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THE IMPACT OF COMMERCIAL AFFORESTATION ON BIRD POPULATIONS IN MPUMALANGA PROVINCE, SOUTH AFRICA – INSIGHTS FROM BIRD-ATLAS DATA

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Abstract

Bird-atlas data were used in conjunction with information on the extent of commercial afforestation with alien trees in Mpumalanga Province, South Africa, to assess the effect of afforestation on the avifauna of this region. Ninety species of birds characteristic of grassland habitats occur in the province. Twenty-five of these species are of conservation concern and 10 are globally threatened. A separate suite of 65 species associated with woodlands or forests occurs in the province and benefits from afforestation or at least the spread of alien trees. The areas of highest species diversity of grassland birds overlap extensively with the areas of greatest afforestation and potential additional afforestation. The species diversity of grassland birds generally, and globally threatened grassland birds in particular, is significantly and negatively correlated with the extent of afforestation. Afforestation apparently has a negative impact on grassland bird diversity even when the percentage area under plantation is relatively small. A comparison of the avifaunas negatively and positively impacted by afforestation reveals that the grassland community has more species and is richer in both endemics and threatened species than the plantation community. Any further afforestation in Mpumalanga Province is likely to contribute substantially to the potential extinction of many bird species there, including several globally threatened species. Copyright © 1996 Elsevier Science Limited

Keywords: birds, forestry, grasslands, South Africa.

INTRODUCTION

Large-scale commercial afforestation in South Africa, and elsewhere in the world, can potentially have a profound impact on the biota inhabiting the regions afforested, in addition to having far-reaching water-budget, economic and sociological implications (e.g. Bigalke, 1980; Macdonald, 1989, 1992; Masson, 1992; Duthie, 1994; Everard *et al.*, 1994). This is not surprising, considering the radical extent of the habitat changes brought about by timber cultivation, especially when open and largely treeless ecosystems are transformed to monocultures of closed-canopy forests consisting of alien tree species. This issue is currently intensely relevant to efforts to conserve biodiversity. It is also a highly controversial subject and debates between the proponents of the various interest groups involved are frequently charged with emotion and acrimony. Examples of such pro-/anti-forestry debates are the articles by Johns (1993) and Cellier (1994).

In South Africa, a substantial literature discusses the negative impact of afforestation on certain bird species, largely inhabitants of open, treeless habitats. Negative impacts at the community level, however, have been less intensively studied. An early, but rather superficial, study (Winterbottom, 1968) highlighted the depauperate avifauna associated with plantations of alien trees in the fynbos biome of the Western Cape Province. A recent and detailed study by Armstrong and van Hensbergen (1994) clearly confirmed the depauperate nature of avian communities in plantations situated in the fynbos biome compared with natural vegetation. Snell (1978), in an anecdotal account, discusses both the positive and negative impacts of afforestation in a grassland region of eastern Zimbabwe. Dean (1969) and Fraser (1987), also in anecdotal accounts, demonstrated how the spread of alien trees in parts of the Gauteng Province of South Africa resulted in the replacement of grassland bird communities by woodland avian assemblages. Smith (1974) discussed the birds that have been recorded using eucalypt *Eucalyptus* spp. trees in Africa, and Steyn (1977), in yet another anecdotal account, described the occupation and use of eucalypt plantations in the Tzaneen area of the Northern Province of South Africa. Specific studies of species that may benefit from afforestation, or at least the spread of alien trees, include Brooke (1984*a*), Allan and Tarboton

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(1985), Macdonald (1986*a*,*b*, 1990) and Macdonald *et al.* (1986).

The impact of commercial afforestation on biodiversity, and in particular on bird communities, is not restricted to southern Africa. For example, Avery and Leslie (1990) provide a detailed and balanced examination of the positive and negative impacts of afforestation on the birds of the United Kingdom.

Macdonald (1992) made the point that it is more difficult to track range retractions in the face of afforestation than it is to monitor range expansions due to this industry and the spread of alien trees generally. He suggested that bird-atlas data can be of particular value in this regard, as birds are among the best indicators of the impact of major habitat modifications, such as large-scale afforestation. The aim of this study was to investigate the impact of commercial afforestation on bird populations in Mpumalanga Province (formerly the Eastern Transvaal Province or the southeastern part of the former Transvaal Province), South Africa, based on an examination of bird-atlas data.

METHODS

Extent of forestry

The extent of forestry (comprising plantations of three types of alien trees introduced from outside Africa: pine *Pinus* spp., eucalypt and wattle *Acacia* spp.) in Mpumalanga Province was determined by updating an existing forest resources map (Van der Zel, 1988), using digital LANDSAT Thematic Mapper (TM) satellite imagery captured primarily between 1992 and 1993 (but including some data from 1989 and 1991 images). Satellite imagery was classified by means of field verification, and by reference to afforestation permit data and an annual plantation statistics database. Visual photo-interpretation techniques were used to create transparent overlays, which were then digitized into Arc/Info Geographic Information Systems (GIS) format.

The extent of afforestation, expressed as a percentage, in each quarter-degree-grid cell (see below) in the province was then calculated, so that the information could be made compatible with bird-atlas data. The division of the cells into classes was achieved by ranking the cells with respect to percentage afforestation and grouping them into five classes, each with the same number of cells. The shading of the cells in the derived map reflects the percentage of afforestation.

Avian diversity, distribution and abundance

Information on birds was obtained from the Southern African Bird Atlas Project (SABAP; Harrison, 1992). The geographical resolution of the SABAP data is the quarter-degree-grid cell (QDGC; 15′×15′; *ca.* 24 km × 28 km) and the temporal resolution is the calendar month. In addition to providing information on presence/absence, the SABAP data also provided a simple measure of abundance based on reporting rates. A reporting rate is the percentage of check-lists on which a species was recorded relative to the total number of check-lists for a grid cell. Underhill *et al.* (1991) and Harrison (1992) provided details of the time periods spanned by the atlas data in the various regions of southern Africa. All of the data came from the period 1981–1992, especially 1987–1991.

Four lists of bird species present in Mpumalanga Province were compiled (Tables 1 and 2) and used as the basis for the analyses; as outlined below.

