

Effects of habitat fragmentation on bird communities of sand forests in southern Mozambique

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We investigated the influence of forest fragment size and isolation on the bird assemblages in the species- and endemic-rich sand forests of the Maputaland Centre of Endemism, southern Mozambique. Point-centre surveys were conducted across 12 sand forest patches that varied in size and isolation. Patch size and isolation had little influence on bird species richness, but the number of individuals decreased significantly with increasing isolation. Furthermore, bird abundances were correlated to a combination of the size and isolation of patches. Many forest specialists, in particular large-bodied frugivores, were highly sensitive to reduced patch size and increased distances between patches. Further fragmentation of the landscape may therefore impair the ability of these forests to support viable populations of forest specialists.

Introduction

Habitat fragmentation ultimately results in biological extinctions, by reducing the area of habitat patches and increasing the distances between these patches (e.g. Bierregaard *et al.* 1992, Brooks *et al.* 1999, Laurance *et al.* 2002). Fragmentation may also block dispersal and negate the ability of habitat patches to sustain local populations (Stouffer and Bierregaard 1995, Renjifo 1999, Laurance *et al.* 2002). Habitat loss influences different species in different ways. For instance, habitat specialists and species with small range sizes are often more severely affected by habitat degradation (e.g. escalating edge effects) than generalists and species with large range sizes (Strafford and Stouffer 1999, Connor *et al.* 2000, Manne and Pimm 2001, Laurance *et al.* 2002).

Studies on habitat fragmentation are especially relevant to threatened biota in spatially complex regions. This certainly holds true for the Maputaland Centre of Endemism, which was recently awarded 'biodiversity hotspot' status by Conservation International (Maputaland-Pondoland-Albany: Mittermeier *et al.* 2004). This region is a biogeographical transition zone between the tropics to the north and the subtropics to the south, with several species occurring here at their southernmost or northernmost range limits (Geldenhuys and MacDevette 1989, Watkeys *et al.* 1993, van Wyk 1996). As the Maputaland Centre of Endemism represents a biogeographical transition zone, it is characterised by a diverse array of biomes, which enhances species diversity. Most endemic species in the region are associated with sand forests (van Wyk 1996, van Rensburg *et al.* 2000).

The Maputo Special Reserve (MSR) is the only formal conservation area in southern Mozambique that contains sand forests (Parker and de Boer 2000). Despite protection, man-made fires and African elephants *Loxodonta africana*

may fragment the forests in the area. There is evidence that fires have converted large tracts of sand forests in the west of the MSR into relatively open woodlands (Parker and de Boer 2000). Elephants are also known to induce changes in the composition and structure of sand forest plant communities (van Rensburg *et al.* 2000, Matthews *et al.* 2001, Botes *et al.* 2006), with potential consequences for faunal diversity. Such agents of landscape fragmentation, especially in the MSR, may ultimately alter regional biodiversity through the reduction and isolation of remaining forest patches.

Here we assess the effects of forest patch size and isolation on bird assemblages in the MSR. We expect a decrease in species richness and the number of individuals with decreasing patch size and increasing distances between patches.

Materials and methods

The study took place in the MSR (26°25'S, 32°45'E) (also known as the Maputo Elephant Reserve; Figure 1a) in southern Mozambique. Here the Maputo and Futi Rivers and the high water mark of the Indian Ocean form most of the western and eastern borders of the Reserve (794km²), respectively. The Reserve comprises a mosaic of grassland, sand forest and woodland. The sand forest patches are dense, dry, semi-deciduous to deciduous, and associated with the north-south trending belts of aeolian sand deposits (Moll 1977, van Wyk 1996).

