Can severely fragmented patches of riparian vegetation still be important for arid-land bird diversity?

Article *in* Journal of Arid Environments · December 2008

DOI: 10.1016/j.jaridenv.2008.07.014

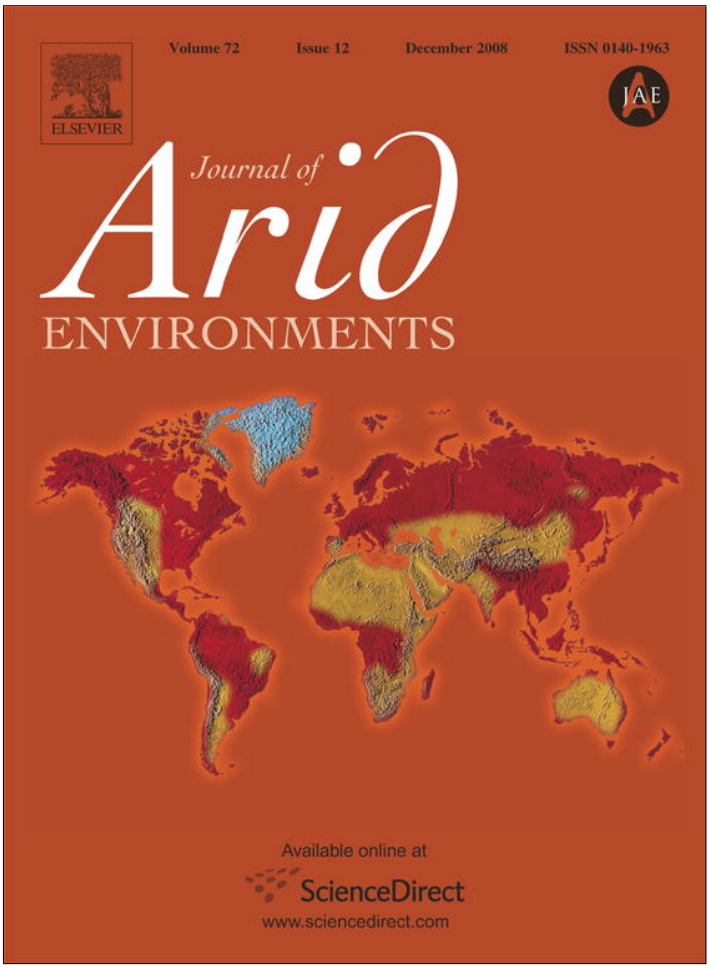
CITATIONS
15

READS
79

2 authors:

Colleen L. Seymour
South African National Biodiversity Institute, …
54 PUBLICATIONS **1,430** CITATIONS
SEE PROFILE

Robert Simmons
University of Cape Town
117 PUBLICATIONS **1,378** CITATIONS
SEE PROFILE



Journal of Arid Environments 72 (2008) 2275–2281

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Short Communication

Can severely fragmented patches of riparian vegetation still be important for arid-land bird diversity?

C.L. Seymour [a,*], R.E. Simmons [b]

[a] Applied Biodiversity Research, Kirstenbosch Research Centre, South African National Biodiversity Institute, Private Bag X7, Claremont 7735, South Africa
[b] Percy FitzPatrick Institute, DST/NRF Centre of Excellence, University of Cape Town, Rondebosch 7701, South Africa

ARTICLE INFO

Article history:
Received 12 March 2008
Received in revised form
21 July 2008
Accepted 22 July 2008
Available online 2 September 2008

Keywords:
Arid savanna
Bird assemblages
Diamond mining
Diversity
Fragmentation
Riparian corridor

ABSTRACT

The vegetation of riparian habitats is often distinct from that of the surrounding landscape, thus representing unique habitat for a variety of biota. Although highly mobile, birds often exhibit distinct species assemblages associated with habitat. Therefore, degradation or removal of riparian habitat, particularly in arid environments, may threaten bird diversity. Along the Vaal River, South Africa, mining and agriculture have reduced natural riparian habitat to ca. 9% of its former extent in the Northern Cape Province. We surveyed bird assemblages within intact riparian, savanna and bush-thickened habitats along the Vaal River to ascertain their importance to bird diversity. Avian abundance and species richness did not differ between the three habitats. Species composition of riparian bird assemblages was significantly different to that of savanna and bush-thickened habitats, however, which were not significantly different from each other, and more species were characteristic of riparian habitat (17 species) than bush-thickened (seven species) or savanna (one species) habitats. Of three species reaching the south-western limit of their African distribution, all occurred in riparian habitat. Thus, despite its fragmented nature, the riparian vegetation on the Vaal still supports an important component of avian diversity, and a landscape-level approach is required to manage this relatively rich, arid-land, river.

