	70	9 x 9
2EL	South slope	3	71	8 x 8
2EL	North slope	9	72	10 x 10
3BH	South slope	1	68	9 x 9

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*TABLE 10. Minimum number of the different small mammals alive per hectare at different sites and environments. North = north-facing slope, South = south-facing slope, East = east-facing slope; P = peanut butter and lard bait, B = both baits (Table 8); *= droppings and runs indicated presence.*

Species	Site	North		South			East	Ridge	Vlei
	Environment	1EH	2EL	1ML	2EL	3BH	1EL	1EL	1EL
	Bait	P	B	P	B	B	P	P	P
Myosorex varius		2	1	8	13	21	3	-	16
Crocidura flavescens		1	-	-	-	-	-	-	1
Crocodura cyanea		-	-	-	1	-	-	-	-
Otomys irroratus		-*	-	-	1	9	-	-	1
Dendromus melanotis		2	-	-	1	-	1	-	-
Dendromus mystacalis		-	-	-	-	1	-	-	-
Rhabdomys pumilio		18	2	13	17	9	-	-	35
Mus minutoides		4	7	1	-	-	-	-	5
Graphiurus murinus		-	1	-	-	-	-	-	-

TABLE 11. Species (Spp) and minimum number of individuals alive (MNA) of small mammals at trapping sites. Shannon indices (H') are for small mammal diversity (SM) and habitat diversity (HA)

Environment	Site	Habitat	Spp	MNA	H' (SM)	H' (HA)
1ML	Ridge/south slope	Short grassland, pavement rock	3	22	0,82	1,53
1EL	Ridge	Short grassland	0	0	0	0,45
1EL	East slope	Short grassland	2	4	0,56	0,85
1EL	Vlei	Tall grassland, pavement rock	5	58	1,01	-
1EH	North slope	Short grass *Protea* savanna, boulder slope	5	27	1,06	1,10
2EL	South slope	Tall grass *Protea* savanna	5	33	1,03	0,93
2EL	North slope	Short grassland, pavement rock	4	11	1,03	0,97
3BH	South slope	Short grassland	4	40	1,10	1,04

TABLE 12. Time since last fire and grazing in relation to animal numbers and diversity

Environment	Site	Last fire (years)	Last grazing (months)	Grasshoppers (total flushed)	Butterflies (mean number)	Birds (H')	Small mammals (H')
2EL	Ridge	1	8	2	1	0,96	
2EL	North slope	1	8	5	1,5	0	
2EL	North slope	1	8	6	2	1,21	1,03
2EL	South slope	1	8	0	0,75	0,69	1,03
3BH	South slope	2	3				1,10
1EL	Ridge	2	5	4	0,25	-	0
1EL	East slope	2	6	46	0	0,85	0,56
1EL	Vlei	3	24	1	6,5	-	1,01
1ML	Ridge	3	36	3	1,75	-	0,82
1MH	Valley	4+	48+	41	0,5	1,72	
1EH	West slope	4+	48+	20	1	2,20	
1EH	North slope	4+	48+	11	3,25	1,26	1,06

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The fewest consecutive trap lines required to sample all species at most sites was between one and three (mean: three; *Table 8*). Six and nine consecutive trap lines were required, respectively at two sites.

The number of randomly selected traps on average required for a 50 % chance of capturing the rarest species was 70. The minimum size of a square grid required on average for a 50 % chance capturing the rarest species was eight-by-eight.

Granivores did not prefer one bait over the other (*Table 9*). Insectivores preferred the bait containing peanut butter and lard. Herbivores preferred bait containing sunflower oil and no peanut butter or lard.

Small mammal distributions were influenced by topography (*Table 10*). High small mammal diversity was apparently associated with high habitat diversity, and conversely (*Table 11*). At three sites one or two new species were caught on the fourth day of trapping. At six sites relatively high numbers of new individuals were caught on the fourth day. Therefore, at least four days of trapping are required.

Fire and grazing effects

The diversity and numbers of grasshoppers and butterflies recorded showed no consistent relationship to fire or grazing frequency (*Table 12*). Relatively high bird diversities were apparently associated with relatively long post-fire and post-grazing periods (*Table 12*). Low bird diversity was associated with recent grazing. Small mammal diversity showed no consistent relationship to fire or grazing frequency (*Table 12*). However, two of the most recently grazed sites prior to sampling had the lowest small mammal diversities.

Time of survey

Mean predicted rainfall, mean minimum temperature, and mean maximum temperature peak between December and March at Maclear (*Figure 2*). The lowest predicted rainfall, mean minimum temperatures, and mean maximum temperatures occur between May and August. Data for other, nearby, places in the NE Cape showed the same trend.

Relevant data for some of the key taxa are summarised in *Figure 3*. More common butterfly species should be on the wing from December to February.

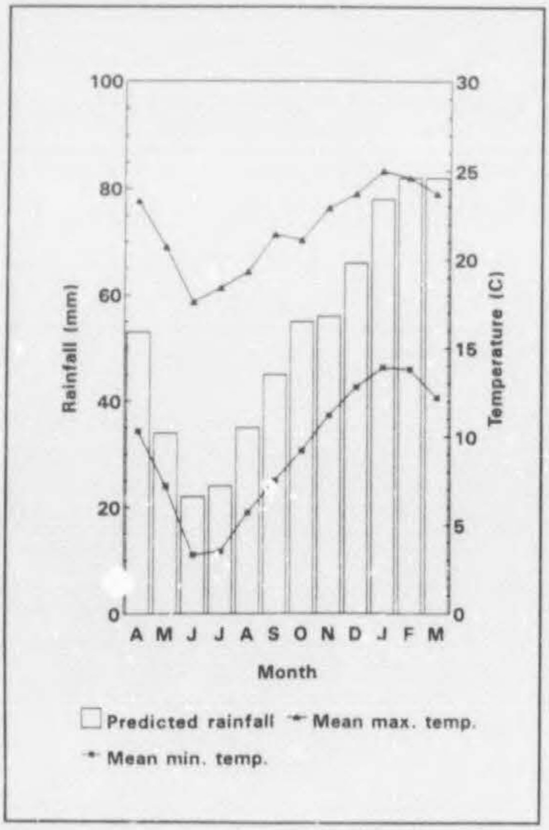

FIGURE 2. Predicted monthly rainfall, and mean monthly minimum and maxmum temperatures for Maclear, NE Cape Province.

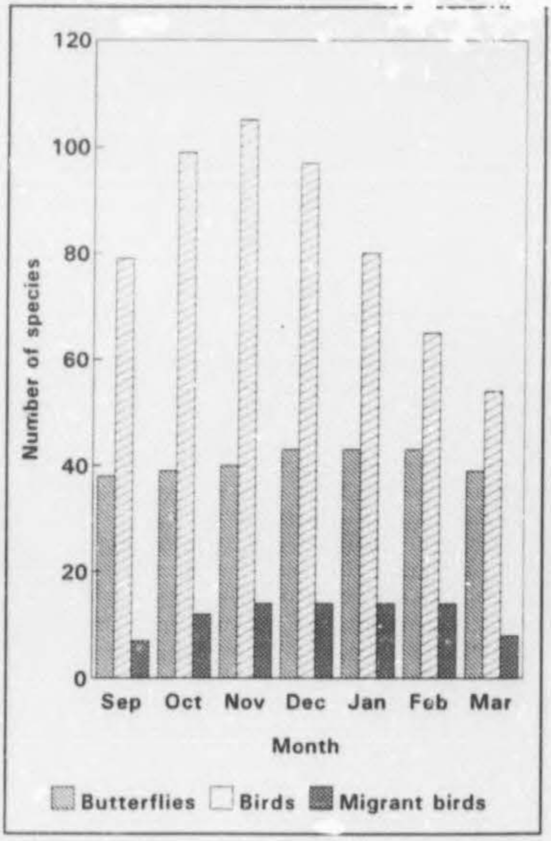

FIGURE 3. Expected numbers of common butterfly species on the wing, breeding bird species, and migrant bird species, in montane grasslands in the NE Cape Province during different summer months.

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Most species of grassland birds should breed between October and December, and most small mammals throughout the summer. Therefore a summer survey should take place between November and March.

DISCUSSION

Habitat description

The step-point method appears to give an adequate indication of habitat composition, but only in very general terms. A visual habitat description at each site, backed up by at least one photographic slide, would be less time-consuming and more appropriate (cf. Stuart-Hill, 1991).

Grasshoppers

Samways and Moore (1991) found that visual sampling recorded more species than three other sampling methods, including sweeping, in a conifer-grass matrix at a site in Natal. Visual identification of flushed individuals may be easier in summer when grasshoppers are bigger and more active, and species with conspicuous wing markings are present (pers. obs.).

Evans, Rogers and Opfermann (1983) have shown that sweeping with a net in tall grassland provides good estimates of the relative abundances of grasshopper species at any one place and time. This method, however, provides poor estimates of how relative abundances differ between sites with different vegetation characteristics. More grasshoppers are caught in more easily swept habitats. Sweeping is difficult in areas of woody or spiny vegetation. It was more difficult, in the present study, on a south slope and a vlei compared with north slopes and ridges owing to the taller, thicker vegetation of the former. Also, species differ in their ability to evade the net and lower vegetation strata are not sampled (references in Evans *et al.* 1983). However, sweeping has been used to compare species richness between different sites (with different vegetation compositions) over a short time period (Evans, 1988; Kemp, Harvey and O'Neill, 1990). An advantage of sweeping with a net is that all individuals recorded are captured.

No significant differences were found between the results obtained from the two sampling methods used in this study. This may partly be due to the generally short height of the montane grasslands, or else both methods may be prone to the same bias. Therefore, searching for and flushing grasshoppers during timed walk-through counts is the method of choice if identification of flushed individuals is easier during the summer. The mean time taken for a flush count was six minutes, so two-minute counts could be used as the time taken would not be excessive. Genera can be used instead of species in the analysis if similar species are present in the same environment (Gaston and Williams, 1993).

Sampling under fine, warm or hot, calm weather conditions was not always possible (cf. Samways, 1990; Samways and Moore, 1991). The survey of grasshoppers should be done over as short a time period as possible and only after all species have matured (eg. Evans *et al.*, 1983). Ideally, the survey should be repeated once or twice during the summer to ensure detection of species with different phenologies (eg. Kemp, Harvey and O'Neill, 1990). However, time constraints preclude this. Phenological bias will perhaps be minimised by sampling the lower (warmer) environments first.

Samways (1990) found that east-facing and north-facing mid-slopes supported the highest numbers of grasshoppers during winter in the Natal Drakensberg at around 1 900 m a.s.l. South-facing slopes supported the fewest grasshoppers. Grasshoppers favoured microhabitats (aspects) with high insolation. In the present, preliminary study some similar results were obtained.

Butterflies

Some individuals could not be identified on the wing and evaded capture because they were too fast-flying or wary. It was sometimes difficult to see if butterflies were only passing over the habitat owing to their relatively small sizes and often fast, zig-zagging flight.

Butterflies can be sampled using 10-minute walk-through counts. Searching for butterflies should be concentrated in a semi-circle of about 20 m radius in front of the observer to minimise identification difficulties and the influence of conspicuous butterflies only overflying the habitat.

Birds

The low density of birds (mean 3,2 individuals/ha) recorded in the montane grassland habitats precludes the use of circular plots during a survey. Large birds, especially, were seldom recorded in plots. Line transect methods (Bibby, Burgess and Hill, 1992) or unbounded-area timed walk-through counts in the habitat are the most suitable methods. Walk-through counts are the most efficient in terms of time and equipment since no prior setting up of transects is required and measurement of perpendicular distances to every bird is not done. Ten-minute counts are preferable to 20-minute counts since double-counting will be minimised and time for sampling is limited.

Bird detectabilities should not vary over the habitats if comparisons are to be made (Bibby and Buckland, 1987). A simple way of assessing changes in bird detectabilities over habitats may be to record birds as within or outside a set distance from the observer (cf. Bibby *et al.*, 1992). Few birds within this distance should remain undetected. The ratio of birds detected within to outside this distance can be compared over the habitats, and adjustments could be made to the field data. The same method could be

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used to assess whether detectabilities of species change relative to others over habitats.

Small mammals

A grid with trapping points 10 m apart in an eight-by-eight arrangement appears to be the minimum size suitable for small mammal trapping in the study region. The grid should be situated to cover as much variability in the habitat as possible.

The results of the bait preference trials paralleled those of Willan (1986). Both baits should be used at each site to sample effectively the range of small mammal species.

Survey design

The survey design appears suitable, because differences in biota between environments and between sites in the same environment were found. Sampling at a site should be over at least four days (or the equivalent number of samples taken), in a different part of the site each day to cover the variability in the habitat. The duration of the daily sampling of all taxa at a site should not exceed 60 to 90 minutes, to keep sampling time within reasonable limits. Sampling should start at the lower altitudes, the higher altitudes being sampled later.

Time of survey

The survey should be timed to cover a period when environmental conditions are similar, and to maximise the number of species recorded. Many adult grasshoppers should be present during December to February. Most butterfly species are on the wing at this time. Some birds (eg. cisticolas, pipits and bishops) are readily identifiable only from the males' breeding displays and breeding plumages. Displaying birds are conspicuous, while incubating birds are inconspicuous. However, by November many species should be well into the breeding season and should be feeding young, although some birds may be incubating second clutches. It is assumed that catchability of small mammals will remain similar over summer because of the lack of a distinct breeding season.

December to February and May to August are therefore the optimal summer and winter survey periods, respectively. The survey could be extended over the month before and after each period. The lower environments should be sampled first during the summer survey since it is expected that the seasonal increase in environmental temperatures will show a lag at higher elevations.

Fire and grazing effects

Although no consistent trends between wildlife diversity and time since fire or grazing were apparent, the data suggested these factors should be considered in wildlife conservation evaluations of montane grasslands in the Northeastern Cape.

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Chapter 6

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Evaluation of afforestable montane grasslands for wildlife conservation in the north-eastern Cape, South Africa

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ABSTRACT

Montane grasslands in high rainfall areas of South Africa are subject to large-scale afforestation making wildlife conservation evaluations necessary. A system which uses landscape features to predict conservation value would be beneficial. This is an initial assessment in the afforestable region of the north-eastern Cape. Sampling of grasshoppers, butterflies and birds was done along a gradient of land types. Differences in conservation value between land types and between landscape elements were demonstrated, but rankings differed according to the criterion used. High-altitude land types and low-altitude Protea *savanna were most valuable for conserving endemic species. Low-altitude land types with a Molteno sandstone lithology and the high-altitude land type with a Clarens sandstone lithology had the highest conservation values for species richness.*

Keywords: Bird, butterfly, endemic, grasshopper, species richness

INTRODUCTION

South Africa has a high diversity of vertebrate species in relation to many other parts of Africa per unit area (Siegfried, 1989). The same is probably true for some of the invertebrate taxa (e.g. Carcasson, 1964). The South African grassland biome has relatively many endemic species of birds, butterflies and grasshoppers (Dirsh, 1956; Brown, 1962; Siegfried, 1992; Pringle *et al.*, 1994), but has been largely transformed by human activity, and only 2 % is in nature reserves (Macdonald, 1989; Siegfried, 1989). 2.7 % of the grassland biome is planted to commercial trees and this area is increasing yearly (Department of Water Affairs and Forestry, 1995; Kruger *et al.*, 1995). The species diversity of grassland birds and grasshoppers declines in afforested areas (Samways & Moore, 1991; Allan *et al.*, 1995). There is therefore an urgent need to increase the protected area of this biome (Siegfried, 1992).

Large-scale afforestation with pines (*Pinus* spp.) has recently commenced in some of the montane grasslands of the north-eastern Cape. Distributional data are lacking for

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most animal taxa in these grasslands, and collection of comprehensive data is not feasible at present. As a result, little is known about the effects of the afforestation on, and its potential threat to, the wildlife of the region. In this context, a system that uses landscape features to predict conservation value for wildlife would be beneficial.

Several taxa have to be used in such a conservation evaluation, because one taxon may not act as an umbrella for the other taxa occurring in the same region (Ryti, 1992; Prendergast *et al.*, 1993; Samways, 1993). It is also important to include species-rich and/or narrowly-distributed, sedentary taxa in the evaluation (Ryti, 1992).

Grasshoppers, butterflies and birds were proposed as suitable taxa for sampling in wildlife conservation evaluations of South African montane grasslands (Armstrong *et al.*, 1994) as they fulfill the following criteria: relatively high species richness and percentage endemism; importance in grassland ecosystem functioning (e.g. Gandar, 1982); occurrence in most or all habitats; wide range of spatial requirements; amenability to simple sampling methods; taxonomically well-known, and; relatively easy identification. Plants are the subject of another study in the region and so were not considered in the present study.

This paper reports an initial wildlife conservation evaluation of the afforestable grasslands in the north-eastern Cape as a first step in the selection of a nature reserve network for the region. The sampling was done by the first author alone to test the methodology proposed by Armstrong *et al.*, (1994) because of the limited manpower available for conservation evaluations in South Africa.

STUDY AREA

The Maclear district (31°04'S, 28°21'E) lies at the southern end of the Drakensberg range in the north-eastern Cape, South Africa. The topography is hilly to mountainous, with numerous streams and rivers. Basaltic lavas occur above 1700 m, and overlie three sedimentary formations, composed of sandstones and mudstones (1:250 000 Geological Series Maps, Geological Survey, Pretoria).

The climate is warm temperate (Schulze & McGee, 1978) with a mean annual precipitation of 600 - 1200 mm (Dent *et al.*, 1987). Mean monthly precipitation is > 50 mm between October and March, and < 25 mm between June and July (Schulze & McGee, 1978; Zucchini & Adamson, 1984). Light to moderate frosts occur during the winter months, and incoming radiation in summer is approximately double that in winter (Schulze & McGee, 1978). The Weather Bureau, Pretoria, gives mean maximum and minimum summer (Jan-Feb) temperatures at 1300 m of 25° and 14°C and winter (June) temperatures of 17° and 1°C, respectively.

The vegetation in the study area is predominantly *Themeda triandra* Forssk. grassland, although montane forest, scrub and *Protea* savanna also occur (Acocks, 1988).

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METHODS

Survey design

Fifteen land types were delimited by combinations of four geological, three altitudinal, and two rainfall classes (Austin & Heyligers, 1989). Nine of these were sampled in the present survey in two transects that maximized accessibility (Fig. 1) (Collinson, 1985; Austin & Heyligers, 1989, 1991). Five land types that were rare, of limited extent, or inaccessible, were not sampled.

There were five sampling sites on each land type, determined by aspect and topography (Austin & Heyligers, 1989), namely: a north-facing slope, a south-facing slope, a slope of easterly or westerly aspect, a crest, and a bottomland (usually a valley). Sites ranged in size, averaging *c.* 35 ha. Most had been burnt within the last two years and were grazed at the time of sampling. The survey design therefore took into account both the large-scale and small-scale structure of the landscape (Forman & Godron, 1986).

Sampling methods

The sampling was done during the summer (Nov-Apr) of 1993/94, with repeat sampling on three land types from January to April 1995. The lowest land types were sampled first, but the repeat sampling was done in reverse order. A high rainfall alternative of the land type with the highest number of endemic species from all groups combined was also sampled during the repeat phase.

Each taxon was sampled on four days at a site, in a different area each day. Ten-minute walk-through counts were used for butterflies and birds, and two-minute counts for grasshoppers, excluding time for capture or identification etc. Unidentified and distinct but undetermined species were recorded separately.

Grasshoppers

Grasshoppers (Acridoidea and Tetrigoidea) seen within a few metres in front of the observer were recorded. Individuals were captured or visually assigned to a morphotype. At least one specimen of each morphotype was identified to species. Some species could not be reliably distinguished in the field, although nearly all of the genera and endemic species could. Therefore, richness is given at the generic level, and endemicity at the species level. Sampling was done between 0900 and 1600.

References sources for identification and distribution were Dirsh (1956, 1965), Brown (1962) and Gunther (1979). Grasshoppers were also identified by reference to specimens in the national collection, Agricultural Research Council, Pretoria.

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Butterflies

Butterflies within 20 m of the observer were recorded, unless they appeared only to be overflying the site. Sampling was done between 0830 and 1600. The references used for identification and distribution were Pringle *et al.* (1994) and Migdoll (1987).

Birds

Birds seen or heard at the site were recorded including soaring birds, but excluding birds overflying the site. Juveniles were excluded. The proportions of birds recorded within 40 m of the observer on each land type were compared to ensure that the assumption of equal detectabilities was not violated. Sampling was done before 1100. The primary references were Gillard (1983), Clancey (1980) and Maclean (1993).

Definitions

Three criteria were used: species richness, endemicity, and relative abundance (Usher, 1986). The term 'montane endemic' is used for species and, in the case of insects, subspecies that are confined to, or are mainly found in, the montane ecosystem in Africa (White, 1978; Dowsett, 1986). 'South African montane endemics' are montane species or subspecies confined to the Republic of South Africa and the kingdoms of Lesotho and Swaziland. Montane grasshoppers could only be classified in this limited sense since African distributions were unavailable for many species. The term 'South African endemic' is used for non-montane endemics restricted to this geographical region.

A species was classified as common on a particular land type, and at all the sites where it was recorded in the study region (i.e. 'local abundance') if the mean number of individuals per count in the first survey was ≥ 1 and if the species was recorded on $>50\%$ of the counts.

Statistical analyses

Statistical analyses were done using BMDP statistical software (Dixon, 1988). The t-value used in the pairwise t-tests was obtained from the appropriate table for a p-value of 0.0007 with 36 d.f., to give a 5 % confidence level for the the whole set of 36 comparisons.

The results of the statistical tests for differences between land types in numbers of taxa can only be used to give weak inferences about their importance for the conservation of the taxa over the whole district. This is because all sites of a particular land type were clustered in the same locality owing to time and accessibility

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constraints. The only strong inference that can be made is that some of the sampled localities are particularly worth conserving relative to the others.

RESULTS

Grasshoppers

The numbers of grasshopper genera in the nine sample areas varied between nine and 20 (Table 1) and richness during the main survey differed between land types (ANOVA: $F_{8,36} = 5.22$; $p<0.001$). Area 4 had a significantly lower number of genera than areas 1, 3, 5, 6, 7 and 8, and area 2 a significantly lower number of genera than area 8 (pairwise *t*-tests: $t_{36}>3.48$; $p<0.05$). The repeat sampling suggested that the low number of genera on areas 2 and 4 was partly due to sampling these land types relatively early in the summer, when the phenology of some species was still at the nymph stage.