We used a satellite TM7 image and IDRISI32 software (a GIS package: Eastman 2001) to delineate all intact forest patches in the southern, accessible areas of the MSR as survey sites (Figure 1b). Forests were defined as those habitats where tree canopies created a closed canopy and

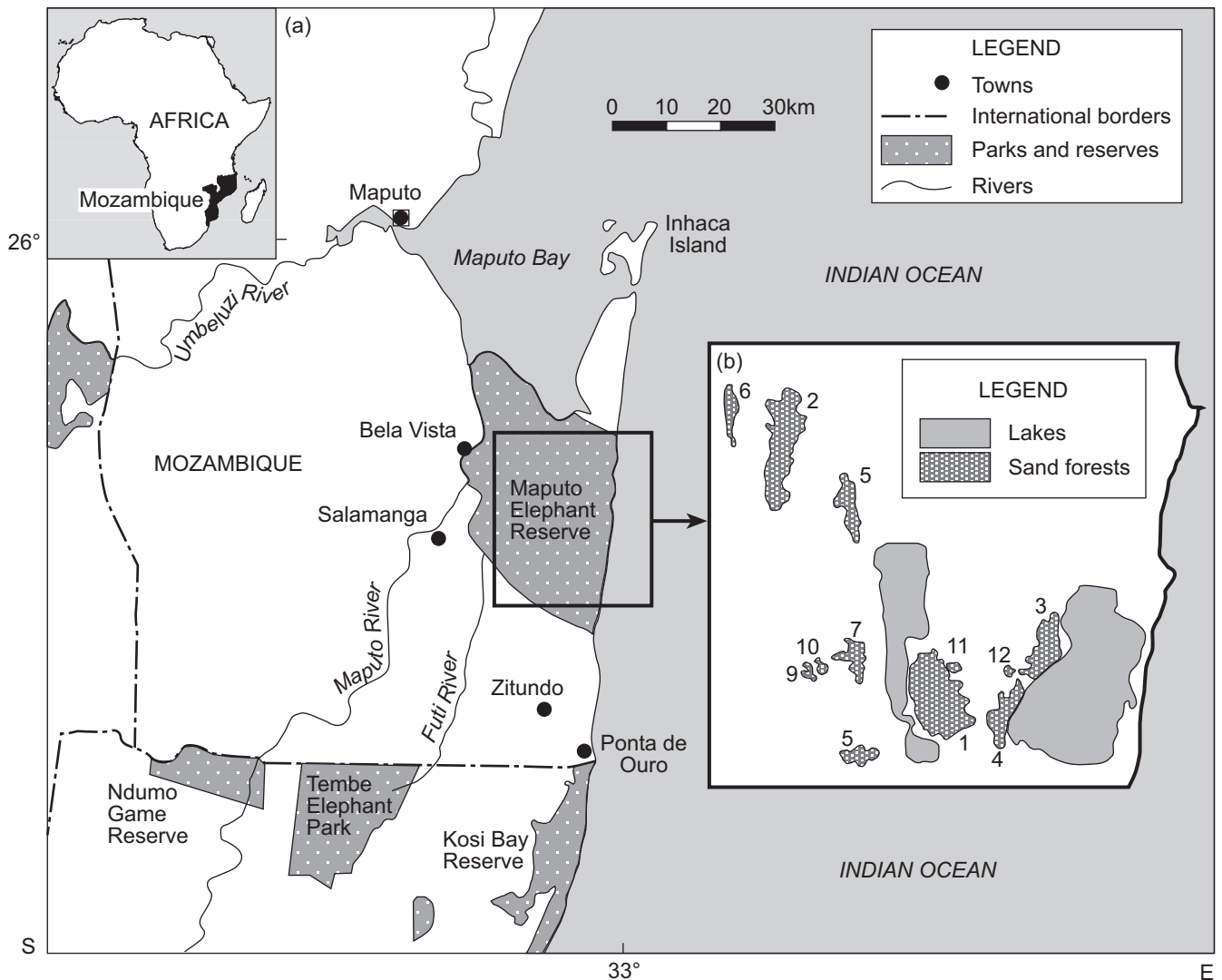


Figure 1: (a) The location of the Maputo Special Reserve (MSR, also known as the Maputo Elephant Reserve), and (b) the location of 12 sand forest patches surveyed for bird species richness and abundance