Natural riparian zones are amongst the most diverse terrestrial habitats on earth, and because they frequently differ significantly in vegetation type from surrounding landscapes, can provide unique habitat for a variety of biota (Naiman et al., 1993). There is some evidence that riparian fringes may also serve as corridors and refugia, particularly in arid environments (Brooke, 1992; Palmer and Bennett, 2006; Simmons and Allan, 2002). We undertook a short-term study of an arid riparian system in South Africa because of the rapid deterioration of this habitat type and the dearth of knowledge of southern African riverbanks as habitat for birds other than wetland species (Allan and Jenkins, 1993; Harrison et al., 1997; Herremans, 1999; Simmons and Allan, 2002). Only one study in southern Africa has assessed riparian woodland birds relative to surrounding savanna areas (Monadjem, 2003, 2005), and found that in comparison to savanna habitats, riparian edges in Swaziland harboured a unique assemblage of birds. This is mirrored by a number of studies across the globe that have found riparian vegetation to support both rich and distinct bird assemblages (Fleishman et al., 2003; Palmer and Bennett, 2006; Woinarski et al., 2000). Yet riparian vegetation is frequently under pressure from other land uses, and the extent of transformation such habitat can sustain before it ceases to be important to bird assemblages is uncertain.

* Corresponding author. Tel.: +27 21 799 8856; fax: +27 21 797 6903.
E-mail address: Seymour@sanbi.org (C.L. Seymour).

0140-1963/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jaridenv.2008.07.014

River terraces on the Vaal River, near Kimberley, South Africa, have been mined for alluvial diamonds since 1867 (Levinson, 1998). Although intensity of use has varied over the years, mining technologies have become increasingly efficient, allowing a far greater scale and intensity of mining than in the past. The threat to biota associated with this land use is potentially negative due to (i) direct disturbance, (ii) removal or degradation of habitat and (iii) fragmentation of the riparian corridor. In addition, small-scale diamond mining operations often lack the financial resources to rehabilitate mined areas, leaving denuded wastelands, which are vulnerable to invasion by non-indigenous plant species including Mesquite (*Prosopis glandulosa*), Mexican Poppy (*Argemone ochroleuca*) and Wild Tobacco (*Nicotiana glauca*) (Anderson, 2002).

Based on SPOT imagery, only ca. 9% of the 702 km of river banks of the 351 km of the Vaal River which flows through the Northern Cape Province remains intact as natural vegetation; the rest comprises agriculture (70%), mining (18%) or human settlement (3%) (Cox, 2008).

We therefore undertook a study to ascertain whether bird assemblages in remaining riparian vegetation differed in (i) species richness and (ii) composition to those of surrounding vegetation, and thus whether this habitat is still important to bird diversity.

Our study took place at Rooipoort Nature Reserve (S 28° 40′; E 24°07′), a Natural Heritage Site that has been managed with conservation goals since the late 1890s. Mean ($\pm$1 SD) annual precipitation at nearby Kimberley is 425($\pm$132) mm/yr (South African Weather Service, 2007). Vegetation at the site is Kimberley Thornveld and Vaalbos Rocky Shrubland, both of which fall into the "least threatened" conservation category (Mucina and Rutherford, 2006), and comprise open savanna characterized by mature *Acacia erioloba* and *Acacia tortilis*, with a grassy layer dominated by *Eragrostis lehmanniana* and a number of *Aristida* spp. In bush-thickened areas, *Acacia mellifera, Rhigozum trichotomum, Grewia flava* and *Tarchonanthus camphoratus* are dominant. The riparian vegetation, intact on the Rooipoort side of the river, but denuded on the opposite bank, is classified as Upper Gariep Alluvial vegetation (Mucina and Rutherford, 2006), and comprises *Acacia karroo*, *Celtis africana*, *Ziziphus mucronata*, and *Combretum erythrophyllum.* There is little understorey vegetation beneath the canopy layer. This vegetation type is listed as "vulnerable", with only 3% within statutory conservation areas (Mucina and Rutherford, 2006).

We carried out 45 intensive 500-m line transect surveys from 12 to 18 November 2007 during early mornings (first light to 11:00) in each of the main habitat types: *Acacia* savanna; bush-thickened areas, and the riparian fringe of the Vaal River. Line transects lasted 40 min and all birds heard and seen within 100 m either side of transects were recorded. We surveyed 25 line transects in open savanna, eight in bush-thickened areas, and 12 transects in riparian habitat. For completeness, we sampled river habitat itself, but birds in, and associated with, the river (e.g. ducks, cormorants, non-terrestrial kingfishers) were excluded from the analyses. Aerial species were included because they are an integral part of the habitat, and their inclusion does not violate assumptions of line transect methods because they are not being flushed and were recorded at first sighting (Bibby et al., 2002).

We compared relative abundance of birds in each habitat type using a Kruskal–Wallis ANOVA by ranks, run in STATISTICA v.8 (StatSoft, 2007).

We compared species density (number of bird species per unit area) and richness (bird species per number of individuals sampled) in each habitat using sample and individual-based rarefaction, owing to uneven sample size (Colwell, 2006; Colwell and Coddington, 1994; Colwell et al., 2004). These analyses were run in EstimateS version 8 (Colwell, 2006). Curves were rarefied to the lowest number of samples recorded to enable valid comparison of species density.

We ascertained if bird assemblages were significantly different between the three habitat types using an analysis of similarities (ANOSIM) (Clarke and Warwick, 1994). We then explored species composition between different habitats using cluster analysis, by constructing a similarity matrix for the bird dataset, using the Bray–Curtis similarity coefficient, sorting the data using group-averaging. Data were square-root transformed to reduce the influence of common and flocking species. An ordination was then performed using multidimensional scaling and the results of the cluster analysis superimposed on the ordination. This exploration of species composition was run in PRIMER v. 5 (Clarke and Gorley, 2001).

