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EFFECT OF FARMING AND RAINFALL ON THE SPECIES DIVERSITY, POPULATION DENSITY AND COMMUNITY STRUCTURE OF BIRDS BREEDING IN THE KALAHARI WOODLAND, NE NAMIBIA

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Effect of Farming and Rainfall on the Species Diversity, Population Density and Community Structure of Birds Breeding in the Kalahari Woodland, NE Namibia. Kopij, G. — The line transect method has been employed to assess species diversity, population densities and community structure of birds breeding in a mosaic of Kalahari Woodland and farmland, NE Namibia. The transect, 4.5 km long, was surveyed in 2014 and 2015. The total annual rainfall in 2014 was much higher than in 2015 (427 mm vs. 262 mm). In total, 40 breeding species in 2014, and 46 in 2015 were recorded. Six species were dominant in 2014 (Cape Turtle Dove, Laughing Dove, Emerald-spotted Dove, Blue Waxbill, and White-browed Scrub Robin) and only three species in 2015 (Cape Turtle Dove and Blue Waxbill and Yellow-fronted Canary). Although the cumulative dominance in 2014 almost doubled that in 2015, the Community Index in both years was almost identical. Also diversity indices and evenness index were very similar in both years compared. Granivorous birds were the most numerous feeding guild. Their contribution was similar in 2014 and 2015 (46.7 % vs. 43.4 %). Two other feeding guilds, insectivores and frugivores, comprised together more than 50 % in both years. The number of bird species and species diversity were not influenced by the differential rainfall. However, contrary to expectations, population densities of most bird species (at least the more numerous ones) were higher in the year with lower than in the year with higher rainfall. The number of species and species diversity was similar in the farmland and in neighbouring Kalahari Woodland in a pristine stage. However, population densities of most species were lower in the farmland than in the pristine woodland.
Key words: community ecology, population density, agroecosystems, birds, feeding & nesting guilds, Kalahari.

Introduction

Throughout the world, agriculture development poses the prime threat to the biodiversity. Both the spread of agricultural lands and the intensification of agriculture production play main role in this regard (Soderstrom et al., 2003; Bolwig et al., 2006). The spread of agricultural land is always at the expense of natural habitats, which are destructed, fragmented or degraded. Agricultural development is, however, essential for food production and with the increase of human population, agriculture expands and is intensified. However, it is also in the interest of human development to mitigate the negative effects of agricultural development on the environment. Agro-ecosystems can be managed in environment-friendly way where crop and animal production is well-balanced with ecological processes. Studies on bio-indicators may show how well the agroecosystem is harmonized.

Birds are some of the best and most sensitive bio-indicators of agroecosystem quality (Sutherland, 1996; Mulwa et al., 2012). They may indicate both the extent of damage to the natural environment and the direction of the negative changes. African agro-ecosystems are especially good for such studies, as they are often converted from savannah or forest ecosystems, which are characterised by rich and diverse avifauna (Moreau, 1966; Waltert et al., 2005).

In Africa, studies on avian assemblages in agroecosystems have been so far conducted in the Highveld Grassland, South Africa (Kopij, 1998, 2006); Highveld Grassland, Lesotho (Kopij, 2018); Fynbos, South Africa (Mangnall & Crowe, 2003); Bushveld, South Africa (Ratcliffe &Crowe, 2001); Mopane Savanna, Namibia (Kopij, 2013, 2015); moist savannah, West Africa (Humle, 2007; Sogah, 2012); and forests of East Africa (Waltert et al., 2005; Mulwa et al., 2012; Nalwanga et al., 2012; Nadng'and'a et al., 2013; Bolwing et al., 2006).

At present, large portions of the Kalahari Woodland are converted into cultivated fields or pastures for livestock in Namibia. In this study, an attempt is made to assess the population densities and community structure of birds breeding in a farmland recently converted from the Kalahari Woodland, and to compare the parameters with those from the neighbouring pristine Kalahari Woodland. In addition, the parameters are compared between two successive years with different rainfall, as to assess the impact of rainfall on the avian community.