There were generally more montane endemics above 1700 m. The repeat sampling confirmed the relatively high number of montane endemics in area 9. Twenty-eight percent of the species and subspecies recorded are endemic to South Africa (Appendix 1).

There were no significant differences between the site types in numbers of genera or total numbers of grasshoppers (ANOVA: $F_{4,40} = 1.85$; ns; F4,40 = 1.19; ns; respectively). However, the generic richness of grasshoppers was generally highest on north slopes and lowest in valleys (Table 2). Relative abundance of grasshoppers was greatest on crests and least on south slopes. The locally common grasshopper species were two South African montane endemics, *Dirshia abbreviata* and *Anablepia dregei*, one South African endemic, *Pseudoarcyptera palpalis*, and two widespread species, *Gastrimargus crassicollis* and *Coryphosima producta* (Appendix 1).

Butterflies

Species richness was greatest at low altitude (< 1500 m) but lowest at intermediate altitude, owing to the relatively large numbers of endemic species above 1700 m, especially on basalt (Table 1). Species richness differed between land types during the main survey (ANOVA: $F_{8,36} = 3.46$; $p<0.005$). Area 1 had a significantly greater species richness than areas 3, 5 and 6 (pairwise *t*-tests: $t_{36}>3.48$; $p<0.05$).

The repeat sampling confirmed the relatively high number of montane endemics on area 9, but not on area 4. Thirty-four percent of the species/subspecies recorded are endemic to South Africa (Appendix 2).

There were no significant differences between the site types in species richness or total numbers of butterflies (ANOVA: $F_{4,40} = 1.85$; ns; $F_{4,40} = 1.19$; ns;

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respectively). However, species richness and relative abundance were generally highest in valleys (Table 2). The fewest butterflies were recorded on crests. The three locally common butterfly species were *Eurema b. brigitta* and *Belenois aurota*, widespread in southern Africa, and *Stygionympha w. wichgrafi*, a South African endemic (Appendix 2).

Birds

Total species richness was highest at low altitudes, especially on Molteno sandstone (Table 1). Species richness differed between land types during the main survey (ANOVA: $F_{8,36} = 3.51$; $p<0.005$). Area 7 had a significantly lower species richness than areas 1 and 2 (pairwise *t*-tests: $t_{36}>3.48$; $p<0.05$).

Endemic species varied between five and nine over the whole altitudinal gradient. However, four of the six South African montane endemics were recorded only above 1700 m (Appendix 3). Another was recorded only at low altitude, while the sixth was widely distributed.

Birds were generally more abundant on species-rich land types. Three of the seven locally common species were Afromontane endemics (Appendix 3).

Evaluation of land types

Ranking the nine land types according to taxic richness (Table 3) showed reasonably good agreement between butterflies and birds (apart from area 3) but virtually no agreement between these groups and grasshoppers. Thus, the mean ranking for all three taxa produced no clear-cut sequence of overall conservation values. However, areas 1, 2 and 8 may be considered to rank highest.

Ranking the nine land types according to the number of endemic species (Table 3) showed fairly good agreement between grasshoppers and butterflies (except for area 6). However, the same number of endemic birds was found on most land types. Therefore, the three high-altitude land types (areas 7, 8 and 9) and low-altitude *Protea* savanna (area 4), ranked highest.

DISCUSSION

Grasshoppers

The similarity in numbers of grasshopper genera over the altitudinal gradient differed from the decline seen in some insect groups in South African montane areas (e.g. Samways, 1989; Stuckenberg, 1962). The presence of many endemics at high altitude was, however, quite typical.

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The relationship between aspect and grasshopper numbers was similar to that recorded during winter in the Natal Drakensberg (Samways, 1990). North slopes and crests are priority for grasshopper conservation if choices have to be made between landscape elements, e.g. when zoning land as conservation areas on forestry estates. Relatively many genera and high numbers were recorded there, and these sites, especially midslopes, are thermal refugia for grasshoppers in winter (Samways, 1990).

Butterflies

The expected pattern of decreasing numbers of butterfly species with increasing altitude was not found in this study because most of the montane endemics occurred above 1700 m. The afforestable region of the NE Cape appears to be a transitional area in which some butterfly species drop out and some montane endemics appear.

Warren (1993) found that threatened British butterflies generally preferred slopes of warm aspect while breeding. Warm slopes were important for butterflies in this study, although valleys were richest for butterflies. Two species were only recorded as males on hilltops. Valleys and north slopes are priority for conservation where choices have to be made between landscape elements.

Birds

A decline in species richness and an increase in montane endemics with increasing altitude was expected (e.g. Dowsett, 1986). There was a decrease in species richness between the low-altitude and mid-altitude land types, but no further decrease with increasing altitude. Most South African montane endemics were recorded only at high altitude, but the number of Afromontane endemics was similar over all the land types. Relative abundance of birds generally followed that of species richness, so this criterion was considered unnecessary in ranking land types for bird conservation.

None of the South African montane endemics was locally common. Rebelo and Tansley (1993) make the distinction between naturally rare species and threatened rare species. The latter are indicative of stressed habitats in need of protection, especially where they are more common than expected in relation to total species richness. The yellow-breasted pipit *Hemimacronyx chloris*, Cape vulture *Gyps coprotheres* and Stanley's bustard *Neotis denhami*, classified as vulnerable in the South African Red Data Book (Brooke, 1984), were the only threatened rare species recorded during sampling. The pipit is confined to South Africa, the vulture virtually so, and the bustard is represented in South Africa by a highly isolated population.

Three other threatened rare species were recorded outside sampling time and a fourth reported by others in the district. In total, one third of the threatened rare species

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of South Africa (Brooke, 1984) occur in the Maclear District. This is a strong case for conservation measures to be initiated in the district.

The yellowbreasted pipit is threatened by excessive burning, grazing and afforestation of its habitat (Brooke, 1984). Forestry companies could play an important role in preserving this species, because their unplanted and conservation areas can be burnt on a controlled, rotational basis and are not grazed by livestock. However, the pipit was only recorded on relatively flat areas, which are suitable for forestry where the soil characteristics are right.

Evaluation of land types

Selecting a series of areas to maximise species richness does not necessarily maximise the number of endemic or rare species, and the best combination of sites may differ among taxa (e.g. Prendergast *et. al.*, 1993; Rebelo & Tansley, 1993; Saetersdal *et al.*, 1993). Taxon richness 'hotspots' were not coincident at both the land type and sampling site scales in this study. Nor were the taxon richness and endemicity 'hotspots' coincident.

The choice of criterion will depend on the goals of the conservation evaluation. In general, low-altitude land types were most important in numbers of species, whereas high-altitude land types were most important for endemics. Mid-altitude land types were the least important for wildlife conservation, with the notable exception of the grasshopper group.

Altitude was more important than rainfall or geology in the defining of biologically-relevant land types. Most species occurring in the low- to mid-altitude class range were recorded in both rainfall classes. New afforestation in the district is now being restricted to land with a mean annual rainfall above 750 mm.

Ideally, large areas of the high-altitude grasslands and low-altitude *Protea* savanna should not be afforested because of the threat to the montane endemics, especially those restricted to South Africa. A reserve network can then be chosen to maximise the number of species protected in the afforestable area, according to various constraints such as complementarity (Pressey *et al.*, 1993), as the final step of the conservation assessment. The taxa predicted to occur on a particular area would be those recorded for its land type. The variable classes, which in combination define the land type, could be used as predictors of which taxa occur on areas with land types that were not sampled.

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TABLE 1

Total number of genera or species and montane endemic species recorded on each land type according to altitude, rainfall and geology (see Fig. 1). R = repeat sampling, A = high rainfall alternative locality.

	Altitude								
	Low				Medium		High		
Geology	Molteno		Elliot		Elliot		Elliot	Clarens	Basalt
Rainfall	Low	High	Low	High	Low	High	High	High	Low
Land type	1	2	3	4	5	6	7	8	9
Grasshoppers									
Genera	17	14,19R	18	9,13R	19	19	18	20	16,19R,16A
Endemic spp.	3	1,2R	3	4,3R	1	6	6	4	6,7R,7A
Butterflies									
Total spp.	23	16,17R	10	16,15R	12	12	14	15	14,18R,9A
Endemic spp.	1	1,1R	1	5,1R	2	1	5	4	6,7R,5A
Birds									
Total spp.	51	46,52R	39	35,39R	23	29	24	34	29,36R,30A
Endemic spp.	7	7,9R	7	7,6R	7	5	6	7	7,8R,8A

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TABLE 2

Numbers of grasshopper genera and total grasshoppers, and numbers of butterfly species and total butterflies, recorded for the five slope/aspect classes. Means of the nine sample areas.

Taxon	Slope/aspect				
	Valley	North Slope	South Slope	East/ West Slope	Crest
Grasshoppers					
Mean # genera	7.6	8.6	8.2	7.8	8.3
(S.D.)	(2.4)	(3.8)	(3.4)	(2.7)	(3.0)
Mean numbers	36.4	44.6	34.9	54.6	59.0
(S.D.)	(28.7)	(32.6)	(22.2)	(37.9)	(35.2)
Butterflies					
Mean # spp.	7.6	6.6	4.8	5.1	4.3
(S.D.)	(4.4)	(2.2)	(3.1)	(2.3)	(2.3)
Mean numbers	30.4	25.6	20.1	17.7	17.4
(S.D.)	(15.1)	(17.0)	(17.6)	(12.5)	(14.8)

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TABLE 3

Ranking of land types (1 = highest) with respect to number of genera or species, and endemicity (E). Land types as in Fig. 1.

Land type	Rank							
	Grasshoppers		Butterflies		Birds		Mean	
	Gen.	E	Spp.	E	Spp.	E	Taxa	E
1	6	6.5	1	7	1	4	2.7	5.8
2	8	8.5	2.5	7	2	4	4.2	6.5
3	4.5	6.5	9	7	3	4	5.5	5.8
4	9	4.5	2.5	2.5	4	4	5.2	3.7
5	2.5	8.5	7.5	7	9	4	6.3	6.5
6	2.5	2	7.5	7	6.5	9	5.5	6.0
7	4.5	2	5.5	2.5	8	8	6.0	4.2
8	1	4.5	4	4	5	4	3.3	4.2
9	7	2	5.5	1	6.5	4	6.3	2.3

APPENDIX 1

Grasshopper species and subspecies recorded on the land types, indicating their distribution, relative abundance and endemicity status. *=present; c=common; l=locally abundant; S=South African endemic; B=South African montane endemic

Taxon[a]	Area													
	1	2	2 R	3	4	4 R	5	6	7	8	9	9 R	9 A	
PYRGOMORPHIDAE														
Taphronota stali I.Bol					*									
Tanitella prasina (Karsch)										*	*	*	*	
Zonocercus elegans (Thunberg)		*	*											
Dictyophorus spumans (Thunberg)									*					
LENTULIDAE														
Lentula callani Dirsh										*	*			S
L. minuta Dirsh												*		B
Eremidium basuto Brown													*	B
Basutacris natalensis Dirsh					*								*	B
B. inflatifrons Brown												*		B
B. minuta Brown					*	*		*				*	*	B
Qachasia fastigiata Dirsh					*	*			*		*	*	*	B
ACRIDIDAE														
Spathosternum nigrotaeniatum (Stal)	*							*		*				
S. pygmaeum Karsch			*										*	
Acorypha ferrifer (Walker)		*	*	*			*		*	*				
Platacanthoides reductus Dirsh	*		*	*			*	*	*	*				B
Calliptamicus semiroseus (Serville)		*		*				*	*		*	*		
Calliptamulus natalensis (Sjostedt)	*										*	*		S
C. sulfurescens Uvarov	*	*	*	*				*	*	*	*	c	*	S
Heteracris calliptamoides testacea Grunshaw	*		*	*	*	*	*	*	*					S

Taxon	Area														
	1	2	2 R	3	4	4 R	5	6	7	8	9	9 R	9 A		
Eyprepocnemis plorans (Charpentier)				*			*	*	*	*	*	*	*		
Dirshia abbreviata Brown			*	*				*	*		*	*	*	I	B
Vitticatantops nr *humeralis* (Thunberg)			*			*	*			*			*		
Anthermus granosus Stal							*								
Cyrtacanthacris aeruginosa (Stoll)				*								*			
C. tatarica (Linnaeus)							*								
Gastrimargus africanus (Saussure)	*												*		
G. crassicollis Saussure	c	*	*	*			*	*	*	*		*		I	
G. drakensbergensis Ritchie	*	*		*	*	*		*	*	*	*	*	*		B
G. determinatus vitripennis (Saussure)	*	*	*	*		*	c	*	*	*					
Acrida turrita Linnaeus	*	*		*		*	*	*	*	*	*	*	*		
Machaeridia bilineata Stal					*		*								
Weenenia lineata Brown										*	*	*	*		B
Duronia curta Uvarov	*	*	*	*			*	*							
Orthoctha prasina I.Bol.	*		*	*	*	c	*	*	*	*					
O. rosacea (Walker)	*	*	*	*	*	*		*	*				*		
O. t. tunstalli Popov & Fishpool			*												
Coryphosima producta (Walker)	c	*	*	c		*	*	c	c	*	*	*	c	I	
C. vicina (Dirsh)	*	*	*	*		*	*	c	c	*	*	*	*		
Gymnobothrus cruciatus I.Bol.[b]	*											*			
G. anchietae I.Bol.						*	*			*					
G. temporalis (Stal)						*	*			*		*			
G. nr *gracilis* Ramme							*			*					
Anaelopus socius (Stal)			*												
Paracinema tricolor (Thunberg)									*	*	*	*	*		

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Taxon	Area														
	1	2	2	3	4	4	5	6	7	8	9	9	9		
			R			R						R	A		
Heteropternis guttifera Kirby				*			*	*	*	*	*				
H. thoracica (Walker)	*			*		*	*	*							
H. pudica (Serville)				*	*			*		*	*	*			
Pycnodictya flavipes Miller		*													S
Scintharista rosacea (Kirby)			*			*		*							
Oedaleus plenus Walker	*	*	*												
Acrotylus furcifer Saussure	*	*	*	*				*	*			*			
A. patruelis (Herrich-Schaeffer)			*												
Anablepia dregei (Ramme)								*	*	c	*		*	1	B
Dnopherula cruciata (I.Bol.)							*			*					
D. dorsata (I.Bol.)										*					
Rhaphotittha sp. ?nov.	*							*	*		*	*			B
Pseudoarcyptera palpalis (Uvarov)	*		*	*	*	c	*	c	c	*	*	*		I	S
Pnorisa squalis Stal			*												
Faureia milanjica (Karsch)			*				*								
TETRIGIDAE															
Paratettix scaber Thunberg							*								
Leptacrydium gratiosum Karsch	*	*		*											
Phloeonotus humilis Gerstaekcer	*	*	*	*		*		*		*					
? *Phloeonotus* sp.	*														

[a] Where a morphotype could potentially represent more than one species, visual records of that morphotype were allocated to a certain species if it was the only one identified from specimens as being present during the count or, otherwise, at the site (if no specimens were collected during that count)

[b] The genus *Gymnobothrus* is under revision and so identifications are tentative

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APPENDIX 2

Butterfly species and subspecies recorded on the land types, indicating their distribution, relative abundance and endemicity status. *=present; c=common; l=locally abundant; M=Afromontane endemic; S=South African endemic; B=South African montane endemic

Taxon	Area 1	2	2 R	3	4	4 R	5	6	7	8	9	9 R	9 A		
NYMPHALIDAE															
Danaus chrysippus aegyptius (Schreber)	*		*			*	*		*	*	*				
Aeropetes tulbaghia (Linnaeus)						*	*	*	*	*	*	*	*		M
Dingana b. bowkeri (Trimen)					*							*			B
Paralethe dendrophilus albina Van Son						*									S
Cassionympha cassius (Godart)					*	*									S
Pseudonympha varii Van Son											*	*	*		B
P. magoides Van Son											*	*	*		B
Stygionympha w. wichgrafi Van Son			*		*	*	*		c	c	*			l	S
S. s. scotina Quickelberge												*			B
Acraea horta (Linnaeus)		*	*					*				*			S
Hyalites anacreon (Trimen)					*				*	*	*		*		M
Precis hierta cebrene (Trimen)	*	*	c	*				*	*	*	*				
P. o. oenone (Linnaeus)						*									
P. octavia sesamus Trimen	*														
P. archesia (Cramer)	*							*							
Vanessa cardui (Linnaeus)	*	*	*	*	*		*	*		*	*				
LYCAENIDAE															
Durbania a. amakosa Trimen		*			*							*			B
Thestor b. basutus (Wallengren)	*														
Oraidium barberae (Trimen)												*			

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Taxon	Area													
	1	2	2	3	4	4	5	6	7	8	9	9	9	
			R			R						R	A	
Leptomyrina lara (Linnaeus)		*	*							*		*		
Capys alpheus extentus Quickelberge					*				*			*		B
C. disjunctus Trimen					*									
Myrina silenus ficedula Trimen	*	*					*	*						
Aloeides macmasteri Tite and Dickson		*		c	*	*								S
Poecilmitis chrysaor (Trimen)				*										S
Lycaena clarki Dickson			*											S
Anthene d. definita (Butler)	*	*												
Cacyreus marshalli Butler	*		*				*	*		*		*		
C. p. palemon (Stoll)	*	*				*		*	*	*	*	*	*	
Leptotes pirithous (Linnaeus)			*			*								
Lampides boeticus (Linnaeus)	*	*	*	*	*	*	*			*				
Harpendyreus noquassa (Trimen and Bowker)									*		*	*		B
Lepidochrysops asteris (Godart)	*			*										B
Orachrysops subravus G.A. & S.F. Henning											*	*		B
Actizera lucida (Trimen)	*	*	*	*										
Zizeeria knysna (Trimen)			*											
PIERIDAE														
Pinacopteryx e. eriphia (Godart)										*				
Colias e. electo (Linnaeus)	*		*			*	*		*	*	*	*		
Catopsilla florella (Fabricius)					*		*		*					
Eurema b. brigitta (Stoll)	c		*			*		*	*		*		*	I
Belenois aurota (Fabricius)	*	c			c							*		I
B. gidica (Godart)	*	*						*						
B. creona severina (Stoll)	*													

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Taxon	Area													
	1	2	2 R	3	4	4 R	5	6	7	8	9	9 R	9 A	
Pontia h. helice (Linnaeus)	*	*		*		*	*	*	*		*	*	*	
PAPILIONIDAE														
Papilio d. demodocus Esper	*	*												
P. nireus lyaeus Doubleday	*													
HESPERIIDAE														
Eretis u. umbra (Trimen)	*	*	*	*										S
Spialia m. mafa (Trimen)				*	*									
S. diomus ferax (Wallengren)		*				*						*		
Metisella malgacha orina Vari										*				B
Kedestes mohozutza (Wallengren)			*		*		*		*	*			*	M
Gegenes n. niso (Linnaeus)			*		*	*	*	*	*	*		*	*	

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APPENDIX 3

Bird species recorded on the land types, indicating their distribution, relative abundance and endemicity status. *=present; c=common; I=locally abundant; M=Afromontane endemic; S=South African endemic; B=South African montane endemic

Taxon	Area														
	1	2	2	3	4	4	5	6	7	8	9	9	9		
			R			R						R	A		
ARDEIDAE															
Ardea melanocephala Vigors and Children	*														
Hagedashia hagedash (Latham)												*	*		
CICONIIDAE															
Ciconia ciconia (Linnaeus)	*		*												
SAGITTARIIDAE															
Sagittarius serpentarius (Miller)			*							*			*		
ACCIPITRIDAE															
Gyps coprotheres (Forster)	*	*	*		*										
Elanus caeruleus (Desfontaines)													*		
Buteo rufofuscus (Forster)		*			*	*			*	*	*	*	*		
B. buteo (Linnaeus)						*						*			
Accipiter rufiventris Smith											*				M
Circus maurus (Temminck)									*				*		
FALCONIDAE															
Falco amurensis Radde	*														
F. tinnunculus Linnaeus					*	*	*	*	*						
PHASIANIDAE															
Francolinus africanus Stephens			*										*		
Coturnix coturnix (Linnaeus)		*	*	*			*						*	I	M
GRUIDAE															
Balearica regulorum (Bennett)													*		

Taxon	Area													
	1	2	2 R	3	4	4 R	5	6	7	8	9	9 R	9 A	
OTIDIDAE														
Neotis denhami (Children)											*			
COLUMBIDAE														
Columba guinea Linnaeus				*	*	*	*			*				
Streptopelia semitorquata (Ruppell)		*	*											
S. capicola (Sundevall)	*	*	*	*	*	*	*				*	*		
CUCULIDAE														
Cuculus solitarius Stephens		*			*									
C. clamosus Latham					*									
Chrysococcyx caprius (Boddaert)	*													
APODIDAE														
Apus barbatus (Sclater)	*	*	*	*	*	*		*	*	*	*	*	*	I
A. melba (Linnaeus)		*	*	*	*	*		*	*		*	*		
A. horus (Heuglin)			*	*		*		*	*	*				
A. caffer (Lichtenstein)	*	*	*	*		*		*	*	*	*			
COLIIDAE														
Colius striatus Gmelin		*		*		*								
ALCEDINIDAE														
Ceryle maxima (Pallas)			*											
PHOENICULIDAE														
Phoeniculus purpureus (Miller)						*								
INDICATORIDAE														
Indicator indicator (Sparrman)	*		*											
PICIDAE														
Geocalyptes olivaceus (Gmelin)	*	*		*	*	*	*	*		*				S
ALAUDIDAE														
Mirafra curvirostris (Herrmann)		*						*		*				
Calandrella cinerea (Gmelin)				*										

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Taxon	Area														
	1	2	2	3	4	4	5	6	7	8	9	9	9		
			R			R						R	A		
HIRUNDINIDAE															
Hirundo rustica Linnaeus			c			*						*	*		
H. cucullata Boddaert	c	*	c	*	*	c	*	c	*	c	*	*	*	l	
H. albigularis Strickland	*								*	*					
H. fuligula Lichtenstein	*	*	*		*	*		*		*	*		*		
Riparia cincta (Boddaert)	*	*	*	*		*		*	*	*		*	*		
Delichon urbica (Linnaeus)						*		*		*					
DICRURIDAE															
Dicrurus adsimilis (Bechstein)			*												
CORVIDAE															
Corvus albicollis Latham	*														
C. capensis Lichtenstein	*	*						*	*	*	*	*	*		
TIMALIIDAE															
Lioptilus nigricapillus (Vieillot)												*			B
PYCNONOTIDAE															
Pycnonotus barbatus (Desfontaines)	*	*	*	*	*	*	*	*							
TURDIDAE															
Monticola rupestris (Vieillot)	*	*	*	*	*	*	*	*		*					
M. explorator (Vieillot)									*				*		B
Chaetops auranticus Layard										*	*	*			B
Cercomela familiaris (Stephens)	*	*	*	*		*	*	*	*	*		*			
Oenanthe monticola Vieillot	*	*	*	*		*			*						
O. bifasciata (Temminck)	*	*	*	*	*	*	*	*		*			*		B
Saxicola torquata (Linnaeus)			*	*					*	c	c	c	c	l	
Myrmecocichla formicivora (Vieillot)			*	*											
Thamnolaea cinnamomeiventris (Lafresnaye)			*	*				*							
Cossypha caffra (Linnaeus)	*	*	*	*	*	*	*	*		*		*			M
SYLVIIDAE															
Sphenoeacus afer (Gmelin)	*		*	*	*	*		*			*				