We identified species that could be considered "indicators" of each habitat type, using the statistical package PC-Ord (McCune and Mefford, 1999). PC-Ord uses a method developed by Dufrêne and Legendre (1997), which considers a perfect indicator species to be always present in, and exclusive to, that habitat (scoring 100), and a species with no indicator value scoring zero. This method produces "indicator values" for each species in each habitat, and then tests the null hypothesis of no difference between habitats using a Monte Carlo simulation, using 1000 randomizations.

We counted 1783 birds representing 108 species, excluding species directly dependent on the river (Appendix 1). Mean relative bird abundance ($\pm$1 SD) per transect in riparian vegetation was 49.58$\pm$13.97 ($n = 12$), in savanna was 38.29$\pm$20.67 ($n = 24$) and 33.63$\pm$18.93 ($n = 8$) in bush-thickened transects. These abundances were not significantly different between habitats (Kruskal–Wallis test: $H = 5.597$, $p = 0.0609$).

Rarefaction of species densities showed riparian areas had comparable species densities to savanna habitats (61 and 58 for riparian and savanna, respectively), compared to 47 species in bush-thickened areas. Comparison of species richness (i.e. number of species vs. number of individuals sampled) showed no significant differences between the three habitat types, however (Riparian: 45.5; Savanna: 50.65: Bush thickened: 42.60: for 230 individuals).

Riparian bird assemblages were significantly different to those in savannas and bush-thickened areas (ANOSIM: global $R = 0.397$, $p = 0.001$, riparian vs. savanna: $R = 0.58$, $p < 0.01$; riparian vs. bush thickened: $R = 0.956$, $p < 0.01$). Bird

assemblages in bush-thickened areas and savannas were not significantly different to each other, however ($R = -0.188$; $p > 0.05$). The ordination with cluster analysis results superimposed confirmed this separation (Fig. 1).

Indicator species analysis identified 17 bird species significantly characteristic of riparian vegetation, one species characteristic of savanna and seven species significantly characteristic of bush-thickened habitats (Table 1). The highest ranked indicator was the Cape Robin-Chat with an almost perfect score of 95.1 in riparian habitat because it was present and common in all transects there. It scored below 100, however, because it also occurred in three savanna transects. Crimson-breasted Shrike, significantly characteristic of bush-thickened sites, only scored 57.7, because four birds were also recorded at three savanna sites.

At the landscape level, three species—green-winged pytilia (*Pytilia melba*), white-fronted bee-eater (*Merops bullockoides*) and red-billed oxpecker (*Buphagus erythrorhynchus*) all occurred at the south-western limit of their distributions, and all occurred in riparian woodland. The presence of the latter species is likely attributable to a reintroduction of this species to Rooipoort in the 1990s (Anderson et al., 1997).

In our study, the distinct species assemblages within riparian vegetation were consistent with findings elsewhere in southern Africa (Monadjem, 2003, 2005), with riparian habitats having a far higher number of characteristic species than the other two habitats. This emphasizes the importance of riparian habitat for bird conservation. In addition, given that only about 9% of the Vaal River's riparian vegetation in the Northern Cape remains intact (Cox, 2008), it is remarkable that the riparian areas surveyed here still contain comparable numbers of species to the surrounding habitat. Habitat characteristics that pre-dispose riparian vegetation to supporting unique avian assemblages in southern Africa (Monadjem, 2003, this study) and elsewhere (e.g. Lehmkuhl et al., 2007), include the relative complexity of vegetation structure, particularly in arid regions (Gregory et al., 1991), and greater productivity, owing to greater soil moisture and nutrient availability (Naiman and Décamps, 1997). Fleishman et al. (2003) found that while species richness was determined by habitat structure (physiognomy), avian species composition was determined more by habitat species composition (floristics). Here, both vegetation structure and tree species composition differed considerably between the riparian belt (e.g. continuous tall canopy) and the surrounding vegetation (open tall-treed savanna and low thicket), so separating the effects of structure and composition requires further research and perhaps experimentation. Relatively high avian richness in riparian areas may also arise from the reduced predation risk from raptorial birds provided by extensive cover in the mature riverine trees. We recorded only one raptorial species within the riparian woodland (spotted eagle owl (*Bubo africanus*)), and three or more raptors (gabar goshawk (*Melierax gabar*), southern pale chanting goshawk (*Melierax canorus*), steppe buzzard (*Buteo vulpinus*), lesser kestrel (*Falco naumanni*) and secretarybird (*Sagittarius serpentarius*)) in the savanna or bush-thickened areas. Lastly, the riparian edge also offers a more benign microclimate: during this study, temperatures were 3 °C cooler within the shaded riparian woodland relative to immediately outside, near midday. These factors likely explain why riparian bird assemblages are different and diverse at the local level, and why riparian vegetation extends the ranges of some species at the landscape level.