All grassland species

Species that are characteristic of open grassland and associated marshy habitats. Harrison *et al.* (1994) provide a habitat classification for bird species occurring in South Africa, including those that use open grassland and associated marshy habitats. The bird-atlas data were examined to identify which of these grassland species are present in the province.

Globally threatened grassland species

Species that are characteristic of open grassland habitats and are considered to be globally threatened with extinction, based on the most recent global red data book for birds (Collar *et al.*, 1994).

All threatened grassland species

Species that are characteristic of open grassland habitats and are considered to be either globally threatened, globally near-threatened (from Collar *et al.*, 1994), nationally threatened, based on the South African bird red data book (Brooke, 1984*b*), or potentially nationally threatened based on recent atlas data. The two species included in the last category are the grey crowned crane *Balearica regulorum* and white-bellied korhaan *Eupodotis senegalensis*.

Species benefiting from afforestation

Species that are considered to benefit from afforestation to at least some degree. The judgement that these species benefit from afforestation is based on habitat statements contained in Steyn (1977) and Tarboton *et al.* (1987*b*), and the bird-atlas data were examined to confirm which of these species occur in the province.

All of the species included in the list of globally threatened grassland species or in the list of all threatened species were also included in the list of all grassland species. All of the species included in the list of globally threatened grassland species were also included in the list of all threatened grassland species. None of these grassland species were included in the list of species benefiting from afforestation.

The references listed in Table 3 provide direct or indirect evidence that several of the species included in the lists of globally threatened and all threatened grassland birds are negatively impacted by commercial afforestation, through the loss of the open grassland habitats on which they are reliant. Many of the studies cited were conducted in Mpumalanga Province.

Table 1. The list of 90 bird species present in Mpumalanga Province that are characteristic of open grassland and associated marshy habitats

These species comprise the list of 'all grassland species'. Also identified are the 10 species comprising the list of 'globally threatened grassland species' and the additional 15 species that are either globally near-threatened or regionally threatened; these 25 species comprise the list of 'all threatened grassland species'. The 26 species endemic to southern Africa are also identified and the 15 species endemic to South Africa.

Species	Conservation status	Endemism
Black-headed heron *Ardea melanocephala*		
Cattle egret *Bubulcus ibis*		
White stork *Ciconia ciconia*		
Southern bald ibis *Geronticus calvus*	Globally threatened	South African endemic
Secretary bird *Sagittarius serpentarius*		
Black-shouldered kite *Elanus caeruleus*		
Steppe buzzard *Buteo buteo*		
Jackal buzzard *Buteo rufofuscus*		South African endemic
African marsh harrier *Circus ranivorus*		
Montagu's harrier *Circus pygargus*		
Pallid harrier *Circus macrourus*	Threatened	
Black harrier *Circus maurus*	Threatened	South African endemic
Lanner falcon *Falco biarmicus*		
Eastern red-footed kestrel *Falco amurensis*		
Greater kestrel *Falco rupicoloides*		
Lesser kestrel *Falco naumanni*	Globally threatened	
Grey-winged francolin *Francolinus africanus*		South African endemic
Red-winged francolin *Francolinus levaillantii*		
Common quail *Coturnix coturnix*		
Kurrichane buttonquail *Turnix sylvatica*		
Black-rumped buttonquail *Turnix hottentotta*	Threatened	
Wattled crane *Bugeranus carunculatus*	Globally threatened	
Blue crane *Anthropoides paradiseus*	Globally threatened	South African endemic
Grey crowned crane *Balearica regulorum*	Threatened	
Corncrake *Crex crex*	Globally threatened	
Baillon's crake *Porzana pusilla*	Threatened	
Striped flufftail *Sarothrura affinis*	Threatened	
White-winged flufftail *Sarothrura ayresi*	Globally threatened	
Denham's bustard *Neotis denhami*	Threatened	
White-bellied korhaan *Eupodotis senegalensis*	Threatened	
Blue korhaan *Eupodotis caerulescens*	Threatened	South African endemic
Black-bellied korhaan *Eupodotis melanogaster*		
Black korhaan *Eupodotis afra*		Southern African endemic
Crowned plover *Vanellus coronatus*		
Black-winged plover *Vanellus melanopterus*		
Wattled plover *Vanellus senegallus*		
Black-winged pratincole *Glareola nordmanni*	Threatened	
Whiskered tern *Chlidonias hybridus*		
White-winged tern *Chlidonias leucopterus*		
Grass owl *Tyto capensis*	Threatened	
Marsh owl *Asio capensis*		
Ground woodpecker *Geocolaptes olivaceus*	Threatened	South African endemic
Rufous-naped lark *Mirafra africana*		
Clapper lark *Mirafra apiata*		Southern African endemic
Rudd's lark *Mirafra ruddi*	Globally threatened	South African endemic
Long-billed lark *Mirafra curvirostris*		Southern African endemic
Spike-heeled lark *Chersomanes albofasciata*		Southern African endemic
Red-capped lark *Calandrella cinerea*		
Pink-billed lark *Spizocorys conirostris*		Southern African endemic
Botha's lark *Spizocorys fringillaris*	Globally threatened	South African endemic
European swallow *Hirundo rustica*		
Blue swallow *Hirundo atrocaerulea*	Globally threatened	
Greater striped swallow *Hirundo cucullata*		Southern African endemic
South African cliff swallow *Hirundo spilodera*		Southern African endemic
Banded martin *Riparia cincta*		
Black crow *Corvus capensis*		
Sentinel rock thrush *Monticola explorator*		South African endemic
Capped wheatear *Oenanthe pileata*		
Buff-streaked chat *Oenanthe bifasciata*	Threatened	South African endemic