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Taxon	Area														
	1	2	2	3	4	4	5	6	7	8	9	9	9		
			R			R						R	A		
Cisticola juncidis (Rafinesque)	*	*	*												
C. ayresii Hartlaub	*	*	*	*			*	*	*	*	*	*	*	I	M
C. fulvicapilla (Vieillot)	*	*	*	*	*	*									
C. lais (Finsch & Hartlaub)	*	*	*	*	*	*	*	*	*	*	*	*	*	I	M
C. aberrans (Smith)	*														
C. tinniens (Lichtenstein)						*					*	*	*		
Prinia maculosa (Boddaert)		*	*	*	*	*	*			*	*	*			
MUSCICAPIDAE															
Sigelus silens (Shaw)	*														
MOTACILLIDAE															
Motacilla capensis Linnaeus								*	*	*		*	*		
Anthus cinnamomeus Ruppell	*	*		*			*	*	*			*	*		
A. similis Jerdon	*	*	*	*	*		*		*	*					
A. leucophrys Vieillot	*														
A. crenatus Finsch and Hartlaub	*														S
Hemimacronyx chloris (Lichtenstein)									*	*	*	*	*		B
Macronyx capensis (Linnaeus)	*	*	*	*	*		*	*	*	*	*	*	*		
LANIIDAE															
Lanius collaris Linnaeus	*	*	*	*	*			*		*		*			
Laniarius ferrugineus (Gmelin)	*														
Telophorus zeylonus (Linnaeus)	*	*	*	*		*					*	*			
STURNIDAE															
Onychognathus morio (Linnaeus)	*	*	*	*	*	*	*			*					
Spreo bicolor (Gmelin)				*						*	*	*		I	S
PROMEROPIDAE															
Promerops gurneyi Verreaux			*		*	*									M
NECTARINIIDAE															
Nectarinia famosa (Linnaeus)	*	*	*	*	c	c	*	*	*		*	*	*		
N. afra (Linnaeus)	*		*		*										B

Taxon	Area													
	1	2	2 R	3	4	4 R	5	6	7	8	9	9 R	9 A	
ZOSTEROPIDAE														
Zosterops pallidus Swainson	*	*	*		*	*				*		*		
PLOCEIDAE														
Passer diffusus (Smith)		*	*											
Ploceus velatus Vieillot		*												
P. capensis (Linnaeus)			*								*	*		S
Euplectes orix (Linnaeus)		*												
E. progne (Boddaert)	*	*	*			*					*	*	*	
E. ardens (Boddaert)	*	*	*			*					*	*		
E. capensis (Linnaeus)	*	*		*	*	*	*	*		*	*	*	*	
ESTRILDIDAE														
Estrilda astrild (Linnaeus)	*		*		*	*					*	*		
Ortygospiza atricollis (Vieillot)	*	*	*	*			*		*		*	*	*	
VIDUIDAE														
Vidua macroura (Pallas)	*			*				*					*	
FRINGILLIDAE														
Serinus flaviventris (Swainson)				*										
S. mozambicus (Statius Muller)	*													
S. canicollis (Swainson)	*	*	*	*	c	*	*		*	*	*	*	*	M
S. gularis (Smith)					*	*								
Emberiza tahapisi Smith	*	*	*	*	*							*		
E. flaviventris Stephens		*												
E. capensis Linnaeus	*	*		*			*	*		*				

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Caption to figure

Fig. 1. The study area showing towns, major roads (continuous lines), minor roads (dashed lines), the two transects, and the location of the sampled area of each land type (areas 1 to 9). Geological formations: M, Molteno sandstone; E, Elliot sandstone; C, Clarens sandstone; B, Basalt. Altitude: low (l), 1300-1500 m; medium (m), 1500-1700 m; high (h), 1700-1900 m. Rainfall: low (l), <900 mm; high (h), ≥900 mm.

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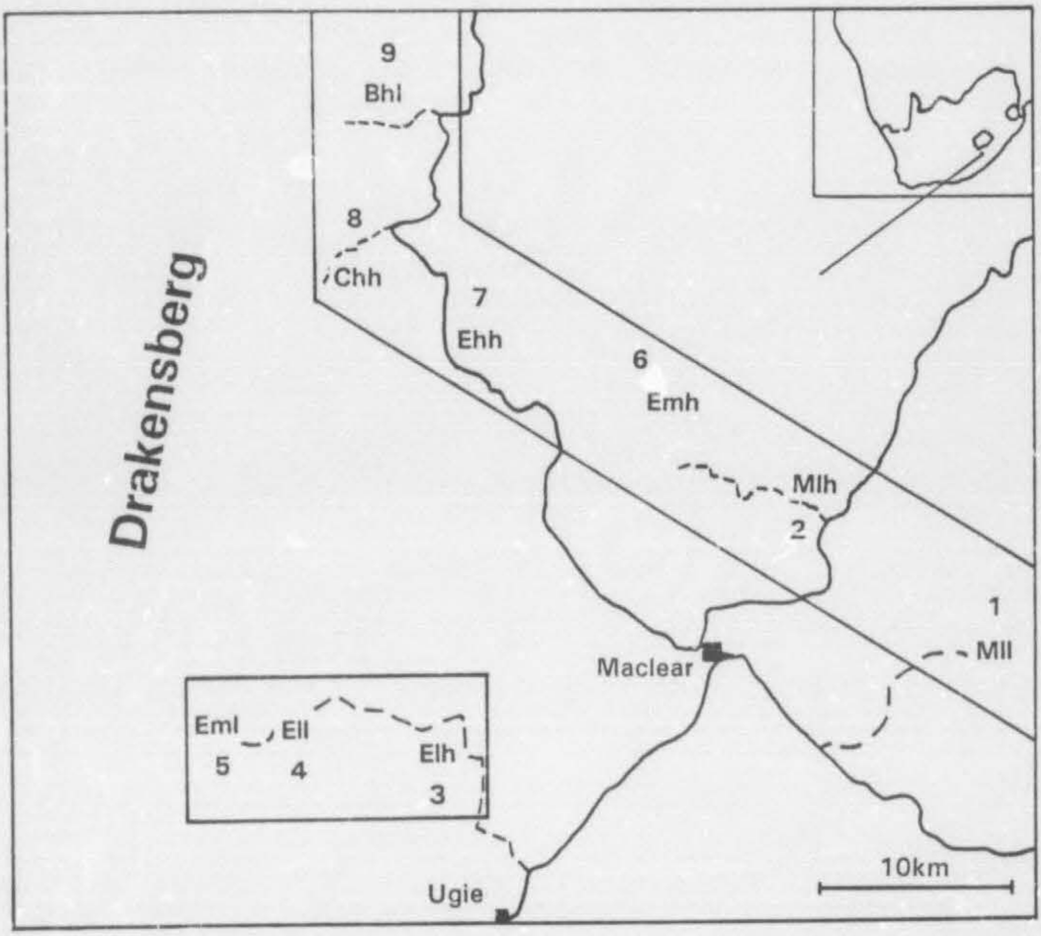

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Chapter 7

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Small mammals in afforestable montane grasslands of the NE Cape, South Africa

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The small mammals at five sites on each of six land types in the afforestable grasslands of the NE Cape were sampled. Sampling grids consisting of 100 equally spaced trapping points were used. Mean species richness and relative abundance per hectare did not differ significantly over the land types. Significant associations between site type and species relative abundances were: valleys and north slopes with *Rhabdomys pumilio*; south slopes with *Myosorex varius* and *Otomys irroratus*; east slopes with *M. varius*; and crests with *Mus minutoides* and *Mystromys albicaudatus*. The threatened, rare species *M. albicaudatus* was associated with crests and ridges.

Keywords: Abundance, grassland, insectivore, montane, rodent

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Introduction

Afforestation and alien tree invasion are two of the major land transformations that negatively affect biodiversity in the grassland biome of South Africa (Macdonald 1989). This biome is the most extensively transformed. Large-scale afforestation with pines has recently begun in the montane grasslands of the Maclear district, in the north of the Eastern Cape Province, without prior conservation evaluations.

Small mammals are important biological components of montane grassland ecosystems. They are found throughout montane grasslands and can occur in relatively large numbers and with high biomass in suitable areas (e.g. Rowe-Rowe & Meester 1982; Lynch 1989; Willan 1992; Bowland & Perrin 1993). They are important in nutrient recycling, habitat modification and soil dynamics, and as herbivores, predators of invertebrates, and prey for carnivores (Rowe-Rowe & Lowry 1982; Rowe-Rowe 1986; Willan 1992).

Species richness and abundance of small mammals is generally greater than other mammal groups in remnant grassland areas owing to their small size and high reproductive rates. This study addresses the question of how small mammals are

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distributed across the small-scale and large-scale structure of the afforestable landscape in the Maclear district (Forman & Godron 1986).

Study area

The Maclear district (31°04'S, 28°21'E) is at the southern end of the Drakensberg range in the Eastern Cape, South Africa. The topography is hilly to mountainous, with numerous streams and rivers. Basaltic lavas occur above 1700 m, and overlie three sedimentary formations, composed of sandstones and mudstones (1:250 000 Geological Series Maps, Geological Survey, Pretoria).

The climate is warm temperate (Schulze & McGee 1978). The Computing Centre for Water Research, University of Natal, gives a mean annual precipitation for a 1' by 1' grid over the district of between 600 mm to 1200 mm (Dent, *Lynch & Schulze* 1987). Mean monthly precipitation is greater than 50 mm between October and March, and is less than 25 mm between June and July (Schulze & McGee 1978; Zucchini & Adamson 1984). Light to moderate frosts occur during the winter months, and incoming radiation in summer is approximately double that in winter (Schulze & McGee 1978). The Weather Bureau, Pretoria gives a peak of 25 °C in mean maximum temperature (January-February) and a low of 1 °C in mean minimum temperature (June-July) at Maclear (1300 m).

The vegetation in the study area is predominantly *Themeda triandra* grassland, although montane forest, scrub and *Protea* savanna also occur (Acocks 1988). *Themeda-Festuca* grassland is common above 1600 m. Planting with commercial trees in the district began in 1990.

Methods

Land type delimitation

Armstrong, van Hensbergen & Geertsema (1994) proposed that the afforestable landscape be divided into land types so that any effect of its large-scale structure on the distributions of small mammals may be apparent. Broad vegetation types are correlated with changes in altitude and geology on the Drakensberg (Hilliard & Burtt 1987; Acocks 1988) and small mammal distributions are influenced by vegetation type (Rowe-Rowe & Meester 1982; Lynch 1989).

Land types were delimited by combinations of four geological and three altitudinal classes (Table 1; Austin & Heyligers 1989). Small mammals were sampled on trapping grids at five different sites on each land type. The sites were a bottomland (valley or vlei), a south-, a north-, and an east-facing slope, and a crest or ridge. Effects of the

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small-scale structure of the landscape on small mammal distributions should be discernible using this approach.

Trapping protocol

The grid at each site was situated to cover a heterogeneous area of the habitat. Trapping points were 10 m apart on a ten-by-ten grid (twenty-by-five grid at three sites). One Sherman trap was placed within approximately 1 m of each point.

Two baits were used. One was a mixture of oats, currants or raisins, peanut butter, lard and candle wax (modified from Willan 1986). The other contained oats, currants or raisins and sunflower oil. The baits were alternated from trap to trap.

Sampling was done between September 1994 and May 1995, before the winter frosts. Most small mammals captured breed throughout the summer (Rowe-Rowe & Meester 1982*b*; Lynch 1989; Skinner & Smithers 1990), so the relative abundance figures should not be unduly biased by time of sampling in relation to breeding season. Trapping was over a four-day period at each site, and traps were checked at least once a day, in the morning.

Rodents were anaesthetized with ether to facilitate handling (Twigg 1975), individually marked, and released near the trapping point. Species were identified by external characteristics and measurements, distribution and, where necessary, hair characteristics (Keogh 1985; Lynch 1989; Skinner & Smithers 1990). *Mastomys* species are indistinguishable in the field and were recorded as *Mastomys (natalensis)* sp.

Habitat description

Brief visual descriptions of the sampling sites are given in Appendix 1. *Themeda triandra*, the dominant grass in the region, is at least 300 mm tall when mature (Gibbs-Russell, Watson, Koekemoer, Smook, Barker, Anderson & Dallwitz 1990). A site was classified as tall grassland if the sward was predominantly mature *Themeda* or if the grass height was 300 mm or more, measured against a 300 mm long spike.

Time since last fire and since last grazing was recorded where such data were available. These data were estimated for sites on unplanted forestry land from the dates of planting of the nearest young trees. The periods were grouped as 0-1 years, 1-2 years, or >2 years post fire; and 0-1 years or >1 years post grazing. Species richness was grouped as 1-2 species, 3 species, or 4-5 species, while relative abundance was grouped as ≤30 animals, 31-60 animals, or >60 animals. All sites were at least six months post burning.

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Additional sampling

Every site on each land type was sampled only once during the period September 1994 to May 1995. However, some of the same sites and some sites at different localities were sampled during 1993, using the same methods but with different baiting protocols (Armstrong *et al.* 1994). Sampling of small mammals at a few other localities was done along traplines or on reduced grids. Two parallel lines of ten traps each, 10 m apart, were placed in an area of heterogeneous habitat at each site where traplines were used. Reduced grids consisted of 49 traps in a 7 x 7 arrangement, with traps 10 m metres apart. All trapping was done over four-day periods. The results from this previous sampling were used to give some indication of seasonal, annual, and geographical variability, and are the alternative samples reported in the paper.

Data analysis

Results were expressed as the minimum number alive (MNA) on one hectare of grassland. The term 'relative abundance' refers hereafter to MNA, because different species have different capture probabilities and all the individuals of a species on a grid may not be captured during the trapping period (White, Anderson, Burnham & Otis 1982; van Hensbergen & Martin 1993). The programme CAPTURE (White *et al.* 1982) was used to estimate population sizes where the number of captures was large enough. When population estimates could not be calculated using this package, the programme NOREMARK was used to analyse data considered appropriate with regard to the underlying assumptions (Bartmann, White, Carpenter & Garrott 1987; Neal, White, Gill, Reed & Olterman 1993).

Differences in capture probabilities between sites were likely (Table 1; White *et al.* 1982; van Hensbergen & Martin 1993). The number of traps found closed by factors other than small mammal captures, or with bait removed, are given in terms of percentage of total trap checks (to nearest 0.1%). This percentage was greater than 5% on only three sites. However, most of the closed traps on these sites did not catch anything during the occasions that they remained open. Therefore no corrections were made to the data. Ideally, there should be a constant number of daily trap checks, but this was not always possible. Standardization prevents possible underestimation of relative abundances where there are fewer daily trap checks.

Other statistical analyses were done using BMDP statistical software (Dixon 1988). Log-likelihood ratio tests were used to detect significant associations between variables. Associations between variable classes that deviated significantly from expectation were noted from the tables of adjusted residuals (d_{ij}; Everitt 1977). Only species that occurred throughout the altitudinal range were used to determine associations between

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site type and species, and the most common of these species were used in the analysis of change in relative abundances over the land types.

The results of the statistical tests for differences between land types can only be used to give weak inferences about the distribution of small mammals over the whole district. This is because all sites of a particular land type were clustered in the same locality owing to time and accessibility constraints.

Results

The species trapped during the survey and their codes are given in Table 2. The species caught at each site and their relative abundances are given in Table 3.

Species richness

The number of species caught on each land type is shown in Figure 1. There were no significant differences between the land types in mean species richness per hectare (ANOVA: $F_{5,24} = 0.76$; ns).

Relative abundance

Mean relative abundance of small mammals per hectare on each land type is given in Figure 1. There were no significant differences between the land types (Brown-Forsythe test: $F_{5,13} = 1.11$; ns). The land type localities that had been most recently burnt and grazed (Appendix 1) had the lowest numbers of small mammals.

Differences between sites

Valleys generally had the highest number of species and north-facing slopes the lowest (Table 4). There were no significant differences between the site types in mean species richness (ANOVA: $F_{4,25} = 1.7$; ns). Valleys and vleis generally contained the highest numbers of small mammals and crests the lowest. Some significant differences between the site types in small mammal relative abundances were found (Brown-Forsythe test: $F_{4,12} = 3.76$; $p<0.05$). Relative abundances in valleys were significantly greater than on north slopes and crests (pairwise t-tests: $t_{25} > |3.08|$; $p<0.05$).

Association between species and site

Site type and small mammal species occurrence were significantly associated ($G_{24} = 37.86$; $p<0.05$). The only significant association between categories, however, was crests and *Mystromys albicaudatus* ($d_{ij} = 3.3$; $p<0.05$).

Site type and the relative abundances of the different small mammal species were significantly associated ($G_{24} = 172.91$; $p<0.001$). The significant associations

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($d_{ij} > 1.96$) were: valleys and north slopes with *Rhabdomys pumilio*; south slopes with *Myosorex varius* and *Otomys irroratus*; east slopes with *M. varius*; crests with *Mus minutoides* and *M. albicaudatus*.

The following significant associations ($d_{ij} < -1.96$) between site type and lower-than-expected relative abundances of the following species were found: valleys with *M. varius*, *M. minutoides* and *M. albicaudatus*; north slopes with *M. varius* and *O. irroratus*; south slopes with *R. pumilio*, *M. minutoides* and *M. albicaudatus*; crests with *R. pumilio*.

Changes in relative abundance over land types

There were no significant differences between the mean relative abundances of *R. pumilio* on the different land types (Brown-Forsythe test: $F_{5,11} = 1.5$; ns). Mean relative abundance of *M. varius* on land type Bh was significantly greater than the mean relative abundance on land type Ch (ANOVA: $F_{5,24} = 3.07$; $p < 0.05$. Pairwise *t*-test: $t_{24} = -3.57$; $p < 0.05$).

Changes in relative abundance of species with altitude

The relative abundances of the three most common small mammals (*M. varius*, *R. pumilio* and *O. irroratus*) over the altitudinal gradient are given in Table 5. Mean relative abundance per hectare decreased in *R. pumilio* and increased in *O. irroratus* with increasing altitude. *M. varius* was most abundant at the highest altitude.

Geographical, seasonal and annual variability

Some indication of variability in the small mammal assemblages at various sites on the land type gradient is given in Table 6. There was some annual, seasonal, or geographical variation, although species recorded only in an alternative sample from a land type were often represented by a single individual.

Time since last fire and last grazing

The were no significant associations between species richness or relative abundance of small mammals and time since last fire ($G_4 = 3.52$; ns; $G_4 = 5.68$; ns; respectively). There were no significant associations between species richness or relative abundance and time since last grazing ($G_4 = 1.35$; ns; $G_4 = 4.97$; ns; respectively).

MNA - population estimate relationship

Population estimates for a few species at some sites were obtained (Table 7). There was a significant linear relationship between MNA and population size estimated from the models (population size = 1.541 X MNA - 8.429; $r = 0.979$; $p < 0.001$; 95% CI for

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slope = 1.316; 1.766, i.e. reject H_0: slope = 1; 95% CI for intercept = -1.428; 18.286, i.e. accept H_0: intercept = 0).

Discussion

Species relations

The results of this study parallel those of several others of small mammals in South African montane grasslands (Rowe-Rowe & Meester 1982; Lynch 1989; Bowland & Perrin 1993). The majority of species captured, including all the common ones, were the same as in the other studies. *R. pumilio*, *M. varius* and *O. irroratus* were the most common species.

Most species were distributed throughout the altitudinal range. *R. pumilio* and *M. varius* were found on most land types. *M. varius*, *R. pumilio*, *O. irroratus* and *Dendromus mesomelas* are all dependent on grass or bush cover (Rautenbach & Nel 1980). *M. varius* and *O. irroratus* were captured wherever the grass was tall and thick, generally on south slopes, east slopes and in valleys and vleis because these are relatively moist sites. These two species avoided the drier north slopes, which *R. pumilio* did not. Crests were not preferred habitat for *R. pumilio*, probably because the grass was generally short and areas of bare ground and rock were relatively common. Bond, Ferguson & Forsyth (1980) found that the abundance of *R. pumilio* was significantly correlated to grass cover and that low numbers were recorded where the ratio of grass to bare soil and rock was low.

Species which avoided the moister, more thickly grassed sites were *M. minutoides* and *M. albicaudatus*. They preferred sites with areas of bare ground or rock. *M. albicaudatus* preferred crests and ridges, seldom being captured on other sites. It was not common in the region, as found by Lynch (1989) for the whole NE Cape.

In accordance with the findings of Rowe-Rowe & Meester (1982) in the Natal Drakensberg, *R. pumilio* was relatively common on all the land types, while *M. minutoides* and *Crocidura flavescens* were widely distributed but not abundant.

In contrast to their findings, *D. mesomelas* was caught in short and tall grassland and *Protea* savanna. *M. minutoides* was caught mainly where there were bare areas of soil, sand or pavement rock. Lynch (1989) noted that *M. minutoides* was patchily distributed in the NE Cape. *Graphiurus murinus* was caught only in scrub and rocky habitats in the present study. *G. murinus* was shown to be widely distributed, occurring at all altitudes, in the study of Lynch (1989).

Mastomys (natalensis) sp. was captured in a variety of habitats, from river valleys to rocky crests, as found by Lynch (1989). *Aethomys namaquensis* was only captured in rocky areas where there were bare patches of ground, as found by Bond *et al.* (1980).

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A few other species were caught rarely or only once in the region. These were *Crocidura cyanea* (on relatively bare rocky ground and under a rock overhang), *Tatera brantsii* (on a crest with sandy soil) *and Dendromus mystacalis* (in tall, thick grassland).