With fragmentation of the continuous canopy of the riparian woodland, not only are some bird species expected to be lost, but there may also be a breakdown in ecological processes like nutrient cycling, flood attenuation and erosion

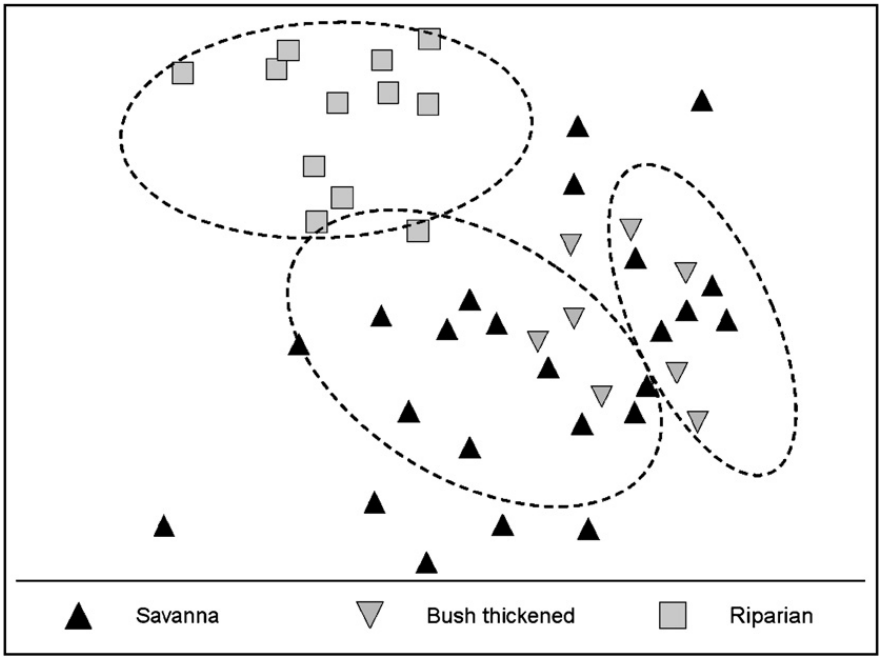


Fig. 1. Ordination representing bird species assemblages in three main habitats in the Rooipoort Reserve, along the Vaal River, South Africa. Broken lines indicate groups of assemblages similar by 40% or more. The stress value for the ordination was 0.22, but imposing the results produced by the cluster analysis confirmed the groupings shown.

Table 1
Indicator values for the top 25 species in each of the three habitats in the Rooipoort Nature Reserve

Riparian	Indicator value	Savanna	Indicator value	Bush thickened	Indicator value
Cape Robin-chat, *Cossypha caffra*	95.1***	Jacobin cuckoo, *Clamator jacobinus*	33.6*	Black-chested prinia, *Prinia flavicans*	59.4**
Southern masked-weaver, *Ploceus velatus*	83.5***	Eastern clapper lark, *Mirafra fasciolata*	28.3	Crimson-breasted shrike, *Laniarius atrococcineus*	57.7***
Orange River white-eye, *Zosterops pallidus*	83.3***	Scaly-feathered finch, *Sporopipes squamifrons*	27.9	White-browed sparrow-weaver, *Plocepasser mahali*	54***
Red-eyed dove, *Streptopelia semitorquata*	56.7***	Fawn-coloured lark, *Calendulauda africanoides*	19.7	Kalahari scrub-robin, *Cercotrichas paean*	47.7*
Southern grey-headed sparrow, *Passer diffusus*	54.4***	Ashy tit *Parus cinerascens*	18.3	Common scimitarbill, *Rhinopomastus cyanomelas*	47.4**
White-fronted bee-eater, *Merops bullockoides*	50**	Desert cisticola, *Cisticola aridulus*	16.7	Red-crested korhaan, *Lophotis ruficrista*	35.3*
Crested barbet, *Trachyphonus vaillantii*	49.4**	Lesser grey shrike, *Lanius minor*	16.7	African black swift, *Apus barbatus*	25*
Diderick cuckoo, *Chrysococcyx caprius*	49.1*	Yellow canary, *Crithagra flaviventris*	16.7	Chestnut-vented tit-babbler, *Parisoma subcaeruleum*	42.9
Cape glossy starling, *Lamprotornis nitens*	47.5*	Barn swallow, *Hirundo rustica*	16.7	Cape turtle-dove, *Streptopelia capicola*	36.5
Hadeda Ibis, *Bostrychia hagedash*	46.2**	Wattled starling, *Creatophora cinerea*	16.1	Neddicky, *Cisticola fulvicapilla*	25
Cape wagtail, *Motacilla capensis*	41.7**	Brubru, *Nilaus afer*	16	Sabota lark, *Calendulauda sabota*	23.7
Golden-tailed woodpecker, *Campethera abingoni*	41.2**	Red-backed shrike, *Lanius collurio*	14.9	Black cuckoo, *Cuculus clamosus*	22.5
Spotted flycatcher, *Muscicapa striata*	39.2*	Cape sparrow, *Passer melanurus*	13.3	Pririt batis, *Batis pririt*	18
Willow warbler, *Phylloscopus trochilus*	38.5*	Black-faced waxbill, *Estrilda erythronotos*	12.5	Brown-crowned tchagra, *Tchagra australis*	17.8
Southern red bishop, *Euplectes orix*	38.2*	Golden-breasted bunting, *Emberiza flaviventris*	12.5	Marico flycatcher, *Bradornis mariquensis*	13.9
Green-winged pytilia, *Pytilia melba*	33.3*	Yellow-bellied eremomela, *Eremomela icteropygialis*	12.5	Rufous-naped lark, *Mirafra Africana*	13.2
Black-throated canary, *Crithagra atrogularis*	28.6*	Stark's lark, *Spizocorys stark*	8.3	Steppe buzzard, *Buteo vulpinus*	12.5
African hoopoe, *Upupa africana*	30.7	African pipit, *Anthus cinnamomeus*	8.3	Crowned lapwing, *Vanellus coronatus*	12.5
European bee-eater, *Merops apiaster*	26.7	Spike-heeled lark, *Chersomanes albofasciata*	8.3	Spotted thick-knee, *Burhinus capensis*	12.5
Swallow-tailed bee-eater, *Merops hirundineus*	20	Capped wheatear, *Oenanthe pileata*	8.3	Lesser kestrel, *Falco naumanni*	12.5
Acacia pied barbet, *Tricholaema leucomelas*	20	Gabar goshawk, *Melierax gabar*	8.3	Southern yellow-billed hornbill, *Tockus leucomelas*	12.5
Spotted eagle-owl, *Bubo africanus*	16.7	Bokmakierie, *Telophorus zeylonus*	8.3	White-backed mousebird, *Colius colius*	8.3
Brown-throated martin, *Riparia paludicola*	16.7	White-throated swallow, *Hirundo albigularis*	8.3	White-rumped swift, *Apus caffer*	8.2
Red-billed oxpecker, *Buphagus erythrorhynchus*	16.7	Namaqua dove, *Oena capensis*	6.9	Rufous-eared warbler, *Malcorus pectoralis*	7.5
Swainson's spurfowl, *Pternistis swainsonii*	16.7	Common fiscal, *Lanius collaris*	5.6	Fork-tailed drongo, *Dicrurus adsimilis*	6.2