contd

Table 1—*contd*

Ant-eating chat *Myrmecocichla formicivora*		Southern African endemic
Stonechat *Saxicola torquata*		
Broad-tailed warbler *Schoenicola brevirostris*	Threatened	
Grassbird *Sphenoeacus afer*		Southern African endemic
Fan-tailed cisticola *Cisticola juncidis*		
Desert cisticola *Cisticola aridula*		
Cloud cisticola *Cisticola textrix*		
Ayres' cisticola *Cisticola ayresii*		
Pale-crowned cisticola *Cisticola brunnescens*		
Wailing cisticola *Cisticola lais*		
Croaking cisticola *Cisticola natalensis*		
Grassveld pipit *Anthus cinnamomeus*		
Long-billed pipit *Anthus similis*		
Plain-backed pipit *Anthus leucophrys*		
Buffy pipit *Anthus vaalensis*		
Rock pipit *Anthus crenatus*		South African endemic
Short-tailed pipit *Anthus brachyurus*	Threatened	
Yellow-breasted pipit *Hemimacronyx chloris*	Globally threatened	South African endemic
Orange-throated longclaw *Macronyx capensis*		Southern African endemic
Fiscal shrike *Lanius collaris*		
Pied starling *Spreo bicolor*		South African endemic
Gurney's sugarbird *Promerops gurneyi*		Southern African endemic
Malachite sunbird *Nectarinia famosa*		
Cape weaver *Ploceus capensis*		South African endemic
Cuckoo finch *Anomalospiza imberbis*		
Red bishop *Euplectes orix*		
Golden bishop *Euplectes afer*		
Red-shouldered widow *Euplectes axillaris*		
Long-tailed widow *Euplectes progne*		
Quail finch *Ortygospiza atricollis*		
Orange-breasted waxbill *Sporaeginthus subflavus*		

Species are described as 'southern African endemics' (Clancey, 1986) and 'South African endemics' (Siegfried, 1992) if 90% or more of their populations are restricted to the southern African subcontinent, or entirely to South Africa (including Lesotho and Swaziland for biogeographical completeness), respectively.

Avian diversity index

Maps were produced showing the diversity of these four groups of birds by QDGCs in Mpumalanga Province. The measure of diversity was based on an application of a modified Shannon Index, termed the H^* index (Harrison & Martinez, 1995). The index corrects for the sampling effort in each QDGC. A QDGC with a large H^* value may be assessed as being relatively species-rich, and this assessment is independent of the sampling effort. The atlas coverage of Mpumalanga Province, in terms of the number of check-lists per QDGC, was more than adequate to allow the calculation of reliable index values (Harrison & Martinez, 1995).

The cells were ranked according to their index values and then divided into five equal quantiles for mapping. These five quantiles were mapped in shades of different intensity, with the intensity of shading increasing with increasing values of the index. It was then possible to compare the patterns of species richness of these four lists of birds visually with the patterns of afforestation from the CSIR map and the derived map of the intensity of afforestation by QDGCs.

In order to examine the association between these species assemblages and the patterns of afforestation statistically, four graphs were produced, one for each list of species, plotting the diversity index of each cell against the percentage of that cell afforested, for cells with more than 1% of their area afforested.

Overall importance of the province for threatened bird species

In order to investigate the overall importance of Mpumalanga Province for all threatened grassland species, the bird-atlas data were used to measure the extent of the range of each species that lies within the province, relative to the total South African range (including Lesotho and Swaziland). Similarly, reporting-rate data were used to measure whether the species is more or less abundant within its range in the province, relative to that part of its range lying outside the province. For those species with appropriate sample sizes, the differences in reporting rates were tested using a generalized linear model with a binomial distribution and logistic link function (McCullagh & Nelder, 1989).

RESULTS

Extent of afforestation

The area of Mpumalanga Province is about 8·3 million ha. Approximately 7% is afforested (roughly 580,000 ha). This consists of 332,000 ha of pines (mainly *Pinus patula*),

214,000 ha of eucalypts (mainly *Eucalyptus grandis* and *E. saligna*) and 34,000 ha of wattle *Acacia mearnsii*. Commercial afforestation is not evenly distributed throughout Mpumalanga Province but is concentrated in a north–south strip, largely corresponding with the escarpment between the coastal lowlands and the interior plateau (Figs 1 and 2(a)). Most plantations occur at elevations between 1000 and 2000 m in the areas receiving more than about 850 mm of rainfall annually. The largest gap in afforestation in the central escarpment region corresponds with the low-lying Komati River valley.

Avifauna impacted by afforestation

Ninety bird species characteristic of grassland habitats occur in Mpumalanga Province (Table 1). Of these, 10 are considered to be globally threatened and an additional 15 are globally near-threatened, nationally threatened or potentially nationally threatened (Table 1). A separate suite of 65 species occurs in the province that is considered to benefit from afforestation (Table 2).

The patterns of species diversity for all grassland birds (Fig. 2(b)), globally threatened grassland birds (Fig. 2(c)) and all threatened grassland birds (Fig. 2(d)) show that the areas of highest diversity largely correspond with the escarpment region, where afforestation is also concentrated, and also extend inland away from the escarpment in the extreme southwest. The area of highest richness of species benefiting from afforestation (Fig. 2(e)) is situated further to the north and east, compared with the grassland species.

Examining the relationship between the extent of afforestation and species diversity in each QGDC, the diversity of all grassland birds and of globally threatened grassland birds is negatively and significantly correlated with the extent of afforestation (Fig. 3(a) and 3(b)). The negative association between the diversity of all threatened grassland species and the extent of afforestation approaches significance (Fig. 3(c)). By contrast, the correlation between the diversity of species benefiting from afforestation and the extent of plantation cover is positive and significant (Fig. 3(d)).

Overall importance of the province for threatened bird species

Eleven of the 25 threatened species (44%) have more than 20% of their respective South African ranges in

Table 2. The list of 65 bird species present in Mpumalanga Province that are considered to benefit from afforestation to at least some degree

These species comprise the list of 'species benefiting from commercial afforestation'. None of these species is globally threatened and only one, the cuckoo hawk (Brooke, 1984*b*), is considered regionally threatened. Two of these species are endemic to South Africa (forest buzzard, fiscal flycatcher), and an additional seven are endemic to the southern African sub-region (Natal francolin, pied barbet, Cape batis, southern boubou, glossy starling, Cape white-eye and swee waxbill).