Species richness did not differ over the range of land types because species were not specific to particular land types. Rowe-Rowe & Meester (1982) also found that most species that occurred in the montane vegetation belt were present in the subalpine vegetation belt (these belts correspond to the range in altitude sampled in this study). Studies in South African montane areas with other vegetation types have shown that increase in altitude does not affect species occurrences (e.g. Nel, Rautenbach & Breytenbach 1980). Willan & Bigalke (1982) found that species richness was highest in riverine habitats and lowest in rocky outcrops in montane fynbos, which is similar to the findings of the present study. In contrast, north-facing slopes had highest small mammal diversities in the montane fynbos studied by Nel *et al*. (1980).

Abundance relations

Relative abundances of small mammals were greatest in valleys and least on north slopes and crests. Willan & Bigalke (1982) found that riverine habitats had the highest number of small mammals out of the habitats sampled in mountain fynbos. Nel *et al*. (1980) found that abundances were greatest on south-facing slopes in a mountain fynbos area. Small mammals were most abundant on sites with tall grassland in the present study and lowest on sites that had been recently burnt or grazed, or both. These findings paralleled those of Bowland & Perrin (1993) in a region of montane grassland in the Natal Drakensberg.

Rowe-Rowe & Meester (1982) and Bowland & Perrin (1993) found that the relative abundance relationship between *R. pumilio* and *M. varius* changes with altitude, the shrew becoming proportionately more abundant at higher altitudes. Rowe-Rowe & Meester (1982) related this to the greater herbage production at lower elevations, *R. pumilio* being favoured by the more luxuriant grass growth. The same pattern was evident in this study. However, there were no significant differences between land types in the mean numbers caught of each species with the exception of a greater number of *M. varius* on land type Bh compared with land type Ch.

MNA - population estimate relationship

MNA underestimated population size except when numbers were low. However, because of the straight line relationship, the use of MNA as a relative abundance term was considered satisfactory.

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Burning and grazing effects

Time since last burning and last grazing were not associated with species richness or relative abundance of small mammals. This indicates that the results need not be corrected for differences between land types in these factors. Most species (the only exception being *M. (natalensis)* sp.) in the main survey were captured on six to eight month post burn grassland, although numbers were low.

Van Hensbergen, Botha, Forsyth & Le Maitre (1992) found that species richness of small mammals did not change as a result of fire, although relative abundance declined for six to nine months post fire, in a high-rainfall area of fynbos. However, Rowe-Rowe & Lowry (1982) found that species richness of small mammals was greatest between one and two years after fire in montane grasslands of the Natal Drakensberg. Numbers peaked between six and twelve months after fire, and declined after two years. Bowland & Perrin (1993) found similar trends.

There are indications from the present study that results from the Natal Drakensberg cannot be extrapolated to the Cape Drakensberg. Herbage production may be greater in the Natal Drakensberg owing to the higher rainfall, and this may account for the differences between the two regions. The relationship between fire, grazing and small mammals should be further studied in the mountains of the NE Cape.

Threatened, rare species

M. albicaudatus was the only threatened, rare species captured (Dean 1978; Rebelo & Tansley 1993). It is listed as vulnerable in the South African red data book for terrestrial mammals and its biology needs further investigation (Smithers 1986). *M. albicaudatus* is predominantly a nocturnal species (i.e. was generally found in traps in the morning), but is also active diurnally (i.e. some captures were during the day). It was nearly always caught on bare patches, including rock, but there was always some vegetation (herbs, bushes or grass) in the immediate vicinity. This corroborates the findings of Lynch (1994) for the *M. albicaudatus* in Lesotho.

This species required rock outcrops or large loose surface rocks in its habitats to provide suitable burrow sites. In three cases the burrow entrance was in soil between two rocks in a rock band (with the entrance either on the horizontal or vertical surface) and in three others in a rock crevice. In other cases the burrow was under a rock or in the soil under a rock, and in one case the burrow was in compacted sandy soil with no rock nearby. Three of the burrow systems appeared to have at least two entrances, these being 1.5 to 2 m apart in two systems. Entrance diameters ranged from 36 x 39 mm to 50 x 110 mm (n=6).

On occasion, white-tailed mice were captured 40 or 50 m away from their burrows. After release they would sometimes hide in cracks under loose flat rocks before

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bounding off to their burrows. White-tailed mice appeared well-adapted to their habitats. They climbed up short vertical surfaces or bounded over rocks with ease and their grey-brown fur camouflaged them well against the rocks.

Geographical variation

Although *M. varius*, *O. irroratus*, and *M. minutoides* were recorded only in an alternative sample at some sites on a particular land type, they were all recorded at other sites on the same land type during the main survey. *C. cyanea*, *A. namaquensis* and *D. mystacalis* were not recorded during the main survey. The shrew and climbing mouse were scarce or absent in the survey of Lynch (1989). *A. namaquensis* appears to occur only marginally in the afforestable region, generally occurring in the drier areas of the district (map in Lynch 1989; this study). The results from the main survey therefore appeared to be adequately representative of the major small mammal associations in the region.

Conservation value and afforestation

Valleys were the most important sites for small mammals in the main survey. South slopes ranked second. During the whole study only *M. albicaudatus*, *T. brantsii* and *A. namaquensis* were not captured on either of these sites. The last-mentioned two species were marginal or scarce in the afforestable region. *M. albicaudatus* was the only threatened rare species in the study. Therefore crests and ridges also have high conservation value.

The two main species which attack young pine trees, *R. pumilio* and *O. irroratus* (Willan 1992), are associated with valleys and south slopes, respectively. Seedlings planted on these sites should be most prone to rodent attack, and so these sites may be less suitable for afforestation than others.

The different land types were considered to have similar conservation values because only *G. murinus* and *T. brantsii* were restricted to a single land type during the main survey.

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Table 1 Land types and sites trapped for small mammals. Land type code: first letter = geology (M=Molteno sandstone, E=Elliot sandstone, C=Clarens sandstone, B=Basalt); second letter = altitude class (l=low=1300-1500 m, m=mid=1500-1700 m, h=high=1700-1900 m). The number of occasions the traps were checked over a 4-day period and the per cent trap closures due to factors other than small-mammal captures are given (see text)

Geological formation	Altitude (m)	Land type	Site	Checking occasions	Percent closures
Molteno	1300-1500	Ml	Vlei	5	2.0
			N slope	6	3.0
			S slope	6	7.5
			E slope	6	11.3
			Crest	6	3.3
Elliot	1300-1500	El	Valley	4	3.5
			N slope	5	1.2
			S slope	7	1.3
			E slope	6	0.8
			Crest	8	2.4
Elliot	1500-1700	Em	Vlei	6	1.2
			N slope	8	0.9
			S slope	7	0.0
			E slope	8	0.4
			Ridge	7	0.7
Elliot	1700-1900	Eh	Valley	7	0.1
			N slope	7	0.4
			S slope	5	1.0
			E slope	7	1.6
			Crest	7	4.3
Clarens	1700-1900	Ch	Valley	6	10.8
			N slope	7	5.4
			S slope	6	0.2
			E slope	8	0.0
			Crest	7	0.0
Basalt	1700-1900	Bh	Valley	7	2.0
			N slope	8	1.1
			S slope	8	0.9
			E slope	6	1.2
			Crest	7	1.6

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Table 2 Species caught during the survey

Species	Species code
Myosorex varius	Mv
Crocidura cyanea	Cc
Crocidura flavescens	Cf
Graphiurus murinus	Gm
Otomys irroratus	Oi
Rhabdomys pumilio	Rp
Mus minutoides	Mm
Mastomys (natalensis) sp.	Mn
Aethomys namaquensis	An
Tatera brantsii	Tb
Mystromys albicaudatus	Ma
Dendromus mesomelas	Ds
Dendromus mystacalis	Dy

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Table 3 Minimum numbers of each small mammal species on one hectare of each site sampled. Land type codes as in Table 1; V=valley or vlei, N=North slope, S=South slope, E=East slope, C=crest or ridge; MNA = minimum number alive; species codes as in Table 2

Land type	Site	Species Mv	Cf	Oi	Rp	Mm	Mn	Ds	Ma	Gm	Tb	No. Spp.	MNA
Ml	V	7	3	5	57			1				5	73
	N	1			20	1						3	22
	S	10	2	1	32		1					5	46
	E			1	8							2	9
	C	4			11			1	1			4	17
El	V	6		1	89							3	96
	N	2			15							2	17
	S	9		3	44	1	1					5	58
	E				9							1	9
	C				6	12	3	1				4	22
Em	V	10	1	10	84							4	105
	N	1			5							2	6
	S	2			3							2	5
	E	4			10							2	14
	C					1			3			2	4
Eh	V	5			4			1				3	10
	N	3			3			2	2			4	10
	S	9	2	20	11							4	42
	E	9				1			1			3	11
	C	6							1		1	3	8
Ch	V	4	3	2		1		4				5	14
	N				4	1						2	5
	S	2		1	7							3	10
	E			1	4	1			1	3		5	10
	C					1			3			2	4
Bh	V	10		3	30							3	43
	N				14							1	14
	S	18		7	24							3	49
	E	20	1	2	41							4	64
	C	9		2	17				1			4	29

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Table 4 Numbers of small-mammal species and total small mammals recorded for the five site types. Means of the six land type areas

	Site type				
	Valley	North slope	South slope	East slope	Crest
Mean # species (S.D.)	3.8 (1.0)	2.3 (1.0)	3.7 (1.2)	2.8 (1.5)	3.2 (1.0)
Mean numbers (S.D.)	56.8 (40.8)	12.3 (6.6)	35.0 (22.0)	19.5 (21.9)	14.0 (10.3)

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Table 5 Mean minimum numbers per hectare of three common species over the three altitude classes (Low = < 1500 m, Mid = 1500 - 1700 m, High = > 1700 m)

Species		Altitude		
		Low	Medium	High
Myosorex varius	Mean	[illegible]	3.4	6.3
	(S.D.)	[illegible]	(4.0)	(6.3)
Rhabdomys pumilio	Mean	29.1	20.4	10.6
	(S.D.)	(27.1)	(35.7)	(12.5)
Otomys irroratus	Mean	1.1	2.0	2.5
	(S.D.)	(1.7)	(4.5)	(5.2)

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Table 6 Species recorded only in an alternative sample to the main survey sample on the same land type. The sampling period was March 1993 to January 1994. Each sample predated the main survey sample by at least nine months. Codes as in Table 3; variation codes: G = different locality to main survey, W = winter; method codes: F = full grid, R = reduced grid, T = trapline; o = one individual only, x = more than one individual

Land type	Site	Variation	Method	Species									
				Mv	Cc	Cf	Gm	Oi	Mm	Mn	An	Ds	Dy
Ml	S	G	R										
	E	G	R	o							x		
	C	G	R							x			
	S	G,W	F						o				
Ei	N		F			o			x			x	
	E	W	F	x								o	
	V	G,W	F			o			x				
	C	G,W	F										
Em	V	G	T							x			
	N	G	T		x								
	S	G	T				o						
	E	G	T			o							
	C	G	T										
	N	G,W	F				o		x				
	S	G,W	F		o			o				o	
Bh	S	G,W	F										o

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Table 7 Population estimates and their approximate 95% confidence intervals (95% CI) for species at various sites. Codes as in Table 3. Model codes: M_b = behavioural heterogeneity, JHE = joint hypergeometric maximum likelihood, M_h = heterogeneity in capture probabilities, Rem. = generalized removal

Land type	Site	Species	Model	Population estimate	Approximate 95% CI	MNA
Ml	V	Rp	M_b	71	59 - 152	57
	N	Rp	JHE	20	20 - 23	20
	S	Rp	M_h	33	32 - 47	32
	C	Rp	JHE	13	11 - 20	11
El	V	Rp	Rem.	150	107 - 676	89
	S	Rp	Rem.	49	44 - 68	44
	C	Mm	JHE	12	12 - 15	12
Em	V	Rp	Rem.	110	91 - 182	84
	E	Rp	JHE	10	10 - 10	10
Eh	S	Oi	JHE	28	21 - 45	20
	S	Rp	JHE	11	11 - 11	11
Bh	S	Rp	Rem.	30	25 - 48	24

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Appendix 1 Description of sampling sites. Most sites had streams, with associated taller riparian vegetation. Category codes for time since last fire and since last grazing: 0 = at time of sampling; <1 = less than one year; >1 = one to two years; >2 = more than two years

Land type	Site	Description	Last fire/ grazing (yrs)
Ml	Vlei	Tall grassland; patches of different grass species	>2/>2
	North	Short grassland; some tall grass; rock bands with shrubs & herbs	>2/>2
	South	Tall grassland, shallow slope; pavement rock with many herbs	>2/>2
	East	Tall grassland; very rocky; many herbs, dwarf *Proteas* & shrubs	>2/>2
	Crest	Short grassland; patches of tall grass; much pavement rock	>2/>2
El	Valley	Tall grassland; patches of short grass	>2/>2
	North	Short grass *Protea* savanna; patches of tall grass	>1/>2
	South	Tall grassland; short grass areas	>1/>1
	East	Short grassland	>1/<1
	Crest	Short grassland; pavement rock edge with shrubs & herbs	>1/<1
Em	Vlei	Tall grassland; patches of grass species	?/>2
	North	Short grassland	>1/<1
	South	Short grass dwarf *Protea* savanna	>1/<1
	East	Tall grassland	>1<1
	Crest	Short grassland; pavement rock; bare areas	>1/<1
Eh	Vlei	Short and tall grassland; many herbs	<1/<1
	North	Short grassland; stony; many bare areas & herbs	<1/<1
	South	Short grassland; much tall grass;	<1/<1

		rocky; many shrubs	
	East	Short grassland; much tall grass; many herbs	<1/<1
	Crest	Short grassland; many bare areas & herbs	<1/<1
Ch	Valley	Short grassland; patches of tall grass; many bare areas & herbs	<1/<1
	North	Short grassland; many herbs	<1/<1
	South	Short grassland; much tall grass; many herbs	<1/<1
	East	Short grassland; patches of tall grass; pavement rock; many herbs	<1/<1
	Crest	Short grassland; stony, pavement rock; much bare ground	<1/<1
Bh	Valley	Tall grassland; patches of grass species	>1/<1
	North	Tall grassland	>1/<1
	South	Tall grassland; short grass intermixed; many herbs	>1/<1
	East	Tall grassland: short grass intermixed; many herbs	>1/<1
	Crest	Tall grassland; pan with thick grass and sedges	>1/<1

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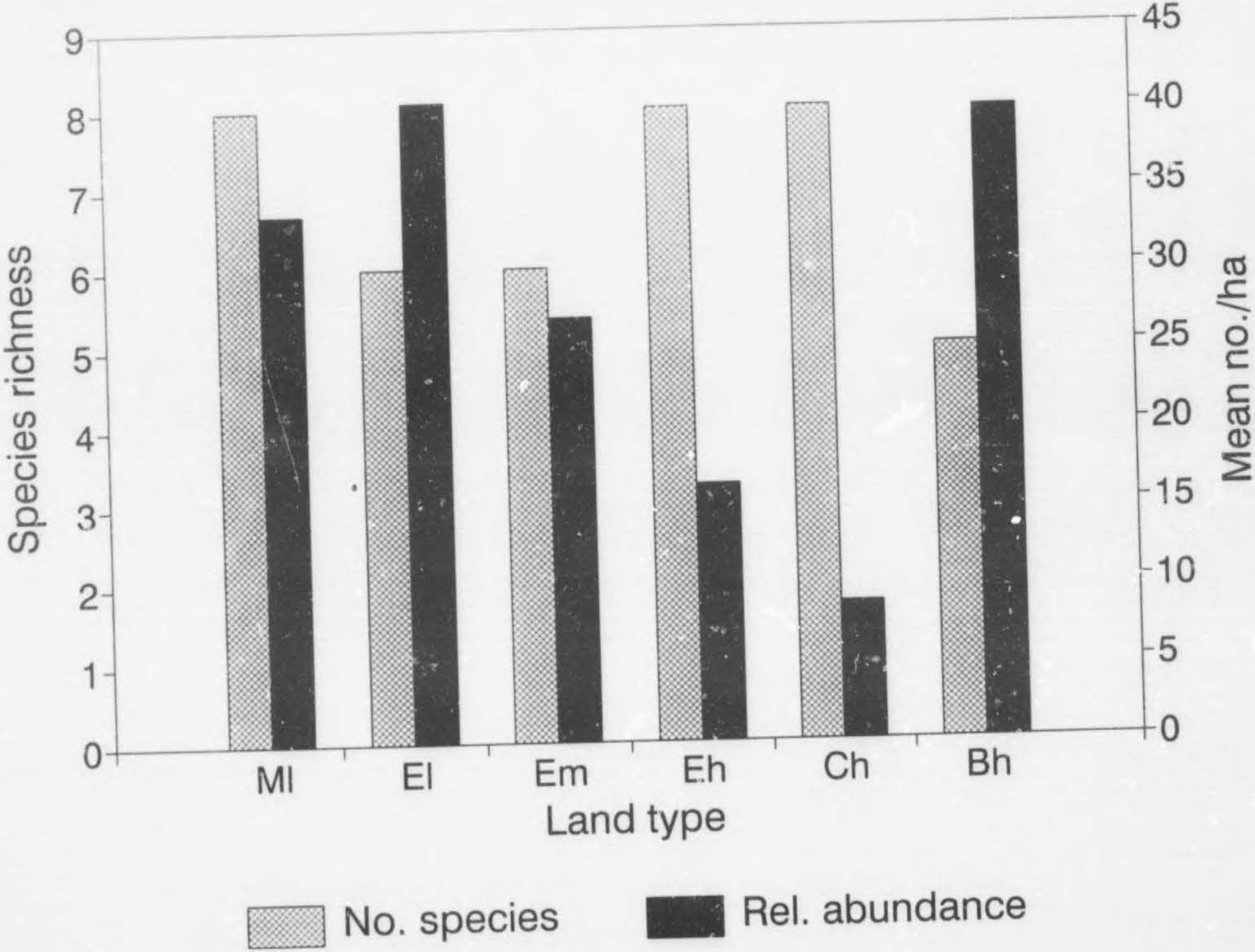
Caption for Figure

Figure 1 Small mammal species richness (number of species), and mean number of small mammals captured per hectare, on each land type.


Species richness
0
1
2
3
4
5
6
7
8
9
Mean no./ha
0
5
10
15
20
25
30
35
40
45
Ml
El
Em
Eh
Ch
Bh
Land type
▨ No. species
■ Rel. abundance

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Section 3

Selection of nature reserves in an afforestable montane region

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Chapter 8

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Selection of nature reserves in afforestable montane grasslands of the NE Cape, South Africa

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ABSTRACT

Large-scale afforestation with pines is taking place in the Maclear district, Eastern Cape Province, South Africa. Most of the afforestation has occurred on land predicted to have had high or medium value for wildlife conservation according to the richness of taxa criterion, and medium conservation value according to the montane endemicity criterion. Many species dependent on the grass sward will be eliminated from the planted areas. Although many smaller species are likely to survive on well-managed, unplanted areas on the forestry estates, some of the larger, threatened species may not. Land should be reserved to ensure the long-term survival of the wildlife within the afforestable area. Sufficiently-large areas of five land types are required to ensure the protection of all the grasshopper genera and species of butterflies, birds and small mammals. Substituting the low rainfall, high-altitude, basalt land type for the high rainfall, low-altitude, Molteno sandstone one in this set of five would protect all the montane endemic species. Potentially suitable areas for reservation are indicated.

Keywords: Commercial afforestation, conservation value, endemicity, land type, species richness

INTRODUCTION

Relatively many species of plants and of certain animal taxa are endemic to the Afromontane region of South Africa, which is therefore of conservation importance (e.g. Dirsh, 1956; Brown, 1962; Hilliard & Burtt, 1987; Siegfried, 1992; Matthews *et al.*, 1993; Pringle *et al.*, 1994). Some of the region is suitable for large-scale afforestation, and this leads to conflict with other land uses, such as nature conservation and water generation (e.g. Allan *et al.*, 1995; Bosch & von Gadow 1990).

The high rainfall montane grasslands of the NE Cape, South Africa, are an example of an Afromontane area where such conflict has arisen. One third of the threatened,

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rare bird species of South Africa, including five globally threatened species, occur in the Maclear district (Brooke, 1984; Collar *et al.*, 1994; Armstrong & van Hensbergen, in press *a*). There are no statutory nature reserves in these grasslands. A rational allocation of land to different land-uses is required.

Pressey *et al.* (1993) give several principles to guide the selection of areas to be incorporated in a nature reserve network for a region. An important principle is complementarity, the choice of areas which maximize the number of species protected on a given total area, owing to them having different suites of species. This paper addresses the question of where nature reserves should be situated in the afforestable parts of the Maclear district.

STUDY AREA

The Maclear district (*c.* 30°42'-31°25'S, 27°55'-28°30'E) lies at the southern end of the Drakensberg range in the north of the Eastern Cape Province, South Africa. The topography is hilly to mountainous, with numerous streams and rivers. Basaltic lavas occur above 1700 m, and overlie three sedimentary formations, composed of sandstones and mudstones (1:250 000 Geological Series Maps, Geological Survey, Pretoria). The climate is warm temperate (Schulze & McGee, 1978) with a mean annual precipitation of 600 - 1200 mm (Dent *et al.*, 1987).

METHODS

The analysis was done at the farm unit scale, because this is the scale at which land is bought. Only original farm boundaries are shown on the maps in this paper (South Africa 1:50 000 sheets, Surveys and Mapping, Mowbray). Sub-units of some of these farms have been sold as separate land units, including for forestry. However, sub-units have not been considered separately. The whole original farm was considered planted if a sub-unit was afforested. The remaining sub-units of some farms may be planted in future.

Each farm in the afforestable part of the Maclear district was classified according to its predominant land type. Land types were defined by combinations of classes of altitude, geology and mean annual precipitation (MAP). There were four major geological classes (Molteno sandstone, Elliot sandstone, Clarens sandstone and basalt), three altitude classes (low: 1200-1499 m, medium: 1500-1699 m, high: 1700-1999 m) and two MAP classes (low: <900 mm, high: ≥900 mm). The land types are given in Table 1.

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Two conservation values were assigned to each land type, according to the richness of taxa and endemicity criteria, respectively, derived from the results published by Armstrong & van Hensbergen (in press *a*). Mean ranks were used to assign conservation values to the land types (Table 2). This was done to prevent value judgements as to whether a species in one taxon is equivalent to a species in another. In this way the conservation values were protected from a more speciose group swamping out the effect of other less speciose groups. Conservation values were assigned on a linear scale.