a grassy understorey was absent, as opposed to woodlands with an open canopy and the presence of a grass layer. Provisionally, 15 forest patches were selected from the satellite image, of which three were discarded during ground-truthing, as their open canopies more resembled a closed woodland habitat type, i.e. containing both woodland and sand forest elements. The remaining 12 intact forest patches in the southern MSR were surveyed to determine the influence of patch size on bird assemblages (Table 1). The 12 forests surveyed were also classified into different size categories following natural breaks, resulting in four large (>150ha), four medium (70–104ha) and four small (8–34ha) forests. We followed Beier *et al.* (2002) to estimate patch isolation, as the distances of each small or medium forest patch to the nearest large forest patch.

We followed Scheiner's (2004) definition of 'species-area curves' whereby an equal sampling effort maintained across different-sized forest patches ensures a comparable measure of the accumulation of species per unit area of different-sized habitat fragments. Consequently, surveys consisted

of five randomly-placed points in each of the 12 forest patches. We attempted to position survey points in such a way that each was homogeneous with respect to density of large trees and canopy closure. Surveys were based on the point sampling method and took place in the mornings (07:30–11:00) and afternoons (14:00–17:30) during July 2003. Sampling points were sited at least 150m apart to reduce the likelihood of seeing a bird more than once, as well as at least 30m from the forest edge, to focus on forest interior species. Before each 8min survey, we allowed 2min for birds, that may have been disturbed while approaching the survey point, to resettle. Observations were based on all birds seen and heard within a c. 25m radius of the survey point.

Harrison *et al.*'s (1997) and Parker's (1999) life history classification was followed, to distinguish forest specialists from woodland- and generalist species (Appendix 1). Forest specialists are species that apparently prefer forests and which we recorded in sand forest patches, while woodland species refer to those birds that do not normally occur in

Table 1: Number of individuals and number of species recorded in each of the 12 sand forest patches, together with the distances, in metres, between those forest patches smaller than 150ha in size and those larger than 150ha in size (as a measure of patch isolation)

Patch size category	Forest patch	Size (ha)	Degree of isolation (m)	Number of individuals (N)	Number of species (S)
Large	1	691	-	30	11
	2	502	-	33	13
	3	286	-	40	11
	4	162	-	41	12
Medium	5	118	2 100	22	10
	6	104	1 100	27	13
	7	98	1 600	27	11
	8	70	2 050	38	13
Small	9	34	3 500	22	11
	10	27	3 050	22	10
	11	14	150	46	10
	12	8	250	45	13

forests but which we noted in sand forests. Birds that utilise a wide range of habitats, including sand forest and woodland, were considered generalists.

Bird abundance (number of individuals) and species richness (number of species) were calculated separately for all birds and for forest specialists only. These values were then correlated with the size and degree of isolation of the forest patches through linear regression analyses, using Statistica Version 6 (StatSoft Inc. 2004). Bird community variables were also correlated with patch size in combination with patch isolation, through multiple linear regression analyses.

Results

Thirty-two bird species (398 individuals) were recorded in the 12 forest patches that we surveyed (Appendix 1). Of these, 18 species (301 individuals) were forest specialists. We identified five species (18 individuals) as woodland species and nine species (79 individuals) as generalist species. We noted a range of 20–28 species in each forest patch. Thirty to 41 individuals were recorded in large patches, while between 22 and 46 were noted in medium and small forest patches, respectively. The Grey Sunbird *Cyanomitra veroxii*, followed by the Square-tailed Drongo *Dicrurus ludwigii* and the Dark-backed Weaver *Ploceus bicolor*, were the most frequently recorded species across all forest patches.

Variability in abundance and species richness could not be explained by variation in patch size alone (Table 2). Species abundances, however, decreased significantly with increasing isolation, and with patch size and patch isolation in combination (Table 2). This was true for both forest specialists and the entire bird community associated with the sand forests. Variability in species richness and abundance of generalists could not be explained by patch size, isolation, or patch size and patch isolation combined (Table 2). Accumulation curves did not reach an asymptote (Figure 2), suggesting that results should be treated with caution, especially those where no clear pattern was observed.