Indicator values generated by PC-Ord (McCune and Mefford, 1999) range from 0 to 100, with a species with no indicative value scoring zero. Significance values are as follows:

*** $p < 0.001$.
** $p < 0.01$.
* $p < 0.05$.

control (Beeson and Doyle, 1995). River conditions then become more difficult (e.g. severe flooding, sedimentation) for existing biota and further species loss is expected (Naiman and Décamps, 1997).

Relaxation effects of fragmentation (see review by Debinski and Holt, 2001) may yet be felt. We believe, however, that continued mining and disturbance may influence avian species composition of this dry-land river system, and steps should be taken to preserve the remaining patches, thus enabling the continued existence of a distinct assemblage of birds. Conservation will need to operate at a regional and landscape-level to ensure the continued existence of this habitat type.

We are grateful to De Beers Consolidated Mining for allowing us access to, and accommodation at, Rooipoort. Andrew and Sharon Stainthorpe and Mark and Tania Anderson were generous with advice, hospitality and logistical help. Dave Cox enabled our participation in this project. We are also thankful to Richard Dean, David Eldridge, and two anonymous reviewers, who commented and improved drafts of this manuscript.

Appendix A

Bird species, their mean abundance (and standard deviation, SD), recorded in all habitats in the Rooipoort Nature Reserve, excluding wetland species associated with the river (Table A1). Nomenclature follows Hockey et al. (2005).