No small mammals endemic to the Afromontane region were recorded during sampling (Armstrong & van Hensbergen, in press *b*). The number of small-mammal species recorded on each land type was lower than that of the other three faunal groups sampled, and most of the species were widely distributed in the district. Therefore, small mammals were not considered when assigning conservation values to the land types.

The five land types that were rare (Ehl, Cml, Cmh, Chl, Bmh; Table 1) were not sampled. Land types Ehl and Chl were given the same conservation values as land types Ehh and Chh, respectively, because rainfall played little role in determining animal distributions (Armstrong & van Hensbergen, in press *a*). The other three land types were not given a conservation value. Table 2 gives the rankings and conservation values of each sampled land type (modified from Armstrong & van Hensbergen, in press *a*, to include land type Bhh).

The method of sampling along a land type gradient was used because it is efficient in terms of area sampled and it allows inference to other unsampled areas (Austin & Heyligers, 1989, 1991). However, only one locality was sampled for each land type. Therefore the results can only give weak inferences about the conservation values of localities that were not sampled. Data manipulations were done using PC ARC/INFO 3.4D, and the map layout using ArcView 2.0C (ESRI, Inc.).

The principle of complementarity was used to prioritize the land types for reservation. The land type with the highest value for the criterion under consideration was selected first, and then the land type with the highest number of complementary taxa was selected. The last-mentioned step was then repeated until all the taxa were present in the selected set of land types. The land type with the greatest number of total complementary taxa was chosen where there was a tie during the selection of land types for montane endemic species. The term 'montane endemic' is used for species and, in the case of insects, subspecies that are confined to, or are mainly found in, the montane ecosystem in Africa (White, 1978; Dowsett, 1986).

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Potentially suitable areas for reservation were parts of the district where farms with required land types were close together, if possible forming a consolidated unit. The management of the set of farms would thereby be facilitated.

RESULTS

The distribution of the land types in the Maclear district is indicated in Fig. 1. The land types with high conservation values for total richness of taxa are predominantly situated in the eastern part of the district (land types Mll & Mlh; Fig. 2), with a smaller concentration in the western part (land types Chh & Chl). Most of the afforested farms are classified as having had high or medium conservation value (Figs 2 & 3).

The combination of land types required to protect all the taxa of the afforestable grasslands is given in Table 3. Areas of all land types are required. The best regions for the situation of nature reserves, using the total richness of taxa criterion and excluding afforested farms from consideration, are indicated on Fig. 3. Only land types contributing more than 5 % new taxa (Table 3) are included.

The land types with high conservation values according to the endemicity criterion are predominantly situated in the high-lying northern part of the district (land types Bhh & Bhl; Fig. 4), with a small concentration in the central part (land type Elh). Most of the afforested farms are classified as having had medium conservation value (Figs 4 & 5).

The combination of land types required to protect all the montane endemic species of the four faunal groups in the afforestable grasslands is given in Table 4. Adequately-large areas of only five land types need to be reserved to protect the complement of endemics. The best region for the situation of nature reserves, using the endemicity criterion and excluding afforested farms, are indicated on Fig. 5.

DISCUSSION

Areas of all the land types need to be reserved to ensure that all the species of the four faunal groups are protected in the afforestable region, according to the survey data. However, some of the taxa recorded only on one or more of land types Ell, Eml, Emh, Ehh and Bhl were recorded outside sampling time on one or more of the first five land types in Table 2. Most of the nine other species probably occur there as well, so it is likely that only land types Mll, Mlh, Elh, Chh and Bhh need to be reserved.

Prediction of species or species assemblage occurrence in unsampled areas has been done in some studies using predictor coverages in a geographical information system together with statistical methods such as generalized linear models (e.g. Cocks &

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Baird, 1991; Bojórquez-Tapia *et al.*, 1995; Schuster, 1995). Verification of the predicted conservation values of unsampled localities was not done in the present study. This should be done for localities selected for reservation before the land is bought. Prediction of taxon richness and species occurrences on unsampled land types could be done using generalized linear models with the variables defining the land types as predictors (Nicholls, 1991). This was not considered necessary in the present study owing to the small number of afforestable farms with unsampled land types.

The potential conflict between commercial afforestation and wildlife conservation is illustrated by the fact that most of the planted farms had high or medium predicted conservation values according to the richness of taxa criterion, and medium conservation value according to the endemicity criterion, before afforestation. More farms with high conservation value according to the endemicity criterion may be planted in the future. There are relatively few of these farms (Tables 1 & 2). Research is needed to determine whether any of the endemic species will persist on grassland remnants in forestry estates. Some endemics with limited spatial requirements may persist on these remnants and therefore will be adequately protected in the forestry areas, provided that the remnants are managed correctly (e.g. burnt within the natural fire regime). The forestry industry could, in this respect, play a beneficial role in the protection of these endemic species.

Two of the montane endemic birds (Cape vulture *Gyps coprotheres* and yellow-breasted pipit *Hemimacronyx chloris*) are globally threatened species (Collar et al., 1994). Other globally threatened species (lesser kestrel *Falco naumanni*, blue crane *Grus paradisea* and wattled crane *Grus carunculatus*) and locally threatened ones (Stanley's bustard *Neotis denhami* and ground hornbill *Bucorvus leadbeateri*) also occur in the afforestable part of the district (Brooke 1984; Collar *et al.*, 1994; Armstrong & Weir, 1995; Armstrong & van Hensbergen, in press *a*). These species require large areas of open grassland and usually occur on flattish ground, which is also prime afforestable land where the soils are suitable. Therefore it may be necessary to reserve sufficiently-large areas of land with high conservation value to ensure the long-term existence of these species in the district. However, the numbers of some of these species (e.g. wattled crane, ground hornbill) may be too low to ensure their long-term persistence in the district.

Five land types need to be reserved to protect all the montane endemic species, and most of the endemics would be protected on three land types (Elh, Bhl, Bhh), providing adequately large areas of these land types were reserved. In fact, adequate areas of only two land types (Elh, Bhh) may be necessary, considering that the cutpoint between the two rainfall classes did not coincide with the distribution limits of most animals in these grasslands (Armstrong & van Hensbergen, in press *a*).

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The locality sampled on land type Elh was predominantly *Protea* savanna. Montane endemic species associated with proteas (e.g. Gurney's sugarbird *Promerops gurneyi*, greater double-collared sunbird *Nectarinia afra* and orange-banded protea-butterfly *Capys alphaeus extentus*) contributed to the importance of land type Elh (Henning & Henning, 1988; De Swardt, 1993; Armstrong & van Hensbergen, in press *a*). Any suitable area of *Protea* savanna at low altitude should contain these species (cf. Armstrong & van Hensbergen, in press *a*; Appendix 3, south slope, land type Mlh).

Therefore, a sufficiently-large area on high-altitude basalt, preferably with some relatively flat land, and an adequately-large area of *Protea* savanna would be sufficient to protect most montane endemic species. Thus the northern part of the district is most suitable for reservation for montane endemics not associated with *Protea* savanna. It is also important for threatened and rare species. The Cape vulture, wattled crane, blue crane, Stanley's bustard, yellow-breasted pipit and striped flufftail *Sarothrura affinis*, a rare montane endemic (Brooke, 1984), have all been recorded in this region (A.J. Armstrong, unpublished data).

The minimum area of land required for reservation would depend on the species targeted for protection, their spatial requirements and distributions, and whether their habitats are adversely influenced by land use practices on areas that will not be afforested. Some of the threatened birds could act as umbrella species (Ryti, 1992). Good candidates would be the yellow-breasted pipit and Stanley's bustard. Both of these species generally occur on ground that is suitable for afforestation, they occur in the same parts of the landscape as many of the endemic animal species, and if sufficiently large areas of land are reserved to ensure their long-term survival (probably tens of thousands of hectares), the long-term survival of many other species should be assured. The Gurney's sugarbird (*Promerops gurneyi*) could act as an umbrella species for *Protea* savanna endemics.

Research would have to be done on these umbrella species to determine the area of land required to maintain a viable population of each in the district. However, this may take many years, so the best alternative may be to reserve as much land as possible of each land type according to the available funds.

The reserved land need not be in one consolidated area, although such an area would be easier to manage and may better protect the larger species owing to their lower densities. Several areas scattered throughout the afforestable district would also suffice. The latter could be sited so as to connect with other unplanted areas such as stock farms or unplanted forestry land, thereby increasing the effective area available as wildlife habitat. Riparian strips and wetlands are not planted with trees. These could act as effective corridors between unplanted areas and as habitat for some wildlife, especially butterflies, small mammals and wetland birds (Bennett 1987; Newbey &

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Newbey 1987; Merriam 1991; Saunders & de Rebeira 1991; Armstrong & Weir, 1995; Armstrong & van Hensbergen, in press *a*, *b*).

The importance of determining a nature reserve network before large-scale afforestation is demonstrated by this study. Afforestation has prevented the consolidation of the five land types into one block in the western area suggested to be potentially suitable for reservation to protect the full complement of the taxa sampled (compare Figs 1 & 4). However, land in more than one region of the district would have had to be reserved to protect the montane endemic species before afforestation.

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TABLE 1

Definition of land types and the number of farms with each land type in the afforestable part of the Maclear district.

Geology	Altitude	Rainfall	Land type	No. farms
Molteno	Low	Low	Mll	116
		High	Mlh	12
Elliot	Low	Low	Ell	65
		High	Elh	15
	Medium	Low	Eml	11
		High	Emh	18
	High	Low	Ehl	3
		High	Ehh	9
Clarens	Medium	Low	Cml	1
		High	Cmh	3
	High	Low	Chl	2
		High	Chh	14
Basalt	Medium	High	Bmh	1
	High	Low	Bhl	14
		High	Bhh	23

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TABLE 2

Ranking of land types (1 = highest) with respect to number of genera or species, and endemicity (E). CV = conservation value.

Land type	Rank								CV	
	Grasshoppers		Butterflies		Birds		Mean			
	Gen.	E	Spp.	E	Spp.	E	Taxa	E	Taxa	E
Mll	6	7.5	1	8	1	5	2.7	6.8	1	6
Mlh	9	9.5	2.5	8	2	5	4.5	7.5	3	8
Ell	4.5	7.5	9	8	3	5	5.5	6.8	4	6
Elh	10	5.5	2.5	3	4	5	5.5	4.5	4	3
Eml	2.5	9.5	7.5	8	10	5	6.7	7.5	7	8
Emh	2.5	3	7.5	8	7.5	10	5.8	7.0	5	7
Ehh	4.5	3	5.5	3	9	9	6.3	5.0	6	4
Chh	1	5.5	4	5	5	5	3.3	5.2	2	5
Bhl	7.5	3	5.5	1	7.5	5	6.8	3.0	8	2
Bhh	7.5	1	10	3	6	1	7.8	1.7	9	1

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TABLE 3

Combination of land types, in descending order of importance (1 = first choice) using the principle of complementarity, required for protecting all the taxa.

Choice	Land type	% new taxa included
1	Mll	52.7
2	Chh	16.0
3	Elh	9.6
4	Bhh	6.9
5	Mlh	5.9
6	Ell	3.2
7	Bhl	2.7
8	Eml	1.6
9	Ehh	1.1
10	Emh	0.5

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TABLE 4

Combination of land types, in descending order of importance (1 = first choice) using the principle of complementarity, required for protecting all the montane endemic species.

Choice	Land type	% new taxa included
1	Bhh	58.8
2	Elh	17.6
3	Bhl	14.7
4	Mll	5.9
5	Chh	2.9

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Captions to figures

Fig. 1. Distribution of land types in the Maclear district. Farm boundaries are indicated. Land type codes as in Table 1 (Beh = non-afforestable escarpment; Out = outside of district).

Fig. 2. Distribution of farms according to conservation value (Cv, 1 = highest) for total richness of taxa in the Maclear district.

Fig. 3. Distribution of unplanted farms with land types required in combination for the protection of the full complement of taxa. Afforested farms are indicated by dark green. A box indicates a region with suitable farms for reservation in close proximity.

Fig. 4. Distribution of farms according to conservation value (Cv, 1 = highest) for montane endemic species in the Maclear district.

Fig. 5. Distribution of unplanted farms with land types required in combination for the protection of the full complement of montane endemic species. Afforested farms are indicated by dark green. A box indicates a region with suitable farms for reservation in close proximity.

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Appendices

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Appendix 1: Impacts of afforestation with pines on assemblages of native biota in other southern hemisphere countries

Plantations of pine trees in different southern hemisphere countries appear to have a similar effect on the number and densities of plant and animal species (e.g. McIlroy 1978; Friend 1980; Happold & Happold 1987; Chapter 2). Generally there is a reduction in the number of organisms and the number of species in pine plantations compared with the original habitat. Species that are dependent on the original vegetation for food or other resources are eliminated from the planted area. This has been interpreted, for vertebrates at least, as a result of the lack of specific resources, such as particular foods and home sites, in commercial plantations compared with the native vegetation. However, the extent to which these resources are lacking depends on the history of the plantation (age, fire and silvicultural history, etc.), the size and shape of the plantation, and the spatial relationship between the plantation and adjacent habitats (Friend 1980; Gilmore 1990).

Differences in spatial and temporal availability of resources in plantations compared with indigenous habitats may determine the spatial and temporal use of the plantations by native animals. For example, animals utilizing plantations are often most abundant near edges, e.g. near the periphery or where some native vegetation grows, because resources are often concentrated there, and utilization of plantations by a particular species may be seasonal in response to seasonal availability of food (Friend 1980; Clout & Glaze 1984; Gilmore 1990).

The importance of indigenous habitat remnants for the maintenance of biodiversity in plantation areas has been shown in many studies. These remnants often have to be large, to adequately protect certain native animals (e.g. Suckling 1982).

Results of some relevant studies from different countries are summarized below.

Africa

Malawi. There was a greater diversity of small mammal species in two indigenous habitats than in different-aged pine stands in one area (Happold & Happold 1987). There was also a decrease in species richness with increasing age of the pines. The total abundance of small mammals, and the abundance of each species, was greater in their indigenous habitats than in the pine plantations. Some species occurring in the area did not occur in pine habitats because they require habitat structures that are absent in pine plantations.

South America

Chile. The diversities of plants and small mammals in an area of indigenous matorral was greater than that of the surrounding pine plantation (Munoz & Murua 1989). Foliage diversity was greater in the

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matorral study area than in the pine stand. The matorral was therefore a more diverse habitat for the small mammals.

Brazil. Many more species and much greater numbers of birds were recorded in native cerradao vegetation than pine plantations in a study by de Almeida (1979). Abundance and species richness of birds in a plantation of two native tree species was also low in comparison to the indigenous habitats. Species richness and relative abundance in the different habitats were influenced by size and spatial context: a small section of pines situated between a cerradao reserve and the plantation of native trees had a relatively high species richness and relative abundance of birds compared with the other areas of plantation studied. The larger (16 ha) cerradao reserve had more birds but a similar number of species than the smaller cerradao reserve (2 ha), both of which were surrounded by plantation. The same number of species was captured in an extensive area of cerradao vegetation outside the plantation area as in the larger reserve, but the latter had a higher relative density.

There was a noticeable edge effect in a homogeneous pine stand: most birds were caught within 100 m of the edge of the plantation. There were no recaptures of birds in most of the exotic plantations during this mist-netting study, indicating that birds were generally not resident in the pines. The requirement for reserves of indigenous vegetation within plantation areas to maintain the diversity of birds was clearly shown (de Almeida 1979).

Australasia

Australia. Plant species diversity generally declines with increasing age of the pines, and species composition varies with plantation age (Friend 1980). The soil biota biomass in pine plantations is dominated by mesofauna, while that in indigenous eucalypt forest is dominated by macrofauna (Spain 1975). This is due to the different natures of the soils and forest floors caused by the different chemical natures of the litter in the two habitats.

Results from bird studies are summarized in Chapter 2. Commercial afforestation may have contributed to regional extinctions or population declines in several bird and mammal species (Gilmore 1990).

Barnett *et al.* (1977) found that three of the six small mammal species, including two introduced murids, caught during a study of pine plantations and indigenous forest in New South Wales, only occurred in pine habitat. Another species was resident in both vegetation types, but only occurred peripherally in the pine habitat. These four species were all omnivores. An insectivore occurred in both habitats but was resident only in the native forest, while a folivore was trapped only in the native forest.

In a study of three different-aged *Pinus radiata* plantations and native eucalypt forest in Victoria, Suckling & Heislers (1978) found that two indigenous small mammal species were permanent inhabitants of all the pine plantations. The third native species was a permanent resident only of the young (8 yr) plantation. The introduced *Mus musculus* was resident in the old (42 yr) plantation. A remnant riparian strip of eucalypt forest in the plantation area had the highest relative abundance of small mammals and all

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four species occurred there. Residency in pine plantations apparently depended on the presence of suitable low vegetation, with riparian areas, which supported such cover, consistently having higher numbers of small mammals than slopes with sparser understorey. Two of the species were absent from most or all of the plantation slopes sampled. Successional changes were recorded: relative abundance of small mammals decreased with increasing plantation age.

Abundances of small mammals were generally greater in eucalypt woodland than in pine plantations in Victoria (Friend 1982). Second rotation pine plantations only had one small mammal species, the exotic house mouse (*Mus musculus*). More mammal species occurred in areas of eucalypt woodland than in areas with pines.

Tree-cavity dwelling mammals are impacted negatively by afforestation since pines lack cavities at the pre-harvest ages (McIlroy 1978). Suckling (1982) showed that large areas of remnant native vegetation, thousands of hectares in size, are required to adequately protect the mammals of a region subject to *Pinus radiata* afforestation and farming.

Remnants of native habitat are crucial for maintaining the presence of at least some indigenous species in transformed landscapes in Australia (e.g. Bennett 1987; Saunders & Ingram 1987). However, the patches must be large enough to buffer against stochastic events and microhabitat variability and to maintain viable populations (Ehrlich & Murphy 1987; Lyon 1987; Main 1987; Recher *et al.* 1987). Corridors between patches allow the dispersal of young or adults, and these may help buffer against the effects of stochastic events on some species dependent on remnant vegetation for survival (e.g. Bennett 1987; Newbey & Newbey 1987; Saunders *et al.* 1991). However, remnants may have to be managed to prevent the local extinction of habitat-dependent species over time, especially isolated remnants. A variety of habitats are required within remnants for the survival of species that are dependent on a combination of habitat types, e.g. species whose nesting habitats differ from their feeding habitats (Saunders *et al.* 1991).

New Zealand. There is apparently a moderate diversity of indigenous plants in pine plantations (Allen *et al.* 1995). Plantation management modifies normal plant compositional development of the understorey, and the relatively short rotation time prevents slowly dispersing species from establishing in plantations. However, the pine understorey in one study consisted mainly of indigenous species. Indigenous species composition varied with topographic position, and therefore areas over the whole topographic gradient should be protected to maintain biodiversity.

Clout & Gaze (1984) found, in a study of the birds of different-aged plantations and native forests in the same region (including paired study areas), that resident native bird species were generally more abundant in native forest. These included species feeding on honeydew and/or fruit, whose food supplies were generally more abundant in native forest or absent in pine plantations. Occupation of pine plantations by the latter species varied seasonally, with some plantations having fewer of these birds in winter. A frugivorous pigeon was absent from pine habitats in winter.

Native bird richness was correlated with foliage height diversity, plantations generally being less diverse structurally than native forest. A hole-nester was absent from plantations. Two insectivorous

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species were mainly found in a relatively old pine stand, being scarce or absent in most of the other habitats studied. More native species were found in older than young (6-12 yr) pine plantations.

None of ten common alien bird species recorded preferred native forest to plantations, and the majority were most common in the pine habitats. Therefore, a major effect of the replacement of native forest with pine plantation was a change in the composition of the bird assemblage in the area. Species richness of all species and of native species was similar between plantations and native forest. Density of birds, however, can be less in plantations than native forest. Most of the forest birds absent from conifer plantations in New Zealand are either hole-nesters or are partially frugivorous or nectarivorous (Clout & Gaze 1984). Native birds found in pine plantations are mainly insectivorous species (Jackson 1971; Clout & Gaze 1984).

Clout & Gaze (1984) concluded that the retention of areas of native forest within forestry areas, preferably throughout each area, and the enhancement of plantations as bird habitat was important for the maintenance of forest bird diversity.

Bats, New Zealand's only native land mammals, are usually not found in pine plantations, although introduced mammals are often common (Bull 1981).

Conclusion

The afforestation of indigenous habitats with pines appears to have similar general effects on the native plant, bird and mammal assemblages in the southern hemisphere countries studied. The richness and abundances of native species are usually reduced. However, there may be area-specific differences within countries in the response of the native biota to afforestation.

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Appendix 2: Characteristics of the plants and mammals used in the analyses of Chapter 4

(a) Plants

Classification of plants recorded at Bosboukloof and Biesiesvlei, Jonkershoek, by Milton (1976) and Rycroft (1950), respectively. Plants are classified with respect to pollination system (PS), seed dispersal system (SD), potential method of persistence (PA) and site (ST). References for the pollination system (RPS), seed dispersal system (RSD) and potential methods of persistence (RPA) are given for each plant. The key to the symbols is given beneath the table.