Although the few sightings made in this study did not allow us to analyse the influence of forest fragmentation on individual species, it is worth noting that several species appeared to be affected by patch size and isolation. Forest

specialists such as Livingstone's Turaco *Tauraco livingstonii* was recorded only in the largest forest patches, while the Brown Scrub-Robin *Cercotrichas signata* was found only in large- and medium-sized patches. The Olive Sunbird *Cyanomitra olivacea*, the Collared Sunbird *Hedydipna collaris*, the Trumpeter Hornbill *Bycanistes bucinator* and the White-starred Robin *Pogonichla stellata* were restricted to large patches and small patches close (<250m) to large ones. The Yellow-bellied Greenbul *Chlorocichla flaviventris* and Neergaard's Sunbird *Cinnyris neergaardi* were restricted to large and medium patches and small patches less than 250m from large patches.

In contrast, most generalists were encountered over all forests, irrespective of patch size or patch isolation, suggesting that they were unaffected by forest fragmentation. A generalist species generally associated with habitat edges, the African Dusky Flycatcher *Muscicapa adusta*, was encountered once in a small forest. Woodland species such as Retz's Helmet-Shrike *Prionops retzii* were found once in a small patch and the Chinspot Batis *Batis molitor* was present in one small and one medium patch.

Discussion

The birds associated with sand forests in the MSR seem to react in a similar way to forest fragmentation as birds and other taxa do elsewhere (reviewed by Debinski and Holt 2000). Bird abundances, of both the entire community and forest specialists specifically, decreased with increased patch isolation. Moreover, abundances of both the entire bird community and forest specialists were negatively correlated with the combined reduction in patch size and increase in patch isolation. In other words, small and medium forest patches far from large forests had significantly fewer birds than small and medium forest patches close to continuous forests. Continuous sand forests may therefore act as source areas, and so maintain the bird communities of small and medium sand forest patches. However, the ability of large forests to maintain the bird community of small and medium forests is severely impaired at distances of greater than 250m (as a minimum threshold) between forest patches.

Several studies have indicated that the consequences of habitat fragmentation are species-specific. Thus, specific

Table 2: Coefficients of determination for the relationships between forest patch size, between forest patch isolation, and between forest patch size and isolation combined ($n = 12$ forest patches), and species richness and abundance using all bird species recorded, and only those considered to be forest specialists and generalists. Significant values are indicated in bold text

Community variable	All species			Forest specialists			Generalists		
	r	F ^{1,11}	p	r	F ^{1,11}	p	r	F ^{1,11}	p
<i>Influence of patch size</i>									
Species richness	-0.087	0.762	0.788	0.324	1.170	0.305	0.158	0.255	0.625
Abundance	-0.001	0.000	0.998	0.129	0.170	0.689	0.022	0.005	0.945
<i>Influence of patch isolation</i>									
Species richness	-0.469	2.826	0.124	-0.439	2.385	0.154	0.099	0.099	0.760
Abundance	-0.808	18.766	0.002	-0.696	9.380	0.012	0.452	2.573	0.140
<i>Influence of patch size and isolation</i>									
Species richness	-0.611	2.679	0.122	-0.452	1.158	0.357	0.158	0.255	0.625
Abundance	-0.949	40.707	<0.001	-0.749	5.732	0.025	0.022	0.005	0.945

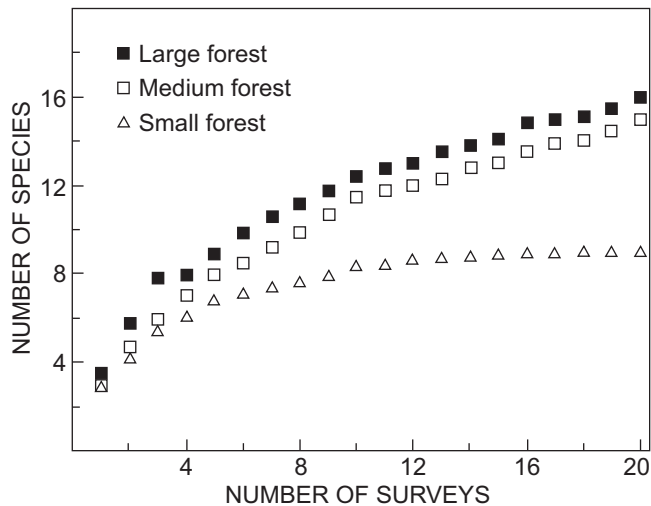


Figure 2: Bird species accumulation curves in large, medium and small forest patches in the Maputo Special Reserve, Mozambique