Methods

The transect line method (Sutherland 1996; Bibby et al. 2012) has been employed in this study to assess the population density and dominance structure of breeding birds. A transect 4.5 km long has been designed. The transect was situated amidst a mosaic of farmland and woodland. The farmland was dominated by maize and sorghum cultivations, while the woodland was represented by Zambezian *Baikiaea* vegetation (Kopij, 2017), a subset of the Kalahari Woodland (Mendelsohn et al., 2009).

Fig. 1. The location of the transect (indicated with red arrow).

The transect was located about 7 km W of Katima Mulilo, eastern part of the Zambezi Region, Namibia (fig. 1). It has been divided into three sections: A: running from S 17°33'91" E 24°13'23" to S 17°33'20", E 24°12'45", 2.1 km; B: running from S 17°33'20", E 24°12'45" to S 17°32'09", E 24°12'03", 1.4 km; C: running from S 17°32'09", E 24°12'03" to S 17°32'42", E 24°12'44", 1.0 km. The sections differed with the degree of the natural woodland transformation into farmland. The most transformed was the section B, the least — section C. Each section was surveyed once in 2014 (23 April) and once in 2015 (26 April). The total amount of rainfall in 2014 (427 mm) was much higher than in 2015 (261.6 mm) (fig. 2).

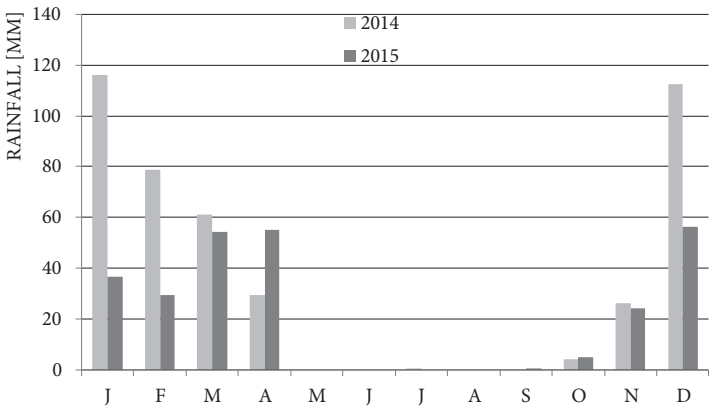

Fig. 2. Monthly rainfall in Katima Mulilo in 2014 and 2015.

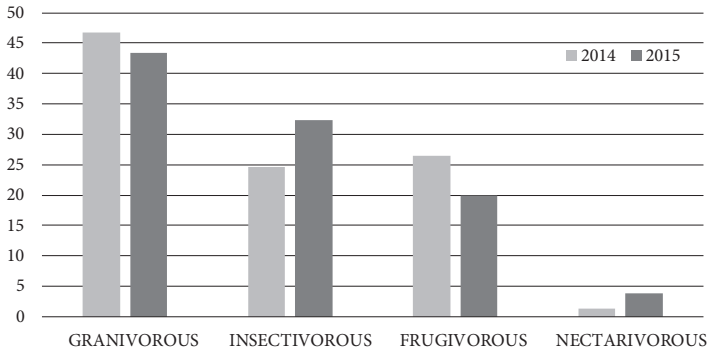

Fig. 3. Percentage of main feeding guilds in 2014 and 2015.

The dominance of particular bird species is expressed as the percentage of the total number of pairs of this species in relation to the total number of all pairs of all species recorded. A dominant species is defined as that comprising 5 % and more of all pairs of all species recorded, while subdominant — that comprising 2–4.99 %.

The following guilds were distinguished:

- Diet: G — granivorous, I — insectivorous, F — frugivorous, N — nectarivorous. but nectarivorous are in fig. 3.
- Nesting: TS — in trees or shrubs, H — in holes, F — herbaceous vegetation, G — on the ground.