SPECIES	PS	SD	PA	RPS	RSD	RPA	ST
Adiantaceae							
ADIANTUM AETHIOPICUM	*	W	d	5	5	7	I
PELLAEA AURICULATA	*	W	d	5	5	7	I
PELLAEA PTEROIDES	*	W	d	5	5	2	P
Aspleniaceae							
ASPLENIUM LUNULATUM	*	W	d	5	5	7	I
Blechnaceae							
BLECHNUM AUSTRALE	*	W	d	5	5	1	I
BLECHNUM CAPENSE	*	W	d	5	5	7	I
Dennstaedtiaceae							
PTERIDIUM AQUILINUM	*	W	d	5	5	1	I,P
Osmundaceae							
TODEA BARBARA	*	W	d	5	5	1	I
Schizaeaceae							
MOHRIA CAFFRORUM	*	W	d	5	5	1	I,P
Thelypteridaceae							
THELYPTERIS BERGIANA	*	W	d	5	5	7	I
Cupressaceae							
WIDDRINGTONIA NODIFLORA	W	W	d	1	36	2	I
Alliaceae							
ZANTEDESCHIA AETHIOPICA	I	V	d	48	48	5	I
Amaryllidaceae							
CYRTANTHUS VENTRICOSUS	I	W	d	98	30	2	P
HAEMANTHUS COCCINEUS	A	O	s	17	18	2	P
Asparagaceae							
PROTASPARAGUS COMPACTUS	I	V	d	31	19	7	P
PROTASPARAGUS RUBICUNDUS	I	V	d	31	31	2	I,P

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SPECIES	PS	SD	PA	RPS	RSD	RPA	ST
MYRSIPHYLLUM ASPARAGOIDES	I	V	d	32	19	7	P
MYRSIPHYLLUM SCANDENS	I	V	d	32	32	7	P
Asphodelaceae							
BULBINE ALOOIDES	I	W	d	99	99	5	P
BULBINE FAVOSA	I	W	d	99	99	5	I,P
KNIPHOFIA OCCIDENTALIS	B	W	d	99	99	5	I
Colchicaceae							
ONIXOTIS PUNCTATA	I	O	s	99	10	5	I
WURMBEA SPICATA	I	W	d	45	45	1	I
Cyperaceae							
CARPHA GLOMERATA	W	A	d	1	99	9	I
CYPERUS SPHAEROSPERMUS	W	A	d	1	99	5	I
CHLOROPHYTUM RIGIDUM	I	O	s	7	99	5	P
TRACHYANDRA HIRSUTA	I	O	s	7	99	2	P
FICINIA CAPILLARIS	W	M	s	1	99	10	P
FICINIA FILIFORMIS	W	M	s	1	99	3	I
FICINIA NIGRESCENS	W	M	s	1	47	2	I,P
FICINIA TRICHODES	W	M	s	1	99	5	I
ISOLEPUS PROLIFERA	W	A	d	1	99	5	I
TETRARIA BROMOIDES	W	M	s	1	99	2,5	I
TETRARIA BURMANNII	W	M	s	1	99	2,5	I
TERTRARIA CUSPIDATA	W	O	s	1	49	2	I,P
TETRARIA INVOLUCRATA	W	M	s	1	99	5	P
Haemodoraceae							
WACHENDORFIA PANICULATA	I	O	s	99	99	3	I
Hyacinthaceae							
LACHENALIA ORCHIOIDES	I	M	s	7	34	2	I,P
ORNITHOGALUM GRAMINIFOLIUM	I	O	s	33	33	7	I
ORNITHOGALUM HISPIDUM	I	O	s	33	33	2	I,P
ORNITHOGALUM THYRSOIDES	I	O	s	33	33	3	I
TENICROA EXUVIATA	I	O	s	55	55	7	I
Hypoxidaceae							
SPILOXENE CAPENSIS	I	O	s	7	56	2	I
SPILOXENE FLACCIDA	I	O	s	50	99	7	I
SPILOXENE SCHLECHTERI	I	A	d	50	99	7	I
SPILOXENE SERRATA	I	O	s	50	99	7	I

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SPECIES	PS	SD	PA	RPS	RSD	RPA	ST
Iridaceae							
ARISTEA GLAUCA	I	W	d	99	58	7	I
ARISTEA CONFUSA	I	W	d	99	58	1	I
BABIANA DISTICHA	I	O	s	59	99	7	I
BOBARTIA INDICA	I	O	s	60	60	2	I,P
CHASMANTHE AETHIOPICA	B	V	d	16	8	1	I
GALAXIA OVATA	I	O	s	62	62	7	I
GEISSORHIZA OVATA	I	O	s	63	99	1	I
GEISSORHIZA ASPERA	I	O	s	63	99	3	I
GLADIOLUS CARNEUS	I	W	d	50	50	2	I
GLADIOLUS GRACILIS	I	W	d	50	99	1	I
GLADIOLUS PUNCTULATUS	I	W	d	50	50	7	I
IXIA COCHLEARIS	I	O	s	64	8	7	I
IXIA MACULATA	I	O	s	64	99	1	I
MICRANTHUS ALOPECUROIDES	I	O	s	99	99	2	I
MORAEA TRICUSPIDATA	I	O	s	42	42	2	I
MORAEA CRISPA	I	O	s	42	42	7	I
MORAEA FUGAX	I	O	s	42	42	7	I
MORAEA PAPILIONACEA	I	O	r	42	42	7	I
MORAEA TRIPETALA	I	O	s	42	42	1	I
THEREIANTHUS SPICATUS	I	O	s	64	99	1	I
TRITONIA CRISPA	I	O	s	66	66	2	I,P
TRITONIOPSIS BURCHELLII	B	W	d	16	57	7	I
TRITONIOPSIS PARVIFLORA	I	O	s	65	65	7	I
TRITONIOPSIS LATA	I	W	d	65	65	7	I
WATSONIA MARGINATA	I	O	s	43	43	7	I
WATSONIA BORBONICA	I	O	s	43	8	2	I
Juncaceae							
JUNCUS CAPENSIS	W	V	d	39	39	1	I
JUNCUS LOMATOPHYLLUS	W	V	d	39	39	1	I
Orchidaceae							
CERATANDRA ATRATA	I	W	d	40	99	5	I
DISPERIS CAPENSIS	I	W	d	7	99	1	I
DISPERIS VILLOSA	I	W	d	40	99	5	I
MONADENIA BOLUSIANA	I	W	d	40	99	5	P
PTERYGODIUM ALATUM	I	W	d	7	41	5	I

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SPECIES	PS	SD	PA	RPS	RSD	RPA	ST
PTERYGODIUM CATHOLICUM	I	W	d	40	41	1	I,P
SATYRIUM CORIIFOLIUM	I	W	d	7	41	5	I
Poaceae							
CYNODON DACTYLON	W	O	s	2	[illegible]	1	I
EHRHARTA BULBOSA	W	V	d	2	99	2	P
EHRHARTA CALYCINA	W	M	s	2	2	1	I,P
EHRHARTA CAPENSIS	W	V	d	2	99	2	I
EHRHARTA LONGIFOLIA	W	V	d	2	99	1	I
EHRHARTA REHMANNII	W	M	s	2	2	7	I
EHRHARTA RAMOSA	W	M	s	2	2	1,2	P
EHRHARTA RUPESTRIS	W	O	s	2	99	7	P
HYPARRHENIA HIRTA	W	V	d	2	2	1	I
IMPERATA CYLINDRICA	W	W	d	2	2	1	I
KOELERIA CAPENSIS	W	O	s	2	2	3	I
MERXMUELLERA RUFA	W	V	d	2	2	2	I
MERXMUELLERA STRICTA	W	V	d	2	2	2	P
PENNISETUM MACROURUM	W	V	d	2	2	1	I
PENTASCHISTIS AMPLA	W	V	d	2	2	1	P
PENTASCHISTIS ARISTIDOIDES	W	V	d	2	2	2	I,P
PENTASCHISTIS ASPERA	W	V	d	2	2	7	P
PENTASCHISTIS CURVIFOLIA	W	V	d	2	2	1,2	I,P
PENTASCHISTIS MALOUINENSIS	W	O	s	2	2	3	I
PENTASCHISTIS PALLIDA	W	V	d	2	2	1	I,P
PENTASCHISTIS STUDELLII	W	V	d	2	2	1	P
PENTASCHISTIS TORTUOSA	W	V	d	2	2	1	I
THEMEDA TRIANDRA	W	V	d	2	2	2	I,P
TRIBOLIUM HISPIDUM	W	O	s	2	2	7	[illegible]
TRIBOLIUM UNIOLAE	W	O	s	2	2	1	I,P
Restionaceae							
CANNAMOIS VIRGATA	W	M	s	1	44	2	I
ELEGIA JUNCEA	W	O	s	1	99	2	I
HYPODISCUS ALBOARISTATUS	W	M	s	1	99	2	I
ISCHYROLEPIS SUBVERTICILLATA	W	O	s	1	99	1	I
ISCHYROLEPIS GAUDICHAUDIANUS	W	O	s	1	99	2	I,P
RESTIO FILIFORMIS	W	O	s	1	99	2	I
RESTIO TRITICEUS	W	O	s	1	99	2	P

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SPECIES	PS	SD	PA	RPS	RSD	RPA	ST
Tecophilaeaceae							
CYANELLA HYACINTHOIDES	I	O	s	35	35	3	I,P
Anacardiaceae							
HEERIA ARGENTEA	I	V	d	37	37	2	I
RHUS ANGUSTIFOLIA	I	V	d	25	19	1	I,P
RHUS ROSMARINIFOLIA	I	V	d	99	19	2	I,P
RHUS TOMENTOSA	I	V	d	37	19	2	I,P
Aquifoliaceae							
ILEX MITIS	I	V	d	37	37	1	I
Apiaceae							
ARCTOPUS ECHINATUS	I	O	s	7	99	5	P
CENTELLA GLABRATA	I	M	s	99	99	11	I,P
ITASINA FILIFOLIA	I	O	s	97	99	5	I,P
LICHTENSTEINIA LACERA	I	O	s	99	99	2	P
PEUCEDANUM TENUIFOLIUM	I	O	S	99	99	5	P
PEUCEDANUM MULTIRADIATUM	I	O	S	99	99	5	P
Asclepiadaceae							
SECAMONE ALPINII	I	W	d	99	99	1	P
Asteraceae							
ARCTOTHECA CALENDULA	I	W	D	6	99	5	I
ARCTOTIS SEMIPAPPOSA	I	O	s	99	67	3	I,P
ATHANASIA CRITHMIFOLIA	I	O	S	69	99	12	I,P
BERKHEYA ARMATA	I	W	d	69	99	13	I,P
CASTALIS NUDICAULIS	I	W	d	7	72	1	I,P
CENIA TURBINATA	I	W	D	69	99	3	I
CHRYSANTHEMOIDES MONILIFERA	I	V	d	38	22	3	I,P
CORYMBIUM AFRICANUM	I	W	d	70	70	2	I
CORYMBIUM VILLOSUM	I	W	d	7	70	2	I
CULLUMIA CILIARIS	I	O	S	99	71	1	I
CULLUMIA SETOSA	I	O	S	99	71	1	I
DIMORPHOTHECA PLUVIALIS	I	W	D	69	99	14	I
ELYTROPAPPUS GLANDULOSUS	I	W	d	99	73	2	I,P
ELYTROPAPPUS RHINOCEROTIS	I	W	d	99	73	1	I
EROEDA PROLIFERA	I	O	s	99	99	5	I
EURYOPS ABROTANIFOLIUS	I	M	S	7	74	2	P
GERBERA CROCEA	I	W	d	73	99	2	I,P

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SPECIES	PS	SD	PA	RPS	RSD	RPA	ST
GERBERA LINNAEI	I	W	d	73	99	7	I
HELICHRYSUM CRISPUM	I	W	D	99	99	3	P
HELICHRYSUM CYMOSUM	I	W	D	29	99	2	I,P
HELICHRYSUM FOETIDUM	I	W	D	7	99	1	I
HELICHRYSUM INDICUM	I	W	D	99	99	3	I
HELICHRYSUM NUDIFOLIUM	I	W	d	99	99	2	I
HELICHRYSUM ODORATISSIMUM	I	W	D	99	99	1	I
HELICHRYSUM TERETIFOLIUM	I	W	d	99	99	2	I,P
HELICHRYSUM ZEYHERI	I	W	d	29	99	2	I
METALASIA CEPHALOTES	I	W	D	7	99	1	I
METALASIA MURICATA	I	W	D	7	99	2	I
OSMITOPSIS AFRA	I	M	s	76	76	1,2	I,P
OSTEOSPERMUM SPINOSUM	I	M	S	99	99	1	I
OSTEOSPERMUM TOMENTOSUM	I	W	d	7	72	2	I,P
OTHONNA QUINQUEDENTATA	I	O	S	7	99	3	I
SENECIO BURCHELLII	I	W	D	99	99	3	I
SENECIO CYMBALARIFOLIUS	I	W	d	7	99	1	I
SENECIO GRANDIFLORUS	I	W	D	99	99	2	P
SENECIO PINIFOLIUS	I	W	d	7	99	2	I
SENECIO PINNULATUS	I	W	D	99	99	1	P
SENECIO PUBIGERUS	I	W	D	99	99	2	I,P
SENECIO SUBCANESCENS	I	W	d	99	99	5	I
STOEBE AETHIOPICA	I	W	d	99	99	1	I
STOEBE CAPITATA	I	W	D	99	99	3	I
STOEBE CINEREA	I	W	d	99	99	1	P
STOEBE INCANA	I	W	D	99	99	5	I
STOEBE PLUMOSA	I	W	d	99	99	1	I
SYNCARPHA CANESCENS	I	W	D	99	99	5	I
URSINIA ANETHOIDES	I	W	D	99	99	5	I
URSINIA PALEACEA	I	W	d	99	99	1,5	I,P
URSINIA PINNATA	I	W	D	99	99	2	P
Bruniaceae							
BRUNIA NODIFLORA	A	O	s	16	99	1	I
Campanulaceae							
ROELLA CILIATA	I	O	S	7	99	2	I
WAHLENBERGIA OBOVATA	I	W	D	99	99	3	I

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SPECIES	PS	SD	PA	RPS	RSD	RPA	ST
Caryophyllaceae							
CERASTIUM CAPENSE	I	O	S	99	99	5	I
Illecebraceae							
SILENE UNDULATA	I	O	S	99	99	1,5	I
Celastraceae							
HARTOGIELLA SCHINOIDES	I	V	d	37	19	2	P
MAYTENUS ACUMINATA	I	V	d	37	19	1,2	P
MAYTENUS OLEOIDES	I	V	d	37	19	2	I,P
Crassulaceae							
CRASSULA CAPENSIS	I	W	d	82	99	1	I,P
CRASSULA FLAVA	I	W	d	97	99	1,5	I
CRASSULA FASCICULARIS	I	W	D	7	99	1	I,P
Cunoniaceae							
CUNONIA CAPENSIS	I	W	d	36	36	1	I
Dipsacaceae							
SCABIOSA COLUMBARIA	I	V	d	7	99	2	I,P
Droseraceae							
DROSERA CAPENSIS	I	W	d	83	83	2	I
DROSERA PAUCIFLORA	I	W	d	83	99	7	I
DROSERA RAMENTACEA	I	W	d	83	83	7	I
DROSERA CISTIFLORA	I	W	d	7	99	3	I
Ebenaceae							
DIOSPYROS GLABRA	I	V	d	99	19	2	I,P
Ericaceae							
ERICA ARTICULARIS	I	W	d	3	27	2	I
ERICA BICOLOR	I	W	D	3	27	7	I
ERICA CERINTHOIDES	B	W	d	3	27	1	I
ERICA COCCINEA	B	W	d	3	27	2	I
ERICA HISPIDULA	W	W	D	3	27	2	I,P
ERICA IMBRICATA	I	W	D	3	27	6	I
ERICA NUDIFLORA	I	W	D	3	27	1	I
ERICA RACEMOSA	I	W	D	3	27	7	I
ERICA SPHAEROIDEA	I	W	D	3	27	2	I,P
Euphorbiaceae							
CLUTIA ALATERNOIDES	I	M	s	99	99	2	I,P
CLUTIA POLIFOLIA	I	M	s	99	99	1	I

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SPECIES	PS	SD	PA	RPS	RSD	RPA	ST
EUPHORBIA ERYTHRINA	I	M	s	7	99	1	I
EUPHORBIA GENISTOIDES	I	M	s	99	99	2	I,P
ADENOCLINE PAUCIFLORA	I	O	S	99	99	5	P
Fabaceae							
AMPITHALEA CUNEIFOLIA	I	M	S	84	84	7	I
ARGYROLOBIUM LANCEOLATUM	I	O	s	99	99	1	I,P
ASPALATHUS ARANEOSA	I	O	S	11	99	1	I
ASPALATHUS CEPHALOTES	I	O	S	11	11	5	P
ASPALATHUS CILIARIS	I	O	s	11	11	2,5	I
ASPALATHUS CORDATA	I	O	S	11	99	1	I
ASPALATHUS CRENATA	I	O	s	11	99	1,5	I
ASPALATHUS CYMBIFORMIS	I	O	S	11	99	5	I
ASPALATHUS DIVARICATA	I	O	s	11	99	5	I
ASPALATHUS LARICIFOLIA	I	O	s	11	99	1,5	I
ASPALATHUS NIGRA	I	O	s	11	99	5	I
ASPALATHUS SPICATA	I	O	S	11	11	1,5	I
BOLUSAFRA BITUMINOSA	I	O	S	97	99	1	I
CYCLOPIA MACULATA	I	M	s	99	99	1	I
INDIGOFERA CYTISOIDES	I	C	s	97	99	1	I
INDIGOFERA DIGITATA	I	O	s	99	99	5	I
PODALYRIA CALYPTRATA	I	M	s	7	99	1	I
PODALYRIA MONTANA	I	M	s	99	99	2	P
PODALYRIA MYRTILLIFOLIA	I	M	s	99	99	1,5	I
PSORALEA APHYLLA	I	M	S	7	99	1	I
PSORALEA ASARINA	I	M	S	97	99	5	I
OTHOLOBIUM FRUTICANS	I	O	s	97	99	6	I,P
OTHOLOBIUM OBLIQUUM	I	O	s	99	99	1	I,P
OTHOLOBIUM ROTUNDIFOLIUM	I	O	s	99	81	5	I
OTHOLOBIUM ZEYHERI	I	O	s	99	81	5	I
RAFNIA PERFOLIATA	I	O	s	99	99	1	I
Flacourtiaceae							
KIGELARIA AFRICANA	I	V	d	38	19	1,2	I,P
Fumariaceae							
PHACOCAPNOS CRACCA	I	W	D	99	99	5	I
Gentianaceae							
CHIRONIA LINOIDES	I	O	s	7	99	5	I

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SPECIES	PS	SD	PA	RPS	RSD	RPA	ST
SEBAEA AUREA	I	W	D	99	99	15	I
SEBAEA EXACOIDES	I	W	D	97	99	2	I
Geraniaceae							
GERANIUM CANESCENS	I	O	s	99	90	16	I
GERANIUM INCANUM	I	O	s	97	90	16	I
PELARGONIUM CUCULLATUM	I	W	d	12	28	2	I
PELARGONIUM LONGIFOLIUM	I	W	d	12	28	2	I,P
PELARGONIUM MYRRHIFOLIUM	I	W	d	12	28	2	I,P
PELARGONIUM PINNATUM	I	W	d	12	28	1,3	I
PELARGONIUM TABULARE	I	W	d	12	28	2	P
PELARGONIUM TRISTE	I	W	d	12	28	1,4	P
Haloragaceae							
GUNNERA PERPENSA	W	V	d	1	99	5	I
Lauraceae							
CASSYTHA CILIOLATA	I	V	D	99	99	5	I
Lamiaceae							
LEONOTUS LEONURUS	B	O	s	16	75	1	I
SALVIA AFRICANA-CAERULEA	I	O	s	14	14	1	I,P
STACHYS AETHIOPICA	I	O	s	14	14	1	I
Linaceae							
LINUM THUNBERGII	I	O	s	97	99	1	I
Lobeliaceae							
CYPHIA BULBOSA	I	W	d	7	80	1	I
CYPHIA PHYTEUMA	I	W	d	7	80	7	I,P
CYPHIA VOLUBILIS	I	O	s	7	80	2	I,P
MONOPSIS SIMPLEX	I	W	D	7	81	7	I
MONOPSIS LUTEA	I	A	D	7	99	5	I
LAURENTIA PYGMAEA	I	A	D	99	99	1	P
Menispermaceae							
CISSAMPELOS CAPENSIS	I	V	D	99	24	5	P
Montiniaceae							
MONTINIA CARYOPHYLLACEA	I	W	d	36	36	2	I,P
Myricaceae							
MYRICA INTEGRA	W	V	d	1	87	1	I
Myrsinaceae							
MYRSINE AFRICANA	W	V	d	1	19	2	I,P

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SPECIES	PS	SD	PA	RPS	RSD	RPA	ST
Myrtaceae							
METROSIDEROS ANGUSTIFOLIA	I	A	d	25	88	1	I
Oleaceae							
OLEA EUROPAEA	[illegible]	V	d	38	19	1	I,P
Oliniaceae							
OLINIA VENTOSA	I	V	d	38	22	1	P
Oxalidaceae							
OXALIS BIFIDA	I	O	s	97	89	2	I,P
OXALIS COMMUTATA	I	O	s	50	89	7	I
OXALIS DENTATA	I	O	s	97	89	7	I
OXALIS ECKLONIANA	I	O	s	97	89	3	I
OXALIS GLABRA	I	O	s	97	89	7	I
OXALIS INCARNATA	I	O	s	97	89	1	I
OXALIS LANATA	I	O	s	97	89	2	I,P
OXALIS LUTEOLA	I	O	s	97	89	3	I
OXALIS NIDULANS	I	O	s	89	89	7	I
OXALIS OBTUSA	I	O	s	97	89	3	I
OXALIS PES-CAPRAE	I	O	s	97	89	3	I
OXALIS PURPUREA	I	O	s	7	89	2	I,P
OXALIS TENUIFOLIA	I	O	s	7	89	2	I,P
OXALIS VERSICOLOR	I	O	s	97	89	7	I
Penaeaceae							
PENAEA MUCRONATA	I	M	s	99	99	2	I
Polygalaceae							
MURALTIA HEISTERIA	I	M	s	97	91	1	I
MURALTIA ALOPECUROIDES	I	M	s	91	91	1	I
POLYGALA BRACTEOLATA	I	M	S	7	92	2	I
Proteaceae							
BRABEJUM STELLATIFOLIUM	I	A	d	36	81	1	I
LEUCADENDRON SALIGNUM	I	W	d	53	53	1	I
LEUCADENDRON DAPHNOIDES	I	O	S	53	53	7	I
LEUCADENDRON SPISSIFOLIUM	I	W	d	53	53	7	I
LEUCADENDRON RUBRUM	W	W	D	53	53	6	I
LEUCOSPERMUM CONOCARPODENDRUM	A	M	s	78	44	1	I
LEUCOSPERMUM LINEARE	A	M	S	78	99	1	I
PROTEA ACAULOS	R	O	s	16	99	2	I

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SPECIES	PS	SD	PA	RPS	RSD	RPA	ST
PROTEA NITIDA	A	W	d	79	99	1	I
PROTEA LEPIDOCARPODENDRON	A	W	D	79	99	17	I
PROTEA REPENS	A	W	D	16	100	2	I
PROTEA BURCHELLII	A	W	D	16	99	6	I
SERRURIA BIGLANDULOSA	I	M	S	99	99	5	I
SERRURIA KRAUSII	I	M	s	99	99	1	I
Ranunculaceae							
KNOWLTONIA VESICATORIA	I	V	d	93	93	1	I
RANUNCULUS MULTIFIDUS	I	A	d	99	99	5	I
Rhamnaceae							
PHYLICA SPICATA	I	M	s	7	99	1	I,P
PHYLICA STIPULARIS	I	M	s	99	99	1	I
Rosaceae							
CLIFFORTIA CUNEATA	W	O	S	1	99	2	I
CLIFFORTIA ODORATA	W	M	s	1	99	1	I
CLIFFORTIA POLYGONIFOLIA	W	M	S	1	99	2	P
CLIFFORTIA PTEROCARPA	W	M	S	1	99	5	I
CLIFFORTIA RUSCIFOLIA	W	M	s	1	99	1	I
RUBUS RIGIDUS	I	V	d	1	99	1	P
Rubiaceae							
ANTHOSPERMUM AETHIOPICUM	W	O	S	4	99	2	I,P
ANTHOSPERMUM GALIOIDES	W	M	S	4	99	2	P
GALIUM MUCRONIFERUM	W	V	D	15	99	7	P
GALIUM TOMENTOSUM	I	V	d	24	24	7	I
Rutaceae							
ADENANDRA MARGINATA	I	M	s	99	99	1	I
AGATHOSMA CILIATA	I	M	S	97	99	5	I
DIOSMA HIRSUTA	I	M	s	97	99	1	I,P
Santalaceae							
THESIUM SCABRUM	I	M	S	97	99	5	I
Scrophulariaceae							
FREYLINIA LANCEOLATA	I	A	d	99	99	1	I
HALLERIA ELLIPTICA	B	V	d	16	99	2	I
HEMIMERIS RACEMOSA	I	W	D	7	99	5	I
MANULEA CHEIRANTHUS	I	W	D	97	99	1	I
SUTERA HISPIDA	I	O	[illegible]	7	99	5	I

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SPECIES	PS	SD	PA	RPS	RSD	RPA	ST
Selaginaceae							
AGATHELPIS DUBIA	I	O	S	7	99	2	I
DISCHISMA CILIATUM	I	O	S	7	99	5	I
HEBENSTREITIA DENTATA	I	O	S	99	99	1	I
SELAGO CORYMBOSA	I	O	S	97	99	1	I
SELAGO QUADRANGULARIS	I	O	S	97	99	1	I
SELAGO SPURIA	I	O	S	7	99	2	I
Sterculiaceae							
HERMANNIA GROSSULARIFOLIA	I	W	D	99	99	5	I
Thymelaeaceae							
GNIDIA INCONSPICUA	I	O	s	99	99	5	P
STRUTHIOLA MYRSINITES	I	O	s	50	99	1	I

Key

Pollination system: A=birds and insects; B=birds; I=insects; R=rodents; W=wind; *=no pollination.