habitat needs (e.g. for breeding or feeding), large territory requirements, high energy demands, and poor dispersal abilities over non-forest habitat areas (Stouffer and Bierregaard 1995, Stratford and Stouffer 1999, Beier *et al.* 2002) render some species, notably forest specialists, more sensitive to fragmentation than others. Predictably, several forest specialists in our study, especially large-bodied frugivores such as Livingstone's Turaco and the Trumpeter Hornbill (see also Owens and Bennett 2000), were sensitive to forest fragmentation. Notably, various woodland species were recorded predominantly in smaller forest patches, suggesting that if fragmentation continues, birds may perceive forest patches as woodlands (i.e. an open canopy habitat). Similarly, several studies suggest that ongoing disturbance of sand forests often results in a more open canopy structure and, over time, the habitat structure resembles a mixed woodland that contains elements of both sand forests and woodland (Matthews *et al.* 2001, Botes *et al.* 2006). The occurrence of the African Dusky Flycatcher (a forest-edge species) in small forests also

suggests that fragmented forest patches may resemble edge habitats. These 'edge habits' have been shown elsewhere to have various negative conservation implications for forest species (e.g. Donovan *et al.* 1997).

An increase in distance between forest patches, as well as a combination of reduced patch size and increased patch isolation had a negative impact on the abundance of birds living in the sand forests. It is not clear, though, why species richness did not decline with reduced patch size and increased distances between patches, which would be the expected result according to the island biogeography theory of MacArthur and Wilson (1967). We offer several explanations. First, due to the short time-scale of our study, we were not able to capture seasonal effects — therefore, summer patterns were not included in the analysis. Second, African birds might be capable of withstanding considerable habitat modification and disturbance (the resilience of the African fauna to human activities has repeatedly been discussed in the context of the low levels of recorded Quaternary extinctions; see MacPhee (1999) and references therein). Third, forest fragmentation may be in its initial stages, enabling the various large sand forests in the area to maintain the bird community (see also Debinski and Holt 2000). Elsewhere, forest birds display a time lag between habitat fragmentation and extinction (Brooks *et al.* 1999). Fourth, the patchy occurrence of forests in the MSR is natural and the birds here may have adapted to overcome some degree of habitat fragmentation. Finally, accumulation curves did not reach an asymptote, suggesting that some species may not have been recorded. These results should therefore be interpreted with caution. Nevertheless, the accumulation curves suggest that bird species richness in medium forests will reach an asymptote earlier than in large or small forests, implying that large forests and small forests hold more species than medium forests. This implication is in agreement with our results, indicating that many forest specialists, that are sensitive to habitat loss, occur in the vicinity of large forests, while many woodland species were recorded within small forests (which resemble woodlands).

In conclusion, increased forest fragmentation, especially the fragmentation of the large forest patches, may ultimately

surpass the threshold of the birds to overcome the negative consequences of forest fragmentation. Large forests will then be unable to maintain the area's bird community, leading to a reduction of species richness in isolated forest patches and, ultimately, to local extinctions. Continued large-scale forest fragmentation in this endemic- and species-rich area is thus reason for concern. In order to ensure the continued persistence of the bird community of the sand forests of the Maputaland Centre of Endemism, urgent measures need to be implemented, to reduce continued forest fragmentation and ensure the maintenance of the area's large forests.