Table A1

Common name	Scientific name	Riparian		Savanna		Bush thickened	
		Mean	SD	Mean	SD	Mean	SD
Hamerkop	*Scopus umbretta*	0.25	0.87	0.00	0.00	0.00	0.00
Hadeda Ibis	*Bostrychia hagedash*	1.50	2.15	0.00	0.00	0.13	0.34
Steppe buzzard	*Buteo vulpinus*	0.00	0.00	0.13	0.35	0.00	0.00
Gabar goshawk	*Melierax gabar*	0.00	0.00	0.00	0.00	0.08	0.28
Southern pale chanting goshawk	*Melierax canorus*	0.08	0.29	0.00	0.00	0.04	0.20
Lesser kestrel	*Falco naumanni*	0.00	0.00	0.75	2.12	0.00	0.00
Natal spurfowl	*Pternistis natalensis*	0.00	0.00	0.00	0.00	0.08	0.41
Swainson's spurfowl	*Pternistis swainsonii*	0.17	0.39	0.00	0.00	0.00	0.00
Helmeted guineafowl	*Numida meleagris*	0.50	1.17	0.00	0.00	0.75	3.27
Red-crested korhaan	*Lophotis ruficrista*	0.00	0.00	0.50	0.53	0.21	0.51
Northern black korhaan	*Afrotis afraoides*	0.00	0.00	0.00	0.00	0.04	0.20
Crowned lapwing	*Vanellus coronatus*	0.00	0.00	0.13	0.35	0.00	0.00
Spotted thick-knee	*Burhinus capensis*	0.00	0.00	0.13	0.35	0.00	0.00
Double-banded courser	*Rhinoptilus africanus*	0.00	0.00	0.00	0.00	0.04	0.20
Namaqua sandgrouse	*Pterocles namaqua*	0.08	0.29	0.00	0.00	0.00	0.00
Red-eyed dove	*Streptopelia semitorquata*	1.42	1.78	0.00	0.00	0.04	0.20
Cape turtle-dove	*Streptopelia capicola*	2.83	1.95	3.25	1.83	1.71	1.55
Laughing dove	*Streptopelia senegalensis*	1.08	1.62	0.50	0.93	0.29	0.69
Namaqua dove	*Oena capensis*	0.17	0.58	0.00	0.00	0.21	0.59
African cuckoo	*Cuculus gularis*	0.08	0.29	0.00	0.00	0.04	0.20
Black cuckoo	*Cuculus clamosus*	0.00	0.00	0.75	1.49	0.08	0.28
Jacobin cuckoo	*Clamator jacobinus*	0.08	0.29	0.00	0.00	0.71	1.16
Klaas's cuckoo	*Chrysococcyx klaas*	0.08	0.29	0.00	0.00	0.00	0.00
Diderick cuckoo	*Chrysococcyx caprius*	1.50	1.51	0.25	0.46	0.54	0.83
Spotted eagle-owl	*Bubo africanus*	0.25	0.62	0.00	0.00	0.00	0.00
African black swift	*Apus barbatus*	0.00	0.00	1.50	3.51	0.00	0.00
White-rumped swift	*Apus caffer*	0.00	0.00	1.25	3.54	0.67	3.27
Little swift	*Apus affinis*	0.42	1.16	0.63	1.77	1.00	4.13
White-backed mousebird	*Colius colius*	0.00	0.00	0.25	0.71	0.13	0.61
Red-faced mousebird	*Urocolius indicus*	0.58	1.08	0.50	1.07	0.58	1.47
Brown-hooded kingfisher	*Halcyon albiventris*	0.08	0.29	0.00	0.00	0.04	0.20
European bee-eater	*Merops apiaster*	0.83	1.53	0.00	0.00	0.21	0.72
White-fronted bee-eater	*Merops bullockoides*	1.83	3.19	0.00	0.00	0.00	0.00
Swallow-tailed bee-eater	*Merops hirundineus*	0.33	0.65	0.00	0.00	0.08	0.28
African hoopoe	*Upupa africana*	0.58	0.79	0.00	0.00	0.21	0.51
Green wood-hoopoe	*Phoeniculus purpureus*	0.50	0.80	0.00	0.00	0.00	0.00
Common scimitarbill	*Rhinopomastus cyanomelas*	0.42	0.67	1.00	0.76	0.17	0.38
Southern yellow-billed hornbill	*Tockus leucomelas*	0.00	0.00	0.13	0.35	0.00	0.00
Acacia pied barbet	*Tricholaema leucomelas*	0.50	0.67	0.25	0.71	0.29	0.55
Crested barbet	*Trachyphonus vaillantii*	0.92	0.90	0.00	0.00	0.17	0.48
Greater honeyguide	*Indicator indicator*	0.08	0.29	0.00	0.00	0.04	0.20
Golden-tailed woodpecker	*Campethera abingoni*	0.58	0.67	0.13	0.35	0.00	0.00
Cardinal woodpecker	*Dendropicos fuscescens*	0.08	0.29	0.00	0.00	0.00	0.00
Rufous-naped lark	*Mirafra africana*	0.00	0.00	0.38	0.74	0.33	0.70
Eastern clapper lark	*Mirafra fasciolata*	0.00	0.00	0.13	0.35	0.71	1.40
Fawn-coloured lark	*Calendulauda africanoides*	0.00	0.00	0.38	0.74	0.54	0.88
Sabota lark	*Calendulauda sabota*	0.08	0.29	0.50	0.76	0.21	0.41
Eastern long-billed lark	*Certhilauda semitorquata*	0.00	0.00	0.00	0.00	0.04	0.20
Spike-heeled lark	*Chersomanes albofasciata*	0.00	0.00	0.00	0.00	0.54	1.98
Stark's lark	*Spizocorys starki*	0.00	0.00	0.00	0.00	0.67	3.06
Barn swallow	*Hirundo rustica*	0.92	1.98	2.00	2.88	1.67	3.40
White-throated swallow	*Hirundo albigularis*	0.00	0.00	0.00	0.00	0.08	0.28
Pearl-breasted swallow	*Hirundo dimidiata*	0.00	0.00	0.00	0.00	0.08	0.41
Red-breasted swallow	*Hirundo semirufa*	0.00	0.00	0.00	0.00	0.04	0.20
Greater striped swallow	*Hirundo cucullata*	0.33	0.89	0.00	0.00	0.25	0.61
Common house-martin	*Delichon urbicum*	0.08	0.29	0.00	0.00	0.00	0.00
Brown-throated martin	*Riparia paludicola*	0.17	0.39	0.00	0.00	0.00	0.00
Fork-tailed drongo	*Dicrurus adsimilis*	0.00	0.00	0.13	0.35	0.13	0.45
Pied crow	*Corvus albus*	0.00	0.00	0.00	0.00	0.04	0.20
Ashy tit	*Parus cinerascens*	0.83	1.11	0.75	1.16	0.92	1.32

Table A1 (*continued*)