Seed dispersal system: A=aquatic; M=ants; O=ballistic/gravity/unknown; V=vertebrates (epicochory and endocochory); W=wind.

Potential mode of persistence: D=relatively wide dispersal of seed; d=relatively wide dispersal of seed, and resprouting; S=non-dispersal or relatively short distance dispersal of seed; s=non-dispersal or relatively short distance dispersal of seed, and resprouting.

Primary references for the classification of plants: *pollination system*: Koutnik (1987), *S. Afr. Nat. Sci. Prog. Rpt.* 141:126-133; Whitehead *et al.* (1987), *S. Afr. Nat. Sci. Prog. Rpt.* 141:52-82; Rebelo (1987), *S. Afr. Nat. Sci. Prog. Rpt.* 141:83-108; Rebelo & Breytenbach (1987), *S. Afr. Nat. Sci. Prog. Rpt.* 141:109-125; *seed dispersal system*: Bond & Slingsby (1983), *S. Afr. J. Sci.* 79:231-233; R.S. Knight (1988), PhD thesis, University of Cape Town; le Maitre & Midgley (1992), in: ed. R.M. Cowling, The ecology of fynbos. Nutrients, fire and diversity, Oxford University Press, Cape Town, pp. 135-174; *method of persistence*: van der Merwe (1966), *Ann. Univ. Stell.* 41(A):691-736; R.S. Knight (1988), PhD thesis, University of Cape Town; van Wilgen & Forsyth (1992), Ecological Studies 93, pp. 54-80.

Pollination system and seed dispersal system references: 1 Koutnik (1987), *S. Afr. Nat. Sci. Prog. Rpt.* 141:126-133; 2 Gibbs-Russell *et al.* (1991), *Mem. bot. Surv. S. Afr.* 58:1-437; 3 Rebelo *et al.* (1985), *S. Afr.J. Bot.* 51:270-280; 4 Puff (1986), *FSA* 31:8-36; 5 Jacobsen (1983), The ferns and fern allies of southern Africa. Butterworths, Durban; 6 Whitehead *et al.* (1987), *S. Afr. Nat. Sci. Prog. Rpt.* 141:52-82; 7 Bond & Goldblatt (1984), *J. S. Afr. Bot. Suppl.* 13:1-455; 8 Goldblatt

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(1991), *Contr. Bolus Herb.* 13:1-74; 9 Obermeyer (1984), *Bothalia* 15:77-88; 10 Dyer (1976), The genera of southern African flowering plants. Vol 1. Dicotyledons. Department of Agricultural Technical Services, Pretoria; 11 Dahlgren (1988), *FSA* 16:1-430; 12 van der Walt & Wand-Hilhorst (1977), Pelargoniums of southern Africa, vol. 1, Purnell & Sons, Cape Town; 13 van der Walt *et al.* (1981), Pelargoniums of southern Africa, vol. 2, Juta, Kenwyn; 14 Codd (1985), *FSA* 28:1-247; 15 Puff (1978), *Jl. S. Afr. Bot.* 44: 203-279; 16 Rebelo (1987), *S. Afr. Nat. Sci. Prog. Rpt.* 141:83-108; 17 Johnson (1992), in: ed. R.M. Cowling, The ecology of fynbos. Nutrients, fire and diversity, Oxford University Press, Cape Town, pp. 175-205; 18 Snijman (1984), *Jl. S. Afr. Bot. Suppl.* 12:1-139; 19 Milewski (1982), *J. Biogeogr.* 9:505-516; 20 Bond & Slingsby (1983), *S. Afr. J. Sci.* 79:231-233; 21 Nicholson & Worsely-Worswick (1990), *S. Afr. J. Zool.* 25:93-96; 22 R.S. Knight (1988), PhD thesis, University of Cape Town; 23 Phillips (1927), *S. Afr. J. Sci.* 24:435-440; 24 Dean *et al.* (1990), *Ecology* 71:1299-1306; 25 Coates-Palgrave (1983), Trees of southern Africa, Struik, Cape Town; 27 Oliver (1991), *Contr. Bolus Herb.* 13:158-208; 28 Webb 1984; 29 Hilliard (1983), *FSA* 33:61-310; 30 Reid & Dyer (1984), A review of the southern African species of *Cyrtanthus*, BRI, Dept. of Agriculture, Pretoria; 31 Obermeyer (1985a), *Bothalia* 15:548-549; 32 Obermeyer (1984), *Bothalia* 15:77-88; 33 Obermeyer (1978), *Bothalia* 12:323-376; 34 Barker (1989), *S. Afr. J. Bot.* 55:630-646; 35 Scott (1991), *S. Afr. J. Bot.* 57:34-54; 36 Palmer & Pitman (1972a), Trees of southern Africa, vol. 1, A. A. Balkema, Cape Town; 37 Palmer & Pitman (1972b), Trees of southern Africa, vol. 2, A. A. Balkema, Cape Town; 38 Palmer & Pitman (1972c), Trees of southern Africa, vol. 3, A. A. Balkema, Cape Town; 39 Obermeyer (1985b), *FSA* 4:71-91; 40 Stewart *et al.* (1982), Wild ochids of southern Africa, Macmillan SA, Johannesburg; 41 Stewart *et al.* (1981), Orchids of Africa: a select review, Macmillan SA, Johannesburg; 42 Goldblatt (1986), *Ann. Kirstenbosch Bot. Gdn.* 14:1-224; 43 Goldblatt (1989), *Ann. Kirstenbosch Bot. Gdn.* 19:1-148; 44 Slingsby & Bond (1981), *Veld & Flora* 67:39-45; 45 Nordenstam (1986), *Opera Botanica* 87:1-41; 46 Reid & Arnold (1984), *Bothalia* 15:139-142; 47 Arnold & Gordon-Gray (1982), *Bothalia* 14:15-26; 48 Letty (1973), *Bothalia* 11:5-26; 49 Levyns (1947), *Jl. S. Afr. Bot.* 13:73-93; 50 H.B. Rycroft (1950), PhD thesis, University of Cape Town; 53 Williams (1972), *Contr. Bolus Herb.* 3:1-425; 54 Linder (1991), *Contr. Bolus Herb.* 13:209-264; 55 Obermeyer (1980), *Bothalia* 13:111-114; 56 Thompson (1969), *Flow. Pl. Afr.* 39:1557; 57 Lewis (1960), *Jl. S. Afr. Bot.* 26:51-72; 58 Weimarck (1940), Monograph of the genus *Aristea*, Lunds Universitets Ansskrift, Lund; 59 Lewis (1959), *Jl. S. Afr. Bot. Suppl.* 3:1-149; 60 Strid (1974), *Opera Botanica* 37:1-45; 61 Richardson & van Wilgen (1986), *S. Afr. J. Bot.* 52:309-315; 62 Goldblatt (1979), *Jl. S. Afr. Bot.* 45:385-423; 63 Goldblatt (1985), *Ann. Miss. Bot. Gdn.* 72:277-447; 64 Lewis (1941), *Jl S. Afr. Bot.* 7:19-59; 65 Lewis (1959), *Jl. S. Afr. Bot.* 25:319-355; 66 De Vos (1982), *Jl. S. Afr. Bot.* 48:105-163; 67 Lewin (1922), *Feddes reprium beih.* 11:1-75; 68 Kallersjo (1985), *Nord. J. Bot.* 5:527-542; 69 Kidd (1983), South African Wildflower Guide 3, Botsoc, Claremont; 70 Weitz (1989), *S. Afr. J. Bot.* 55:598-629; 71 Rossler (1959), *Mitt. Bot. Stsamml., Munch.* 3:271-304; 72 Norlindh (1943). Monograph of the genera *Dimorphotheca*, *Castalis*, *Osteospermum*, *Gibbaria* and *Chrysanthemoides*,

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Gleerup, Lund; 73 Hansen (1985), *Opera Botanica* 78:5-36; 74 Nordenstam (1968), *Opera Botanica* 20:1-409; 75 Iwarsson (1985), *FSA* 28:31-37; 76 Bremer (1972), *Bot. Not.* 125:9-48; 77 Boulos (1973), *Bot. Not.* 126:155-196; 78 Rourke (1972), *Jl. S. Afr. Bot. Suppl.* 8:1-194; 79 Vogts (1982), South Africa's Proteaceae. Know them and grow them, Struik, Cape Town; 80 Wimmer (1968), *Das Pflanzenreich* 108:935-1014; 81 Marloth (1913), The flora of South Africa, vol. 1, Darter Bros. & Co., Cape Town; 82 Tolken (1985), *FSA* 14:1-244; 83 Obermeyer (1970), *FSA* 13:187-201; 84 Granby (1985), *Opera Botanica* 80:1-34; 85 Marais & Veldoorn (1963) *FSA* 26:171-243; 86 Hilliard & Burtt (1985), *Notes RBG Edinb.* 42:171-225; 87 Killick (1969), *Bothalia* 10:5-17; 88 Killick (1971), *Flow. Pl. Afr.* 41:1624; 89 Salter (1944), *Jl. S. Afr. Bot. Suppl.* 1:1-355; 90 Yeo (1984), *Bot. J. Linn. Soc.* 89:1-36; 91 Levyns (1954), *Jl. S. Afr. Bot. Suppl.* 2:1-247; 92 Levyns (1955), *Jl. S. Afr. Bot.* 21:9-49; 93 Rasmussen (1979), *Opera Botanica* 53:1-43; 95 Williams (1982), *Jl. S. Afr. Bot.* 48:329-407; 96 Adamson (1951), *Jl. S. Afr. Bot.* 17:1-48; 97 Burman *et al.* 1985; 98 Le Maitre & Brown (1992), in: eds. B.W. van Wilgen, D.M. Richardson, F.J. Kruger & H.J. van Hensbergen, Fire in South African mountain fynbos: ecosystem, community and species response at Swartboskloof, Springer-Verlag, Berlin, pp. 145-160; 99 Herbarium material; 100 Bond (1988), *S. Afr. J. Bot.* 54:455-460. Support was given to the classification of some plants as insect-pollinated by personal observations of insect visitation to flowers and by S. Johnson (pers. comm. 10/1992).

Mode of persistence references: The seed dispersal reference was used in conjunction with the following where necessary. 1 van der Merwe (1966), *Ann. Univ. Stell.* 41(A):691-736; 2 van Wilgen & Forsyth (1992), Ecological Studies 93, pp. 54-80; 3 R.S. Knight (1988), PhD thesis, University of Cape Town; 4 Musil & de Witt (1990), *S. Afr. J. Bot.* 56: 167-184; 5 herbarium sheets (specimens and/or information); 6 Richardson & van Wilgen (1986), *S. Afr. J. Bot.* 52:309-315; 7 reference as for pollination or seed dispersal systems; 8 van der Walt (1981), Pelargoniums of southern Africa, vol. 2, Juta, Kenwyn; 9, 10, 11, 12, 13, 14, 15, 16 = pollination system and seed dispersal system references 46, 10, 96, 68, 70, 72, 85, 86, respectively; 17 Rourke (1980), The proteas of southern Africa, Purnell, Cape Town. A plant was classified as a reseeder when there was no indication that it resprouts after a disturbance in the literature and from herbarium sheets.

Site: I=Biesievlei (indigenous vegetation); P=Bosboukloof (plantation)

Plants growing in or at the edge of waterbodies (eg. rivers, marshes; information from Bond & Goldblatt (1984), *J. S. Afr. Bot. Suppl.* 13:1-455, and herbarium sheets) were considered to have water-dispersed seeds if the seeds floated or were very small. Such plants inhabiting seasonally inundated habitats were considered to have water-dispersed seeds if they flowered around the beginning of the wet season. Seeds were considered wind-dispersed if they were winged, had well-developed pappi, or were small and covered in long hairs. The seeds of orchids (mean length 0.3-0.4 mm) and of *Ericas* (mean length 0.6mm) are considered to be wind dispersed (Kurzweil (1993), *Pl. Syst. Evol.* 85:229-247; Oliver (1991), *Contr. Bolus Herb.* 13:158-208, respectively). Therefore very small seeds (approximate length ≤1mm) without obvious adaptations for dispersal were considered wind-dispersed if the habit, habitat

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and height of the plant (information from Bond & Goldblatt (1984), *Jl. S. Afr. Bot. Suppl.* 13:1-455, and herbarium sheets) potentially allowed wind dispersal and if seeds approaching 1mm length were aerodynamically shaped. Seeds were considered vertebrate-dispersed if they are part of a fleshy or mucilagenous fruit (endozoocochory), if they had hooks, hairy calluses, awns or clinging hairs (epizoocochory), or if they were known to be incorporated into nests as part of the nesting material (nest-dispersal).

Nomenclature follows Gibbs Russell *et al.* (1985), *Mem. bot. Surv. S. Afr.* 51:1-152, (1987), *Mem. bot. Surv. S. Afr.* 56:1 270.

(b) Birds

Information for the birds and mammals was obtained from the results of studies in the southwestern Cape or the Cape Province where possible in an attempt to minimize bias caused by geographical variation in ecological and life history characteristics. The references used in the classification of birds are given in Armstrong & van Hensbergen (1994), *S. Afr. J. Wildl. Res.* 24:48-55.

(c) Mammals

Mammals are classified with respect to diet (DI), foraging microhabitat (FM), and resting place (RP). The key to the symbols is given beneath the table. Species in plantations from Scott (1978) and species in fynbos and scrub from Stuart (1971).

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Species	FT	FM	RP
Young plantation			
CROCIDURA FLAVESCENS	I	U	U
MYOSOREX VARIUS	I	U	G
ACOMYS SUBSPINOSUS	G	GR	G
RHABDOMYS PUMILIO	H	GR	GR
HYSTRIX AFRICAEAUSTRALIS	S	G	G
GENETTA TIGRINA	C	M	H
GALERELLA PULVERULENTA	C	S	C
SYLVICAPRA GRIMMIA	F	GR	GR
RAPHICERUS MELANOTIS	V	S	S
Middle-aged plantation			
MYOSOREX VARIUS	I	U	G
RHABDOMYS PUMILIO	H	GR	GR
GENETTA TIGRINA	C	M	H
RAPHICERUS MELANOTIS	V	S	S
Mountain fynbos			
MYOSOREX VARIUS	I	U	G
CROCIDURA FLAVESCENS	I	U	U
PAPIO URSINUS	H	G	R
LEPUS SAXATILIS	V	GR	GR
ACOMYS SUBSPINOSUS	G	GR	G
AETHOMYS NAMAQUENSIS	H	G	C
RHABDOMYS PUMILIO	H	GR	GR
MUS MINUTOIDES	H	U	G
OTOMYS SAUNDERSIAE	V	GR	GR
HYSTRIX AFRICAEAUSTRALIS	S	G	G
GEORHYCHUS CAPENSIS	S	G	G
CRYPTOMYS HOTTENTOTTUS	S	G	G
GENETTA GENETTA	C	S	G
GALERELLA PULVERULENTA	C	S	C
FELIS LIBYCA	C	S	S
FELIS CARACAL	C	S	S
PANTHERA PARDUS	C	S	S

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Species	FT	FM	RP
PROCAVIA CAPENSIS	V	S	C
SYLVICAPRA GRIMMIA	F	GR	GR
RAPHICERUS MELANOTIS	V	S	S
OREOTRAGUS OREOTRAGUS	H	S	R
Riverine scrub			
CROCIDURA FLAVESCENS	I	U	U
CHRYSOCHLORIS ASIATICA	I	G	G
PAPIO URSINUS	H	G	R
MYOMYSCUS VERREAUXII	G	U	U
RHABDOMYS PUMILIO	H	GR	GR
HYSTRIX AFRICAEAUSTRALIS	S	G	G
GEORHYCHUS CAPENSIS	S	G	G
AONYX CAPENSIS	I	W	GR
GENETTA GENETTA	C	S	G
GENETTA TIGRINA	C	M	H
GALERELLA PULVERULENTA	C	S	C
ATILAX PALUDINOSUS	O	W	GR
SYLVICAPRA GRIMMIA	F	GR	GR

Key

Diet class: C=carnivore; F=frugivore; G=granivore; H=herbivore; I=insectivore; O=omnivore; S=subterranean herbivore; V=foliovore

Foraging microhabitat: G=subterranean or ground surface in several microhabitats; M=most or all microhabitats; S=terrestrially amongst shrubby cover; U=amongst herbaceous growth; W=water.

Resting site: C=in rock hole/crevace; G=underground or on "bare" ground; H=in tree-hole; R=among rocks in rocky open areas or on rock ledges; S=among shrubs in shrubland or in thicket; U=amongst herbaceous growth.

Nomenclature follows Meester *et al.* (1986), Classification of southern African mammals, Transvaal Museum, Pretoria.

The references used in the classification of mammals were: Hall (1962), *Proc. zool. Soc. Lond.* 139:181-220; J. Manson (1974), M.Sc. thesis, University of Stellenbosch; Rowe-Rowe (1977), *Lammergeyer* 25:1-48; Millar (1980), M.Sc. thesis, University of Stellenbosch; Stuart (1971), unpublished ms; Stuart (1981), *Bontebok* 1:1-58; Breytenbach (1982), M.Sc. thesis, University of Pretoria; Odendaal (1983), *S. Afr. J. Wildl. Res. 13:27-3*; Norton (1984), *S. Afr. J. Wildl. Res.* 14:33-41; Du Toit *et al.* (1985), *Oecologia* 66:81-87; Norton & Lawson (1985), *S. Afr. J. Wildl. Res.* 15:17-24; T.S.