Cuckoo hawk *Aviceda cuculoides*
Long-crested eagle *Lophaetus occipitalis*
Crowned eagle *Stephanoaetus coronatus*
Steppe buzzard *Buteo buteo*
Forest buzzard *Buteo trizonatus*
Red-breasted sparrowhawk *Accipiter rufiventris*
Ovambo sparrowhawk *Accipiter ovampensis*
Little sparrowhawk *Accipiter minullus*
Black sparrowhawk *Accipiter melanoleucus*
African goshawk *Accipiter tachiro*
Gymnogene *Polyboroides typus*
Natal francolin *Francolinus natalensis*
Helmeted guineafowl *Numida meleagris*
Rameron pigeon *Columba arquatrix*
Red-eyed dove *Streptopelia semitorquata*
Cape turtle dove *Streptopelia capicola*
Laughing dove *Streptopelia senegalensis*
Green-spotted dove *Turtur chalcospilos*
Tambourine dove *Turtur tympanistria*
Red-chested cuckoo *Cuculus solitarius*
Black cuckoo *Cuculus clamosus*
Wood owl *Strix woodfordii*
Spotted eagle owl *Bubo africanus*
Fiery-necked nightjar *Caprimulgus pectoralis*
Narina trogon *Apaloderma narina*
Pygmy kingfisher *Ispidina picta*
European bee-eater *Merops apiaster*
Red-billed woodhoopoe *Phoeniculus purpureus*
Pied barbet *Tricholaema leucomelas*
Lesser honeyguide *Indicator minor*
Sharp-billed honeyguide *Prodotiscus regulus*
Red-throated wryneck *Jynx ruficollis*
Black saw-wing swallow *Psalidoprocne holomelas*
Fork-tailed drongo *Dicrurus adsimilis*
Black-headed oriole *Oriolus larvatus*
Black-eyed bulbul *Pycnonotus barbatus*
Kurrichane thrush *Turdus libonyana*
Olive thrush *Turdus olivaceus*
Groundscraper thrush *Turdus litsitsirupa*
Cape robin *Cossypha caffra*
Willow warbler *Phylloscopus trochilus*
Bar-throated apalis *Apalis thoracica*
Bleating warbler *Camaroptera brachyura*
Neddicky *Cisticola fulvicapilla*
Spotted flycatcher *Muscicapa striata*
Dusky flycatcher *Muscicapa adusta*
Black flycatcher *Melaenornis pammelaina*
Fiscal flycatcher *Sigelus silens*
Cape batis *Batis capensis*
Paradise flycatcher *Terpsiphone viridis*
Southern boubou *Laniarius ferrugineus*
Black-crowned tchagra *Tchagra senegala*
White helmetshrike *Prionops plumatus*
Glossy starling *Lamprotornis nitens*
Black sunbird *Nectarinia amethystina*
Cape white-eye *Zosterops pallidus*
Yellow-rumped widow *Euplectes capensis*
Blue-billed firefinch *Lagonosticta rubricata*
Swee waxbill *Estrilda melanotis*
Bronze mannikin *Spermestes cucullatus*
Red-backed mannikin *Spermestes bicolor*
Black widowfinch *Vidua funerea*
Yellow-eyed canary *Serinus mozambicus*
Cape canary *Serinus canicollis*
Golden-breasted bunting *Emberiza flaviventris*

Mpumalanga Province (Table 4). Five of these species are endemic to South Africa and therefore more than 20% of their world ranges occur in the province. The sample sizes available for 17 of the threatened grassland species are adequate to allow meaningful comparisons of reporting rates, i.e. measurement of relative abundance, at the level of each individual species (Table 4). Six of these species have reporting rates lower in the province than elsewhere in South Africa, four are recorded at higher frequencies in the province, and for seven species the differences in reporting rates are not significant.

DISCUSSION

The bird-atlas data supporting this paper can be considered both comprehensive and reliable. Mpumalanga Province was one of the most thoroughly surveyed regions during the atlassing effort, with more than 40 bird check-lists having been compiled for each of the QDGCs in the province (Harrison, 1993). The distributional data were also subjected to a rigorous vetting procedure by both experienced amateur and professional ornithologists. Allan (1994) and Robertson *et al.* (1995) both subjected atlas data to testing against independent and more sensitive survey techniques, and confirmed its reliability in reflecting relative abundance in terms of reporting rates.

Table 3. References providing direct or indirect evidence that several of the species included in the lists of globally threatened and all threatened grassland birds are negatively impacted by commercial afforestation, through the loss of the open grassland habitats on which they are reliant

Species	References
Southern bald ibis	Collar & Stuart (1985) Manry (1985) Collar *et al.* (1994)
Lesser kestrel	McCann (1994)
Wattled crane	Brooke (1984*b*) Tarboton (1984) Collar & Stuart (1985) Tarboton *et al.* (1987)
Blue crane	Johnson (1992) Collar *et al.* (1994)
Striped flufftail	Taylor (1994)
White-winged flufftail	Taylor (1994)
Denham's bustard	Tarboton (1989) Johnson (1992)
Rudd's lark	Hockey *et al.* (1988) Collar *et al.* (1994)
Botha's lark	Allan *et al.* (1983)
Blue swallow	Snell (1979, 1988) Brooke (1984*b*) Allan *et al.* (1987) Allan (1988) Collar *et al.* (1994) Tarboton (1994)
Broad-tailed warbler	Allan *et al.* (1988)
Yellow-breasted pipit	Brooke (1984*b*) Collar *et al.* (1994).

The 10 globally threatened grassland species represent 71% (10/14) of the globally threatened species occurring on the mainland of South Africa (Collar *et al.*, 1994). This emphasizes the point that open grassland and associated marshy habitats, and their characteristic avifauna, are the most severely threatened in the region. This point has previously been identified by Brooke (1984*b*). The species judged to benefit from afforestation are largely birds associated with woodland and natural forest habitats. The degree of benefit derived from large-scale afforestation by these 65 species is debatable and may be only slight in some cases. Many of these species merely exploit stands of alien trees for roosting, breeding or cover in otherwise natural areas, and are reliant on substantial areas of natural habitat in close proximity for foraging. Indeed, Steyn (1977) identified only 34 of these species as inhabitants of large-scale forestry plantations.