The following indices were used to characterise the diversity, evenness and similarity of the communities:

- Shannon's diversity index: $H' = -\Sigma\, p_i \ln p_{i,}$

where: p_i is the proportion of breeding pairs belonging to the *i*th species

- Simpson's diversity index: $D = ((\Sigma n(n-1))/N(N-1)$,

where: n — the total number of breeding pairs belonging to a given species, N — the total number of breeding pairs of all species.

- Pielou's evenness index: $J' = (-\Sigma\, p_i \ln p_i)/\ln S$,

where p_i is the proportion of breeding pairs belonging to the *i*th species; S — the total number of species. J' varies between 0 and 1. The less variation between species in a community, the higher J' is.

- Community dominance index: $DI = (n_1 + n_2)/N$,

where n_1, n_2 — the number of pairs of two most abundant species, N — the total number of pairs of all species.

- Sörensen's Coefficient: I = 2C/A+B,

where A — the number of bird species in one plot, B — the number of bird species in another plot, C — the number of bird species common to both plots.

Systematics and nomenclature of bird species follow Hockey et al. (2005). Scientific names of bird species are listed in App. 1.

Results and discussion

In total, 51 bird species were recorded in both years, 40 in 2014, and 46 in 2015 (App. 1). Although in the neighbouring pristine Kalahari Woodland (Kopij 2017), the total number of species on all transects was much higher (n = 88), the number ranged from 35 to 53 on particular transects. Also the Simpson's Diversity Index was very similar in the farmland mixed with wood (0.94–0.95) and in the pristine wood (0.95–0.97).

Six species were dominant in the study area in 2014: Cape Turtle Dove, Laughing Dove, Emerald-spotted Dove, Blue Waxbill, and White-browed Scrub Robin. Two of them, namely the Cape Turtle Dove and Blue Waxbill dominated also in 2015. However, there were only three dominant species in 2015. The only dominant species in 2015 other than those recorded in 2014 was, unexpectedly, the Yellow-fronted Canary (app. 1). The cumulative dominance in 2014 almost doubled that in 2015.

The Community Index in both years was almost identical (table 1). Also diversity indices and evenness index were very similar in both years compared (table 1). Despite this, the Sörensen Index of Similarity between 2014 and 2015 was only I = 0.58.

In the neighbouring Kalahari Woodland in a pristine stage (Kopij, 2017), the average number of species per transect was 43, while the mean number of dominant species per transect was 3.8, and mean cumulative dominance was 28.5 %. There was only one dominant species, the Cape Turtle Dove, if data from all transects are pooled (Kopij, 2017).

Overall population density was higher in 2015 than in 2014. Population densities of the Blue Waxbill (x^2 test, $x^2 = 3.79$, $p < 0.05$), and Grey Go-away-bird ($x^2 = 5.50$, $p < 0.05$) were found statistically different between 2014 and 2015; while there was no statistical inter-annual difference in the numbers of the Cape Turtle Dove ($x^2 = 0.92$, $p > 0.05$), Emerald-spotted Dove ($x^2 = 2.33$, $p > 0.05$), Fork-tailed Drongo ($x^2 = 0.09$, $p > 0.05$), White-browed Scrub Robin ($x^2 = 0.03$, $p > 0.05$), and Yellow-fronted Canary ($x^2 = 0.00$, $p > 0.05$).

Although the overall density of birds was similar in the farmland and in the pristine woodland, more numerous bird species (at least 1 pair per 1 km) bred in a lower density in the farmland than in the neighbouring pristine woodland (table 2). Among 37 such species, only 10 reached the density higher in the farmland than in the pristine woodland, and only the Blue Waxbill and the Laughing Dove appeared to be much more numerous in the farmland than in the pristine woodland.