Common name	Scientific name	Riparian		Savanna		Bush thickened	
		Mean	SD	Mean	SD	Mean	SD
African red-eyed bulbul	*Pycnonotus nigricans*	1.08	1.51	0.63	1.41	0.46	0.83
Capped wheatear	*Oenanthe pileata*	0.00	0.00	0.00	0.00	0.08	0.28
Ant-eating chat	*Myrmecocichla formicivora*	0.00	0.00	0.00	0.00	0.04	0.20
Cape Robin-chat	*Cossypha caffra*	3.25	1.29	0.00	0.00	0.17	0.48
Kalahari Scrub-Robin	*Cercotrichas paena*	0.25	0.62	2.75	1.58	2.04	1.78
Chestnut-vented tit-babbler	*Parisoma subcaeruleum*	1.50	1.93	3.00	1.51	2.50	1.87
Willow warbler	*Phylloscopus trochilus*	0.50	0.67	0.00	0.00	0.04	0.20
Long-billed crombec	*Sylvietta rufescens*	0.50	0.80	0.25	0.46	0.29	0.81
Yellow-bellied eremomela	*Eremomela icteropygialis*	0.08	0.29	0.13	0.35	0.25	0.68
Desert cisticola	*Cisticola aridulus*	0.00	0.00	0.00	0.00	0.38	1.10
Neddicky	*Cisticola fulvicapilla*	0.25	0.62	0.88	0.99	0.63	0.92
Black-chested prinia	*Prinia flavicans*	0.25	0.62	2.50	2.00	1.46	1.32
Rufous-eared warbler	*Malcorus pectoralis*	0.00	0.00	0.13	0.35	0.08	0.28
Spotted flycatcher	*Muscicapa striata*	0.67	0.98	0.00	0.00	0.04	0.20
Marico flycatcher	*Bradornis mariquensis*	0.00	0.00	0.63	1.19	0.50	1.02
Fiscal flycatcher	*Sigelus silens*	0.58	1.00	0.38	0.74	0.21	0.59
Pririt batis	*Batis pririt*	0.08	0.29	0.50	0.76	0.46	0.83
Cape wagtail	*Motacilla capensis*	0.67	0.89	0.00	0.00	0.00	0.00
African pipit	*Anthus cinnamomeus*	0.00	0.00	0.00	0.00	0.46	1.61
Plain-backed pipit	*Anthus leucophrys*	0.00	0.00	0.00	0.00	0.08	0.41
Buffy pipit	*Anthus vaalensis*	0.00	0.00	0.00	0.00	0.04	0.20
Lesser grey shrike	*Lanius minor*	0.00	0.00	0.00	0.00	0.25	0.61
Common fiscal	*Lanius collaris*	0.08	0.29	0.13	0.35	0.17	0.48
Red-backed shrike	*Lanius collurio*	0.08	0.29	0.00	0.00	0.21	0.41
Crimson-breasted shrike	*Laniarius atrococcineus*	0.00	0.00	1.00	1.07	0.08	0.28
Brubru	*Nilaus afer*	0.17	0.39	0.38	0.74	0.50	0.93
Brown-crowned tchagra	*Tchagra australis*	0.00	0.00	0.38	0.52	0.42	0.78
Bokmakierie	*Telophorus zeylonus*	0.00	0.00	0.00	0.00	0.08	0.28
Pied starling	*Spreo bicolor*	0.17	0.58	0.00	0.00	0.04	0.20
Wattled starling	*Creatophora cinerea*	0.00	0.00	0.13	0.35	3.50	9.90
Cape glossy starling	*Lamprotornis nitens*	1.75	0.97	0.50	0.76	1.13	1.75
Red-billed oxpecker	*Buphagus erythrorhynchus*	0.33	0.78	0.00	0.00	0.00	0.00
Orange River white-eye	*Zosterops pallidus*	2.75	2.60	0.00	0.00	0.00	0.00
White-browed sparrow-weaver	*Plocepasser mahali*	0.00	0.00	1.50	1.07	0.58	1.02
Great sparrow	*Passer motitensis*	0.08	0.29	0.13	0.35	0.08	0.41
Cape sparrow	*Passer melanurus*	0.42	1.16	0.38	0.74	0.67	1.20
Southern grey-headed sparrow	*Passer diffusus*	1.17	1.19	0.00	0.00	0.08	0.41
Scaly-feathered finch	*Sporopipes squamifrons*	0.00	0.00	1.00	1.93	2.92	5.52
Southern masked-weaver	*Ploceus velatus*	5.08	4.34	0.13	0.35	0.38	0.97
Southern red bishop	*Euplectes orix*	3.25	5.79	0.00	0.00	1.00	2.72
Green-winged pytilia	*Pytilia melba*	0.17	0.58	0.00	0.00	0.04	0.20
Red-billed firefinch	*Lagonosticta senegala*	0.17	0.58	0.00	0.00	0.08	0.41
Black-faced waxbill	*Estrilda erythronotos*	0.00	0.00	0.00	0.00	0.17	0.48
Pin-tailed whydah	*Vidua macroura*	0.08	0.29	0.00	0.00	0.00	0.00
Black-throated canary	*Crithagra atrogularis*	1.00	1.65	0.00	0.00	0.17	0.56
Yellow canary	*Crithagra flaviventris*	0.00	0.00	0.13	0.35	0.50	1.47
White-throated canary	*Crithagra albogularis*	0.08	0.29	0.00	0.00	0.00	0.00
Golden-breasted bunting	*Emberiza flaviventris*	0.00	0.00	0.00	0.00	0.17	0.48

References

Allan, D.G., Jenkins, A.R., 1993. A count of waterbirds along a section of the lower Orange River. Bontebok 8, 33–34.