The finding that the highest species richness of all three classes of grassland birds corresponds with the escarpment region, where afforestation is also concentrated, is the nub of the conservation problem: afforestation targets precisely the regions where the highest species richness of grassland birds, and especially threatened grassland birds, occurs. Of particular concern is the fact that most of the planned additional afforestation in Mpumalanga Province is targeted for the extreme southwestern parts, in particular the Wakkerstroom District. This is the only region in Mpumalanga Province which at present supports few commercial plantations and has a high species richness of the three classes of grassland birds.

The information presented in Fig. 3 strongly suggests that afforestation has significantly reduced the species diversity of grassland birds in Mpumalanga Province, with the diversity of all grassland birds and globally threatened grassland birds being significantly and negatively correlated with the extent of afforestation. This is the major finding of this study. Confidence in the reliability of these results comes from the expected and congruent finding that species judged to benefit from afforestation show a significant and positive correlation with increasing extent of afforestation.

An important and unexpected finding of this study is that afforestation apparently has a negative impact on grassland bird diversity even when the percentage area under plantation is relatively small (Fig. 3). It is often claimed that the effects of afforestation are greatly ameliorated by the relatively large areas left unafforested in plantation regions. These areas, however, are not randomly chosen and representative of all of the original habitats present before afforestation. They frequently comprise areas with habitations, roads, road verges, managed firebreaks, watercourses, rocky areas, and regions with shallow soils and steep slopes. This may benefit some organisms, including some of the original inhabitants, but serves little purpose in conserving the organisms restricted to the afforestable ground, which is frequently entirely converted to timber

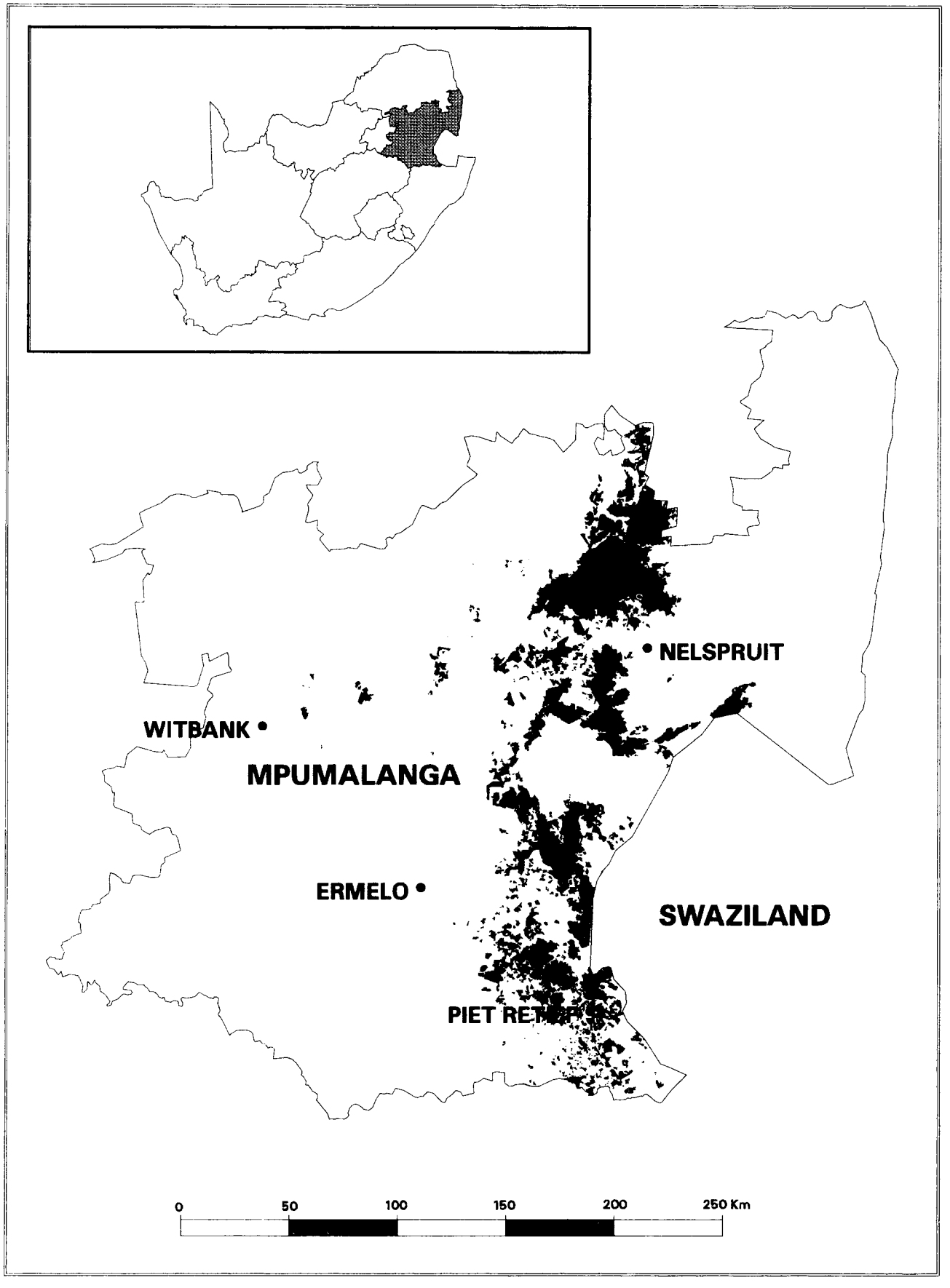

Fig. 1. Map of Mpumalanga Province, South Africa (see inset), with the areas under commercial afforestation with alien pine *Pinus* spp., eucalypt *Eucalyptus* spp. and wattle *Acacia* spp. plantations shaded.