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References

- Beier P, van Drielen M and Kankam BO** 2002. Avifaunal collapse in West African forest fragments. *Conservation Biology* 16: 1097–1111
- Bierregaard RO Jr, Lovejoy TE, Kapos V, Santos AA and Hutchings RW** 1992. The biological dynamics of tropical rainforest fragments. *BioScience* 42: 859–866
- Botes A, McGeoch MA and van Rensburg BJ** 2006. Elephant and human-induced changes to dung beetle (Coleoptera: Scarabaeidae) assemblages in the Maputaland Centre of Endemism. *Biological Conservation* 130: 573–583
- Brooks TM, Pimm SL and Oyugi JO** 1999. Time lag between deforestation and bird extinction in tropical forest fragments. *Conservation Biology* 13: 1140–1150
- Connor EF, Courtney AC and Yoder JM** 2000. Individuals-area relationships: the relationship between animal population density and area. *Ecology* 81: 734–748
- Debinski DM and Holt RD** 2000. A survey and overview of habitat fragmentation experiments. *Conservation Biology* 14: 342–355
- Donovan TM, Jones PW, Annand EM and Thompson FR** 1997. Variation in local-scale edge effects: mechanisms and landscape context. *Ecology* 78: 2064–2075
- Eastman JR** 2001. *IDRISI for Windows, Version 32, Release 2.0*. Clark University, Worcester, Massachusetts
- Geldenhuis CJ and MacDevette DR** 1989. *Conservation status of coastal and montane evergreen forest*. In: Huntley BJ (ed) *Biotic Diversity in Southern Africa: Concepts and Conservation*. Oxford University Press, Cape Town
- Harrison JA, Allan DG, Underhill LG, Herremans M, Tree AJ, Parker V and Brown CJ** (eds) 1997. *The Atlas of Southern African Birds*. BirdLife South Africa, Johannesburg
- Laurance WF, Lovejoy TE, Vasconcelos HL, Bruna EM, Didham RK, Stouffer PC, Gascon C, Bierregaard RO, Laurance SG and Sampaio E** 2002. Ecosystem decay of Amazonian forest fragments: a 22-year investigation. *Conservation Biology* 16: 605–618
- MacArthur RH and Wilson EO** 1967. *The Theory of Island Biogeography*. Princeton University Press, New Jersey
- MacPhee RDE** 1999. *Extinctions in Near Time: Causes, Contexts, and Consequences*. Kluwer Academic, Dordrecht
- Manne LL and Pimm SL** 2001. Beyond eight forms of rarity: which species are threatened and which will be next? *Animal Conservation* 4: 221–229
- Matthews WS, van Wyk AE, van Rooyen N and Botha GA** 2001. Vegetation of the Tembe Elephant Park, Maputaland, South Africa. *South African Journal of Botany* 67: 573–594
- Mittermeier RA, Robles Gil P, Hoffmann M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J and da Fonseca GAB** 2004. *Hotspots Revisited*. CEMEX, Mexico
- Moll EJ** 1977. The vegetation of Maputaland — a preliminary report of the plant communities and their present and future conservation status. *Trees in South Africa* 29: 31–58
- Owens IPE and Bennett PM** 2000. Ecological basis of extinction risk in birds: habitat loss versus human persecution and introduced predators. *Proceedings of the National Academy of Sciences* 97: 12144–12148
- Parker V** 1999. *The Atlas of the Birds of Sul do Save, Southern Mozambique*. Avian Demography Unit and Endangered Wildlife Trust, Cape Town and Johannesburg
- Parker V and de Boer F** 2000. *Birds of the Maputo Special Reserve, Mozambique*. Bright Continent Guide 2. Avian Demography Unit and Endangered Wildlife Trust, Cape Town and Johannesburg
- Renjifo LM** 1999. Composition changes in a sub-andean avifauna after long-term forest fragmentation. *Conservation Biology* 13: 1124–1139
- Scheiner SM** 2004. A mélange of curves — further dialogue about species-area relationships. *Global Ecology and Biogeography* 13: 479–484
- StatSoft Inc.** 2004. *STATISTICA (data analysis software system), Version 6*. Available at www.statsoft.com
- Stouffer PC and Bierregaard RO Jr** 1995. Use of Amazon forest fragments by understory insectivorous birds. *Ecology* 76: 2429–2445
- Stratford JA and Stouffer PC** 1999. Local extinctions of terrestrial insectivorous birds in a fragmented landscape near Manaus, Brazil. *Conservation Biology* 13: 1416–1423
- van Rensburg BJ, Chown SL, van Jaarsveld AS and McGeoch MA** 2000. Spatial variation and biogeography of sand forest avian assemblages in South Africa. *Journal of Biogeography* 27: 1385–1401
- van Wyk AE** 1996. *Biodiversity of the Maputaland Centre*. In: van der Maesen LJG, van der Burgt XM and van Medenbach de Rooy JM (eds) *The Biodiversity in African Savannas*. Kluwer Academic Publishers, Dordrecht
- Watkeys MK, Mason TR and Goodman PS** 1993. The role of geology in the development of Maputaland, South Africa. *Journal of African Earth Science* 16: 205–221