Anderson, T.A., 2002. Reconnaissance botanical survey of three areas selected for bulk sampling on Rooipoort Nature Reserve. De Beers Consolidated Mines, Kimberley, South Africa.

Anderson, M.D., Knight, M.H., Berry, M.P.S., 1997. Restoring the pecking order. Redbilled oxpeckers re-established in the Kimberley area. African Wildlife 51, 13–14.

Beeson, C.E., Doyle, P.F., 1995. Comparison of bank erosion at vegetated and non-vegetated channel bends. Water Resources Bulletin 31, 983–990.

Bibby, C.J., Burgess, N.D., Hill, D.A., Mustoe, S., 2002. Bird Census Techniques, second ed. Academic Press, London.

Brooke, R.K., 1992. The bird community of *Tamarix*-clad drainages, northwestern Karoo, Cape Province. Ostrich 63, 42–43.

Clarke, K.R., Gorley, R.N., 2001. Plymouth Routines in Multivariate Ecological Research (PRIMER). Primer-E Ltd., Plymouth.

Clarke, K.R., Warwick, R.M., 1994. Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. Plymouth Marine Laboratory, Plymouth.

Colwell, R.K., 2006. EstimateS: Statistical Estimation of Species Richness and Shared Species from Samples. Version 8. User's Guide and Application. Published at: 〈http://purl.oclc.org/estimates〉.

Colwell, R.K., Coddington, J.A., 1994. Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society B: Biological Sciences 345, 101–118.

Colwell, R.K., Mao, C.X., Chang, J., 2004. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. Ecology 85, 2717–2727.
Cox, D., 2008. Proposed mining on Rooipoort Nature Reserve. Draft Environmental Impact Assessment Report. Institute of Natural Resources, Pietermaritzburg.
Debinski, D.M., Holt, R.D., 2001. A survey and overview of habitat fragmentation experiments. Conservation Biology 14, 342–355.
Dufrêne, M., Legendre, P., 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67, 345–366.
Fleishman, E., McDonal, N., Mac Nally, R., Murphy, D.D., Walters, J., Floyd, T., 2003. Effects of floristics, physiognomy and non-native vegetation on riparian bird communities in a Mojave Desert watershed. Journal of Animal Ecology 72, 484–490.
Gregory, S.V., Swanson, F.J., McKee, W.A., Cummins, K.W., 1991. An ecosystem perspective of riparian zones. BioScience 41, 540–551.
Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V., Brown, C.J. (Eds.), 1997. The Atlas of Southern African Birds, vols. 1 and 2. BirdLife South Africa, Johannesburg.
Herremans, M., 1999. Waterbird diversity, densities, communities and seasonality in the Kalahari Basin, Botswana. Journal of Arid Environments 43, 319–350.
Hockey, P.A.R., Dean, W.R.J., Ryan, P.G., 2005. Roberts–Birds of Southern Africa, seventh ed. The Trustees of the John Voelcker Bird Book Fund, Cape Town.
Lehmkuhl, J.F., Burger, E.D., Drew, E.K., Lindsey, J.P., Haggard, M., Woodruff, K.Z., 2007. Breeding birds in riparian and upland dry forests of the Cascade Range. Journal of Wildlife Management 71, 2632–2643.
Levinson, A.A., 1998. Diamond sources and their discovery. In: Harlow, G.E. (Ed.), The Nature of Diamonds. Cambridge University Press, Cambridge, UK pp. 72–104.
McCune, B., Mefford, M.J., 1999. Multivariate Analysis of Ecological Data. Version 4.25. MjM Software, Gleneden Beach, OR, USA.
Monadjem, A., 2003. Population densities and community structure of birds in riverine forest in the lowveld of Swaziland. Ostrich 74, 173–180.
Monadjem, A., 2005. Association between avian communities and vegetation structure in a low-lying woodland–savanna ecosystem in Swaziland. Ostrich 76, 45–55.
Mucina, L., Rutherford, M.C., 2006. The Vegetation of South Africa, Lesotho and Swaziland. South African National Biodiversity Institute, Pretoria.
Naiman, R.J., Décamps, H., 1997. The ecology of interfaces: riparian zones. Annual Review of Ecology and Systematics 28, 621–658.
Naiman, R.J., Décamps, H., Pollock, M., 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications 3, 209–212.
Palmer, G.C., Bennett, A.F., 2006. Riparian zones provide for distinct bird assemblages in forest mosaics of South-East Australia. Biological Conservation 130, 447–457.
Simmons, R.E., Allan, D.G., 2002. The Orange River avifauna: abundance, richness and comparisons. Ostrich 73, 92–99.
South African Weather Service. 2007. Rainfall Data for the Kimberley Area, 1960–2007, Pretoria.
StatSoft. 2007. STATISTICA (data analysis software system), version 8 〈www.statsoft.com〉.
Woinarski, J.C.Z., Brock, C., Armstrong, M., Hempel, C., Cheal, D., Brennan, K., 2000. Bird distribution in riparian vegetation in the extensive natural landscape of Australia's tropical savanna: a broad-scale survey and analysis of a distributional data base. Journal of Biogeography 27, 843–868.