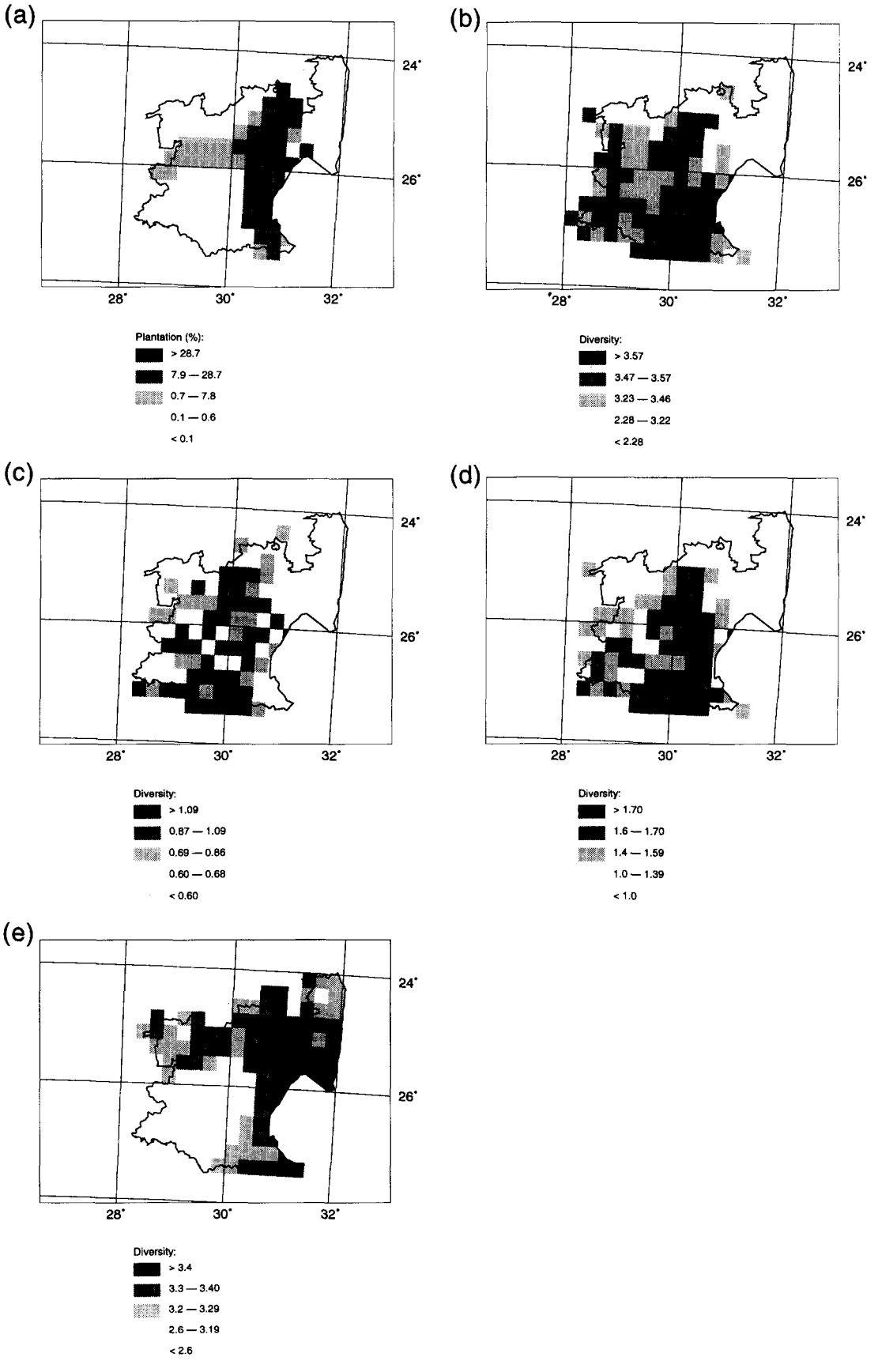

Fig. 2. Grid maps of Mpumalanga Province showing: (a) the extent of afforestation, summarized as percentage area per QDGC; (b) the pattern of diversity for all grassland species; (c) the pattern of diversity for globally threatened grassland species; (d) the pattern of diversity for all threatened grassland species; and (e) the pattern of diversity for species benefiting from afforestation.

production. An example of this problem is the blue swallow *Hirundo atrocaerulea* (Allan *et al.*, 1987), which is reliant on the habitats most favoured for planting and does not exploit the habitats that are left unafforested.

A further problem comes from the impact of habitat fragmentation itself, and associated extinction through random processes and lack of extensive areas of suitable habitat for those species with large spatial requirements. Bond *et al.* (1988) provide a South African example of the effect of habitat fragmentation on botanical species richness. In addition, unplanted grasslands in proximity to plantations may degrade owing to the reduced availability of ground water and reduced seepage. Afforestation may also result in a reduction of microhabitat variation, previously maintained by mixed grazing regimes, pasture rotation and burning, when land is no longer used by stock farmers. There is an urgent need to investigate the full range of impacts which afforestation has upon indigenous grassland biota, apart from the obvious one of habitat destruction at the site of planting.

An analysis of the number of species negatively and positively impacted by afforestation, their endemism and their threatened status is illuminating (Table 5). It is clear that more species are jeopardized by afforestation than benefit; that these negatively impacted species show high endemism, and therefore are of greatest conservation concern; and that many of them are currently viewed as seriously declining and threatened. Of further concern is the finding by Siegfried (1989) that the grassland biome (along with the Karoo) is poorly represented in the South African national network of protected areas (2% conserved), compared with the forest (77% conserved) and woodland (10% conserved) biomes, from which most of the species which benefit from afforestation originate.

The overall importance of the province for threatened bird species

The finding that 11 of the 25 threatened grassland species have more than 20% of their South African ranges in Mpumalanga Province emphasizes the importance of