Appendix 1: The number of individuals for each bird species recorded in the three sand forest patch size classes within the Maputo Special Reserve. Species were classified as forest, generalist, or woodland, species, following Harrison *et al.*'s (1997) and Parker's (1999) life history classification

Life history type and species	Sand forest patch size		
	Large	Medium	Small
Forest species			
Grey Sunbird <i>Cyanomitra veroxii</i>	33	30	26
Dark-backed Weaver <i>Ploceus bicolor</i>	16	12	19
Square-tailed Drongo <i>Dicrurus ludwigii</i>	22	11	11
Yellow-bellied Greenbul <i>Chlorocichla flaviventris</i>	12	9	9
Woodward's Batis <i>Batis fratrum</i>	6	6	6
Blue-mantled Crested-Flycatcher <i>Trochocercus cyanomelas</i>	5	5	2
Neergaard's Sunbird <i>Cinnyris neergaardi</i>	1	4	5
Trumpeter Hornbill <i>Bycanistes bucinator</i>	6	-	3
Collared Sunbird <i>Hedydipna collaris</i>	3	-	6
Terrestrial Brownbul <i>Phyllastrephus terrestris</i>	2	4	2
Red-capped Robin-Chat <i>Cossypha natalensis</i>	1	2	4
Olive Sunbird <i>Cyanomitra olivacea</i>	1	-	3
Brown Scrub-Robin <i>Cercotrichas signata</i>	1	2	-
White-starred Robin <i>Pogonocichla stellata</i>	2	-	1
Livingstone Turaco <i>Tauraco livingstonii</i>	3	-	-
Narina Trogon <i>Apaloderma narina</i>	1	-	1
Olive Bush-Shrike <i>Telephorus olivaceus</i>	1	-	1
Grey Cuckooshrike <i>Coracina caesia</i>	-	-	1
Generalist species			
Yellow-breasted Apalis <i>Apalis flavida</i>	10	6	6
Green-backed Camaroptera <i>Camaroptera brachyura</i>	3	7	6
Black-bellied Starling <i>Lamprotornis corruscus</i>	6	1	5
Sombre Greenbul <i>Andropadus importunus</i>	4	1	5
Black-backed Puffback <i>Dryoscopus cubla</i>	3	4	2
Golden-tailed Woodpecker <i>Campethera abingoni</i>	1	2	1
African Paradise-Flycatcher <i>Terpsiphone viridis</i>	-	3	-
Black-headed Oriole <i>Oriolus larvatus</i>	1	-	1
African Dusky Flycatcher <i>Muscicapa adusta</i>	-	-	1
Woodland species			
Retz' Helmet-Shrike <i>Prionops retzii</i>	-	-	6
Chinspot Batis <i>Batis molitor</i>	-	1	5
Dark-capped Bulbul <i>Pycnonotus tricolor</i>	-	2	1
African Yellow White-eye <i>Zoosterops senegalensis</i>	-	2	-
Spectacled Weaver <i>Ploceus ocularis</i>	-	-	2