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Appendix 3: Visual description of the sampling sites (for grasshoppers, butterflies and birds) in the Maclear district during the first survey period. Most sites had streams, with associated taller riparian vegetation. Category codes for time since last fire and since last grazing: 0 = at time of sampling; <1 = less than one year; ≥ 1 = one or more years

Land type	Site	Description	Last fire/ grazing (yrs)
MII	Valley	Tall grassland; short grass areas; boulder edges & scattered boulders on sides, scattered bush/tree clumps & herbs, bare areas	$\geq 1/0$
	North	Short grassland & boulder slope, flat to steep; tree & bush clumps, bare areas	$\geq 1/0$
	South	Short grassland, flat to steep; some bare areas; few tree clumps, scattered herbs	$\geq 1/<1$
	West	Short open grassland & boulder slope, flat to steep; tree & bush clumps; bare areas; many herbs	$\geq 1/0$
	Crest	Short grassland; many herbs, few *Protea* trees & bushes, bare areas	$\geq 1/0$
MIh	Valley	Tall grassland; upper sides steep & boulder-strewn with bush/tree clumps, lower slopes gentle & open; some herbs	$\geq 1/<1$
	North	Short, sparse grassland; mainly dolerite; jumbled stones & rocks; many herbs in flatter areas	$<1/<1$
	South	Short grassland; steep, stoney slope with boulder bands, scattered bush clumps & *Protea* trees, many herbs	$<1/\geq 1$
	East	Short grassland, with some tall	$<1/0$

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Land type	Site	Description	Last fire/ grazing (yrs)
		grass; boulder slope; riparian forest along streams; many herbs	
	Crest	Short grassland; pavement rock along edges with bushes & trees; many herbs	<1/0
Ell	Bottom flats	Short grassland; scattered anthills; some herbs	<1/0
	North	Short grassland; boulder slope; scattered bush/tree clumps; bare areas	≥1/0
	South	Short grassland; tall grass areas; steep, with boulder bands and *Leucosidea* scrub; bare areas	≥1/<1
	East	Short grassland; gentle slope, rocky with herbs at top	≥1/<1
	Crest	Short grassland; pavement rock edge	≥1/0
Elh	Valley	Tall grassland; *Leucosidea* scrub & riparian forest patches	≥1/≥1
	North	Short grass *Protea* savanna; boulder slope	≥1/≥1
	South	Tall grass *Protea* savanna; steep slope, one sheer and one smaller rock band; some herbs	≥1/≥1
	East	Short grass *Protea* savanna; steep slope	≥1/≥1
	Crest	Short grass Protea savanna; some tall grass; pavement rock	≥1/≥1
Eml	Valley	Short grassland; some tall grass; rocky with bare areas; some bush clumps	≥1/0

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Land type	Site	Description	Last fire/ grazing (yrs)
	North	Short grassland; boulder bands; bare areas; bush clumps	≥1/0
	South	Tall grassland; some short grass; boulder bands	≥1/0
	East	Short grassland; some tall grass	≥1/0
	Crest	Short grassland; pavement rock; bare areas	≥1/0
Emh	Valley	Short grassland; some tall grass; stream mainly under-ground; several rock bands, associated trees, shrubs & small waterfalls; some herbs	<1/<1
	North	Tall grassland; mid to upper portion rocky; tree/bush clumps & flowering herbs associated with rocks & boulders; bare areas on lower portion	<1/<1
	South	Tall grassland; boulders scattered & in bands, associated *Protea* & other trees & bushes; many flowering herbs	<1/<1
	East	Short grassland; many herbs & bare areas; two pavement rock bands with *Protea* & other trees & bushes	<1/<1
	Crest	Short grassland; pavement rock, many flowering herbs	<1/<1
Ehh	Valley	Short grassland; tall grass, herbs & some *Leucosidea* shrubs along underground stream course; lower portion open with boulders, herbs & *Protea* trees	<1/0

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Land type	Site	Description	Last fire/ grazing (yrs)
Chh	North	Short grassland; some tall grass; stoney, with several rock bands; scattered flowering herbs; bare areas	<1/<1
	South	Short grassland; some tall grass; steep slope with pavement rock areas; *Leucosidea* or *Protea* clumps at stream heads; many flowering herbs; bare patches	<1/0
	West	Short grassland; some tall grass; slope steep & rock-strewn higher up, gentler lower down; many bare areas	<1/0
	Crest	Short grassland; pavement rock with flowering herbs & dwarf shrubs; some rocky areas	<1/0
	Valley	Tall/short grassland; boulder field in lower section with rocky sides; many flowering herbs; couple of dense *Leucosidea* patches	<1/0
	North	Short grassland; tall grass intermixed; some rocky areas; many herbs & some dwarf *Protea* shrubs	<1/0
	South	Short grassland; tall, thick grass in more sheltered areas; some rocky areas; many flowering herbs and some *Leucosidea* shrubs	≥1/0
	East	Short grassland; some tall grass patches; top of slope very steep with several rock bands &	<1/0

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Land type	Site	Description	Last fire/ grazing (yrs)
		scattered shrubs, lower slope shallower with large boulders; many herbs	
	Crest	Short grassland; areas of tall grass; some pavement rock, some stoney areas; scattered dwarf *Proteas* & herbs	< 1/0
Bhl	Valley	Tall grassland; short grass areas intermixed; dense flowering herb patches	≥1/0
	North	Short grassland; tall grass clumps intermixed; gentle slope; scattered rocks & flowering herbs; couple of dense patches of *Leucosidea* and other trees/bushes	< 1/0
	South	Tall grassland; steep slope & rock cliff faces; small shrubs & dense flowering herb patches	≥1/0
	West	Short grassland; tall grass patches intermixed; stoney, with rock cliff faces, rock outcrops & associated shrubs; many flowering herbs	≥1/< 1
	Crest	Short grassland; tall grass clumps intermixed; small rock outcrops; scattered flowering herbs	≥1/0

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Appendix 4: Tests of assumptions of the timed-count sampling methods used in the evaluation of afforestable montane grasslands in the Maclear district (both survey periods)

Grasshoppers

There were no significant differences between the proportions of grasshoppers unidentified at the genus level recorded on the different land types (G_{12} = 9.946; ns). The null hypothesis that the proportion of grasshoppers unidentified at the genus level was equal over all the different sites was rejected (G_{64} = 90.825; $p<0.05$). Significantly more unidentified grasshoppers than expected were recorded at the following sites on the respective land types: valley - Mlh, Bhl; north slope - Ehh; south slope - Chh. Significantly fewer unidentified grasshoppers than expected were recorded at the north slope on land type Eml.

The overall results for grasshoppers remain unchanged for the following reasons. The repeat sampling confirmed that valleys were coldspots for grasshoppers. The Ehh north slope had more genera than the other Ehh sites, and the Eml north slope had a substantially higher number of genera than the other Eml sites. The Chh south slope had relatively few grasshoppers, and the fewest genera out of the five Chh sites, so it is unlikely that there were many "new" genera among the unidentifieds.

There was a significant linear relationship between number of recorded species and genera over the environmental gradient (species richness = 1.455 x number of genera - 3.06; r = 0.971; $p<0.001$; 95 % CI for slope = 1.217 to 1.693, i.e reject H_0: slope = 1; 95 % CI for intercept = -7.098 to 0.978, i.e. accept H_0: intercept = 0). Use of the genus taxonomic level in place of the species level is acceptable.

Butterflies

There was no significant difference between the proportions of unidentified butterflies recorded on the different land types (G_{12} = 14.978; ns). The null hypothesis that the proportion of unidentified butterflies was equal over all the different sites was rejected (G_{64} = 109.229; $p<0.001$). Significantly more unidentified butterflies than expected were recorded at the following sites on the respective land types: valley - Mlh, Mlh (repeat sample), Bhl (repeat sample) and Bhh; north slope - Bhh; intermediate aspect slope - Mlh (repeat sample); crest - Elh, Emh. Significantly fewer unidentified butterflies than expected were recorded at the following sites on the respective land types: north slope - Mlh; intermediate aspect slope - Bhh.

The overall results for butterflies remain unchanged for the following reasons. The valleys had the highest butterfly species richnesses of the five site types, on the respective land types and overall. The Elh crest and Mlh (repeat sample) intermediate slope had the highest species richnesses on their respective land types (the richness of the latter being equal to that of the valley site). Only three butterflies were recorded on the Emh crest. The Bhh north slope had relatively very few butterflies and few species compared with the other Bhh sites.

Birds

The assumption of similar detectability on all land types was tested by determining what proportion of the birds and the species detected in a land type were within 40m of the observer, and comparing the proportions from all the land types. The same procedure was also used to test whether detectability varied between sites. Each bird recorded was considered as one detection. Expected proportions had to be calculated for two fairly steep valley sites because counting was done from along the top of the valley sides.

The null hypothesis that the proportion of the birds recorded within 40 m of the observer was equal over the land types was rejected ($X^2_{12} = 54.713$; $p<0.001$). Significantly more birds than expected were recorded within 40 m on land types Elh, Bhh and Bhl (during repeat sampling), and significantly less on Mlh, Elh (during repeat sampling) and Emh. If significantly more birds than expected were recorded within 40 m, the number of species and of birds recorded from the land type may be less than expected, and conversely.

These results for birds do not substantially affect the overall trends of the study. The species total and relatively high bird abundance on Mlh were confirmed by the repeat sample and the species totals and abundance figures from the two Elh samples should theoretically be brought towards each other. The Emh figures would be reduced theoretically, confirming the mid altitude as having low bird diversity, and the Bhl values would not be affected by the repeat samples.

The null hypothesis that the proportion of the birds recorded within 40 m of the observer was equal over all the sites was rejected ($G_{64} = 255.941$; $p<0.001$. Significantly more or significantly less birds than expected were recorded within 40 m at a total of 21 sites.

The null hypothesis that the proportion of unidentified birds was equal over the land types was rejected ($G_{12} = 70.206$; $p<0.001$). Significantly more unidentified birds than expected were recorded on land types Mll, Mlh and Ell, and significantly less than expected on land types Chh and Bhl. Species richness was greatest on land types with Molteno sandstone and was relatively high on Ell, so the general trends should not be affected by variation in number of unidentified birds.

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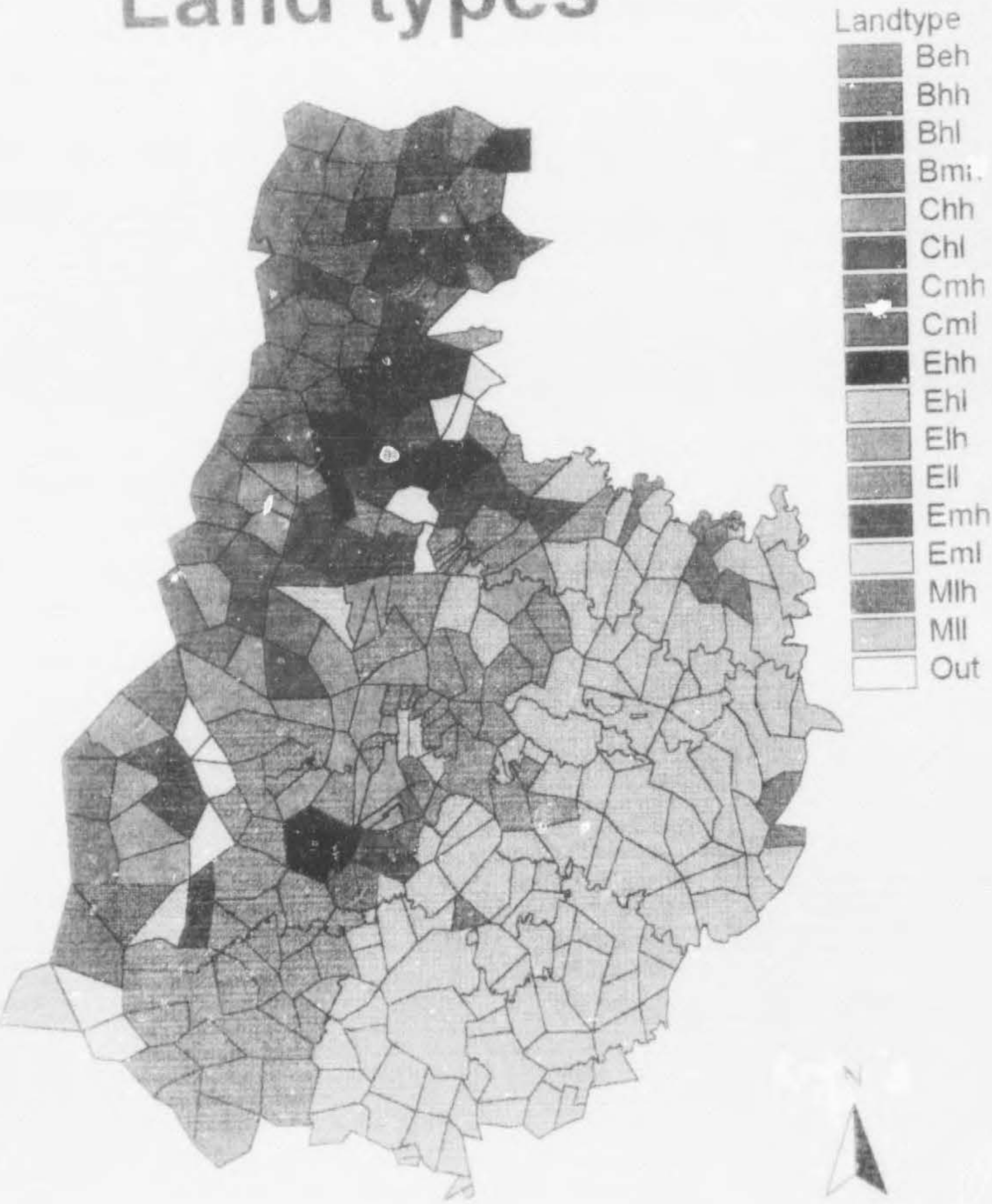
Land types



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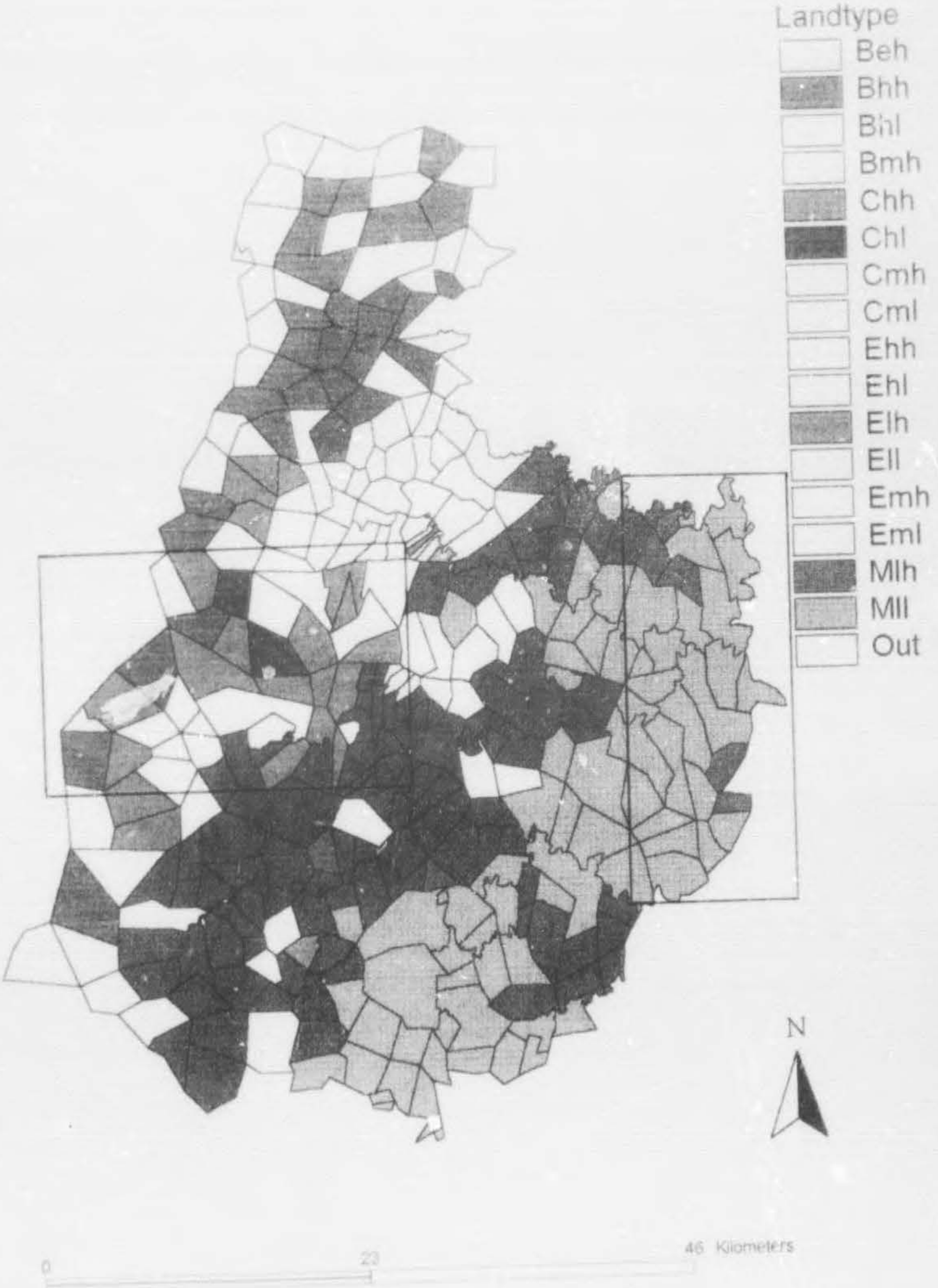

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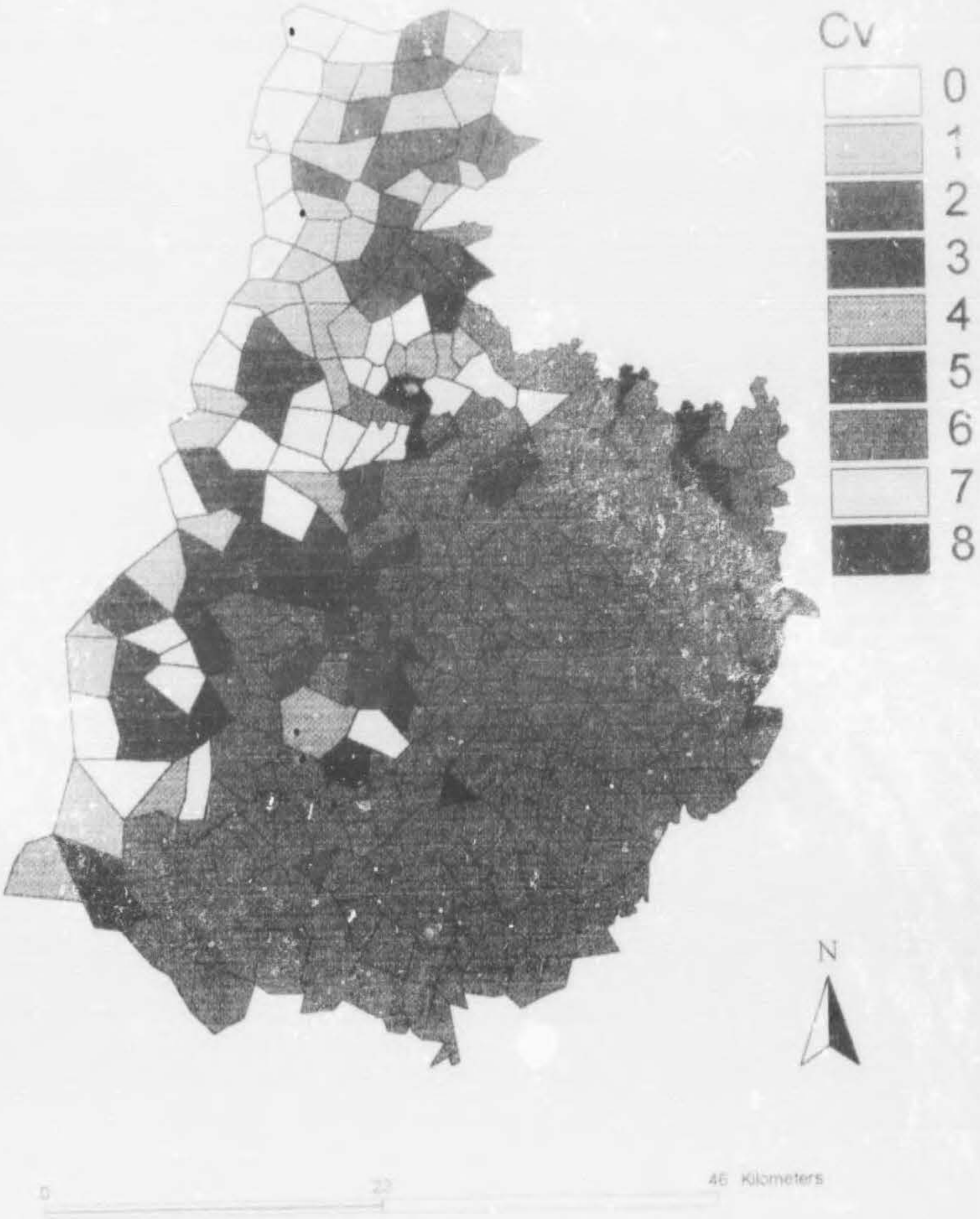
Endemicity



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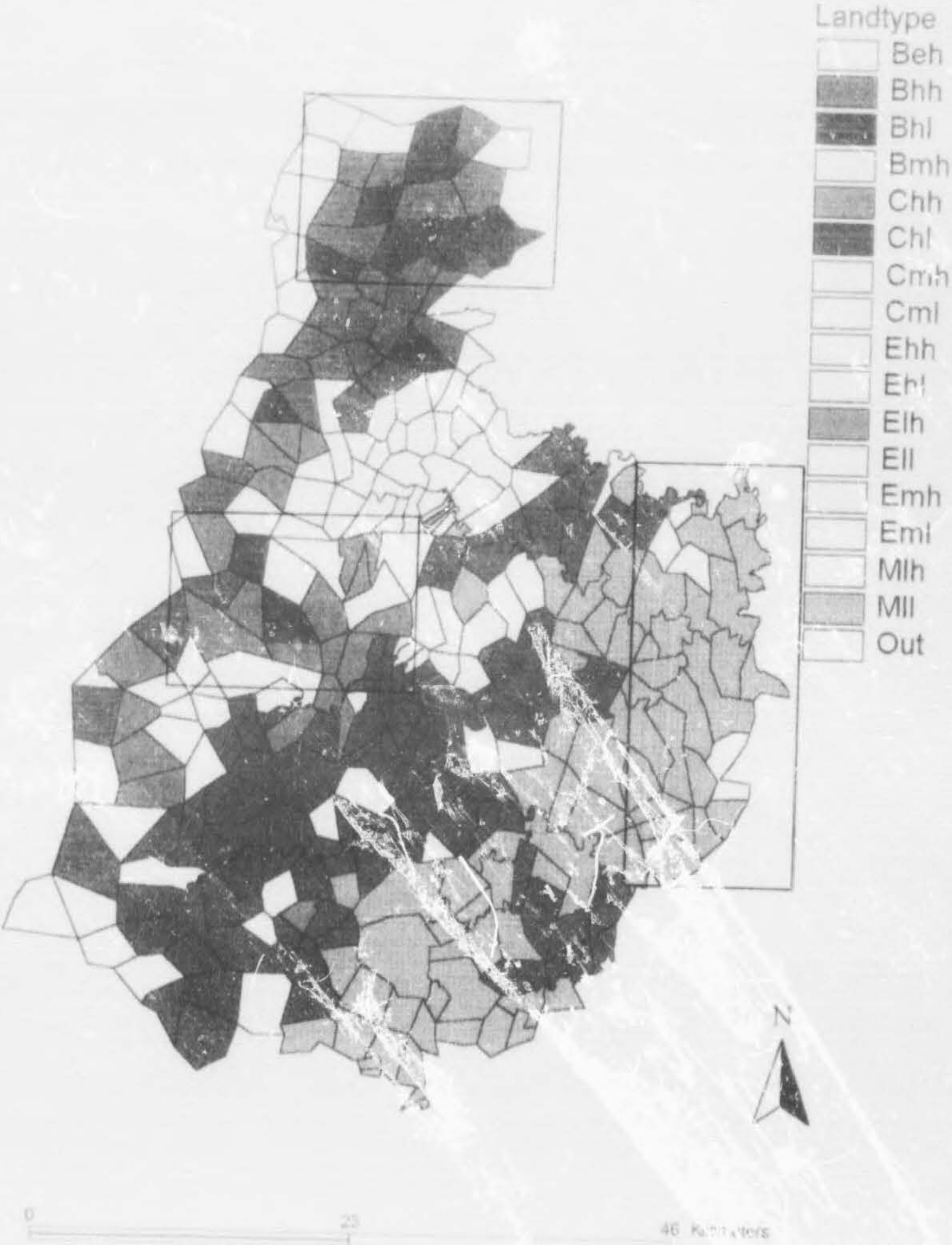

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Richness of taxa