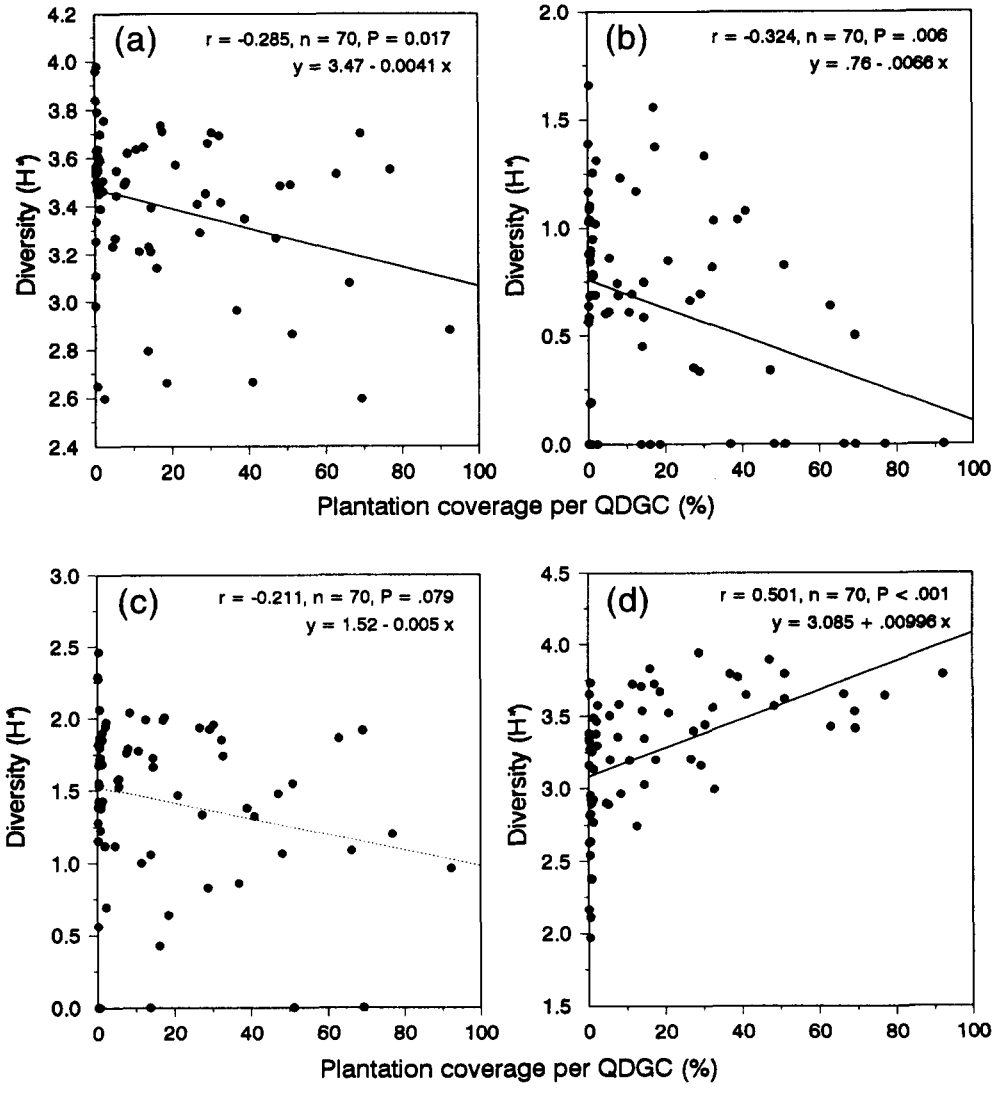

Fig. 3. Plots of species diversity against percentage of plantation coverage per QDGC, for all grassland birds (a), globally threatened grassland birds (b), all threatened grassland birds (c), and species benefiting from afforestation.

this region for these species. This is especially so for the five species endemic to South Africa (southern bald ibis *Geronticus calvus*, Rudd's *Mirafra ruddi* and Botha's *Spizocorys fringillaris* larks, buff-streaked chat *Oenanthe bifasciata* and yellow-breasted pipit *Hemimacronyx chloris*), i.e. having more than 20% of their world ranges in the province. Of these five, four are considered globally threatened. Rudd's and Botha's larks are of particular concern in this regard, having 71% and 89% of their respective world ranges in the province. In addition, the globally threatened white-winged flufftail *Sarothrura ayresi* was recorded during the southern African bird atlas only in Mpumalanga Province, and outside South Africa this species is known to occur regularly only in the ecologically similar highlands of Ethiopia (Urban *et al.*, 1986).

The finding that four of these species (southern bald ibis, blue swallow, buff-streaked chat and yellow-breasted pipit) have significantly higher reporting rates in the province compared with elsewhere in their ranges suggests that the remaining available habitat there appears to be particularly favourable. This adds to the responsibility on the province to ensure the protection of the areas where these species occur. The finding that some species have lower reporting rates in Mpumalanga Province than elsewhere in their ranges cannot be interpreted as direct evidence that afforestation is the cause of this apparent lower relative abundance, without additional information on the extent of afforestation, and other habitat parameters and threats, in the remainder of the South African ranges of these birds.

Table 4. The total number of QDGCs in which each threatened grassland bird species has been recorded in Mpumalanga Province and the total number of cells where each has been recorded outside the province, in the rest of South Africa

The percentage of the total number of cells which lie in the province relative to the remainder of South Africa is listed. The reporting rate (RR) for each species, both inside and outside the province, is also provided, using data from cells where the species has been recorded. The final column in the table identifies significant differences between reporting rates inside and outside the province for each species (ns = $p > 0.05$; — = sample sizes too small for meaningful statistical analysis). Entries in bold represent significantly higher reporting rates in Mpumalanga Province.

Species	QDGCs inside	QDGCs outside	% inside	RR inside	RR outside	p
Southern bald ibis	78	180	30·2	20·6	18·4	**$p < 0.001$**
Pallid harrier	10	54	15·6	1·2	1·6	ns
Black harrier	17	530	3·1	5·5	6·3	ns
Lesser kestrel	91	688	11·7	6·1	8·8	$p < 0.001$
Black-rumped buttonquail	5	26	16·1	1·6	0·9	—
Wattled crane	22	49	31·0	9·4	10·4	ns
Blue crane	96	627	13·3	10·3	12·9	$p < 0.001$
Grey crowned crane	46	229	16·7	17·1	18·2	ns
Corncrake	5	40	11·1	0·9	0·7	—
Baillon's crake	3	50	5·7	1·2	1·4	—
Striped flufftail	2	19	9·5	2·9	0·9	—
White-winged flufftail	1	0	100·0	4·8	0·0	—
Denham's bustard	54	275	16·4	6·4	10·1	$p < 0.001$
White-bellied korhaan	78	132	37·1	4·7	5·0	ns
Blue korhaan	62	310	16·7	11·7	17·7	$p < 0.001$
Black-winged pratincole	45	87	34·1	2·2	1·8	ns
Grass owl	51	157	24·5	2·3	2·3	ns
Ground woodpecker	41	451	8·3	8·7	11·6	$p < 0.001$
Rudd's lark	10	4	71·4	7·3	10·7	—
Botha's lark	16	2	88·9	5·1	5·7	—
Blue swallow	9	21	30·0	10·2	3·2	**$p < 0.001$**
Buff-streaked chat	58	176	24·8	19·9	14·1	**$p < 0.001$**
Broad-tailed warbler	17	72	19·1	2·4	3·8	$p < 0.001$
Short-tailed pipit	1	10	9·1	1·0	1·1	—
Yellow-breasted pipit	15	37	28·9	4·7	2·8	**$p < 0.001$**

Table 5. Summary of the number of bird species negatively and positively impacted by afforestation in Mpumalanga Province, their endemism (Clancey, 1986; Siegfried, 1992) and conservation status (Brooke, 1984*b*; Collar *et al.*, 1994)

	Negatively affected		Positively affected	
Number of species	90		65	
Southern African endemics	26	(29%)	9	(14%)
South African endemics	15	(17%)	2	(3%)
Globally threatened	10	(11%)	0	
Threatened	25	(28%)	1	(2%)

Do patterns of grassland bird diversity reflect patterns of overall grassland biodiversity?

This question is of critical importance in the assessment of the impact of commercial afforestation on biodiversity generally. Several studies are mentioned below that confirm the overall trend that patterns of species richness for birds are correlated with those of other less well-known groups. The International Council for Bird Preservation (ICBP, 1992), in a global investigation, identified four endemic bird areas in South Africa, one of which ('South African Grasslands') occurs in Mpumalanga Province. This endemic bird area was defined by the presence of three of the globally threatened grassland species discussed here: Rudd's and Botha's larks, and yellow-breasted pipit. ICBP stressed that birds are particularly useful in the investigation of overall biodiversity richness owing to their distribution and taxonomy being well known, to the wide variety of habitats and biotopes exploited by birds, and to their being largely diurnal and conspicuous and therefore easy to survey compared to other groups. They present several examples of bird species-richness patterns reflecting those of other groups, for example mammals and reptiles in the Philippines and Indonesia, reptiles, amphibians and butterflies in Central America, and amphibians and mammals in Africa. It is of particular interest that Cowling and Hilton-Taylor (1994) identified seven South African hot-spots of botanical endemism and diversity, including one centred on the grasslands of the escarpment in Mpumalanga Province, and all four endemic bird areas identified by ICBP (1992) overlapped with these botanical hotspots. Heydenrych (1995) specifically highlighted the threat by afforestation to grasslands and compared maps of botanical regions and centres of endemism with a map of existing and potential forestry areas, the latter map modified from Van der Zel (1989).

Along a similar vein, 30% of rare and endangered plants in the former Transvaal Province were found to occur in grassland habitats subject to afforestation, even though such plantations only covered 2% of the province (Raal, 1986). Matthews *et al.* (1993) found high plant endemism, and major centres of plant biodiversity, that were directly associated with the remaining blue swallow sites on the escarpment of the former Transvaal Province, which were all threatened by afforestation. All the endemic plants were grassland species.

More generally, Crowe and Crowe (1982) found that the patterns of distribution, diversity and endemism in Afrotropical non-passerine and passerine birds largely mirrored one another and of greater importance here, were clearly associated with the major African vegetation types. In addition, Turpie and Crowe (1994) found that, with some minor exceptions, patterns of distribution, diversity and endemism of larger African mammals also corresponded well with those of vegetation types and resident non-aquatic birds. Further, Crowe (1990) found that patterns of distribution, species richness and endemism in southern African frogs, lizards, snakes, large mammals and birds were all approximately congruent with one another. Crowe (1993) describes some of the most recent developments in this field and the value of using well-known 'surrogate' species, such as birds, to predict biodiversity hot-spots is highlighted.

The impact of additional afforestation in Mpumalanga Province

Considering the demonstrated and substantial negative impacts that afforestation poses for biodiversity in Mpumalanga Province, it is questionable whether any further afforestation should occur in this region. As mentioned above, it is of particular concern that much of the proposed additional afforestation is targeted at areas with high species richness of grassland birds, and, especially, threatened grassland birds. Duthie (1994) stressed the need for Environmental Impact Assessments and other Integrated Environmental Management procedures in the commercial forestry industry. These should be implemented in full if any further afforestation in the province is contemplated. Armstrong *et al.* (1994) provided details of the appropriate methods to be used in such assessments. A major challenge, and one not currently being met in South Africa, is to plan and manage forestry plantations with the active conservation and promotion of a full range of biodiversity as a priority. Examples of progress in this regard elsewhere in the world can be found in Avery and Leslie (1990).

Duthie (1994) also highlighted the inadequacies in the current permit system for afforestation. Conservation agencies should hold a pivotal position in the decision-making processes involved in the granting of such permits. The present conflict of interests in the issuing of permits should be rectified, along with other deficiencies. The recently released discussion paper on a policy for sustainable forest management in South Africa (Kruger *et al.*, 1995) is flawed in restricting its conservation statements to natural forests and woodlands, ignoring the fact that it is the threat to natural grasslands that is the prime cause for concern.

In the Foreword to the discussion paper (Kruger *et al.*, 1995), the South African Minister of Water Affairs and Forestry stated in relation to forestry: 'The era of an industry, conservative, self-sufficient and perhaps somewhat complacent, has come to an end however. It is to become part of the new South Africa, to recognise that there are other aspects of our national life, hitherto largely neglected, on which forestry impinges and on which forestry must in future have a positive effect'.

South Africa's endemic grasslands, and the unique biodiversity supported by them, *have* been neglected and impinged upon by the forestry industry in the past. A positive contribution from forestry is needed if biodiversity conservation in the grassland biome is to be viable in the long term. This unavoidably means that large tracts of land suitable for afforestation must be

sacrificed by the industry and be devoted instead to alternative forms of land use which have fewer negative impacts on the grassland biota, for example pastoral farming and ecotourism. Identifying such alternatives and assessing their economic value relative to forestry is an immediate research priority.

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