Granivorous birds were the most numerous feeding guild in the farmland. Their contribution was similar in 2014 and 2015 (46.7 % vs. 43.4 %). Two other feeding guilds, insectivores and frugivores, comprised together more than 50% in both years. While in 2014 the proportion of both guilds was almost equal, in 2015 insectivores were more numerous than granivores (fig. 3). The proportion of main nesting guilds in 2014 and 2015 remained similar (fig. 4). In the pristine Kalahari Woodland (Kopij, 2017), insectivores contributed

Table 1. Characterisation of breeding bird community in 2014 and 2015

Parameter	2014	2015
Number of species and pairs		
Number of species	46	40
Number of breeding pairs	154	183
Overall density (pairs/km)	34.2	40.9
Dominance		
Number of dominant species	5	2
Cumulative dominance (%)	49.7	26.1
Community dominance (DI)	0.22	0.26
Indices		
Shannon's Diversity Index (H')	3.06	3.17
Simpson's Diversity Index (D)	0.94	0.95
Pielou's Evenness Index (J')	0.86	0.86

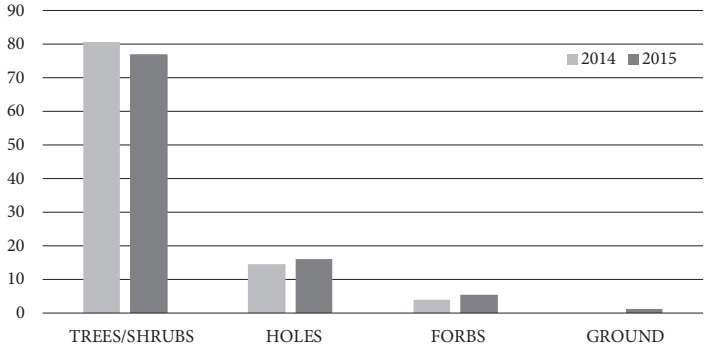

Fig. 4. Percentage of main nesting guilds in 2014 and 2015.

to the total density much higher (51.1 %), while granivorous much lower proportion (26.2 %) than in the farmland. In the pristine Kalahari Woodland tree/shrub nesting guild comprised 63.9 %, while the hole-nesting guild accounted for 28.0 % (Kopij, 2017).

The number of species and species diversity was therefore similar in a farmland mixed with the Kalahari Woodland and in woodland in a pristine stage. However, population densities of most species were lower in the transformed than in the pristine woodland. In the transformed woodland, the number of bird species and species diversity are not

Table 2. Comparison of population densities (pairs per 1 km) of more numerous birds species (> 1 pair per 1 km) in the pristine Kalahari Woodland (Kopij 2017) and in a neighbouring farmland (this study)

Species	Woodland (12 km)	Farmland (4.5 km)
Cape Turtle Dove	10.7	6.7
Blue Waxbill*	2.7	5.6
Emerald-spotted Dove	4.1	3.1
Yellow-fronted Canary*	1.1	2.9
White-browed Scrub Robin	4.8	2.2
Laughing Dove*	0.0	2.0
Green Wood Hoopoe*	0.8	1.6
Meyer's Parrot*	0.6	1.6
Yellow-billed Hornbill*	0.3	1.6
Fork-tailed Drongo	4.8	1.3
Chinspot Batis	2.7	1.3
Red-eyed Dove*	0.8	1.3
Grey Go-away-bird*	0.1	1.3
Grey-backed Camaroptera*	0.0	1.3
Swamp Boubou	4.3	1.1
Yellow-bellied Bulbul	1.4	1.1
Crested Francolin*	0.6	1.1
Cape Starling	**3.5**	0.9
African Grey Hornbill	3.0	0.9
Crimson-breasted Shrike	1.1	0.9
Black-chested Prinia	3.8	0.7
Arrow-marked Babbler	1.8	0.7
Black-backed Puffback	1.6	0.7
Dark-caped Bulbul	1.6	0.7
Brown-headed Tchagra	1.6	0.7
Rattling Cisticola	1.3	0.7
Cardinal Woodpecker	1.1	0.6
Southern Black Tit	2.1	0.2
Brubru	2.1	0.2
Grey-headed Sparrow	1.0	0.2
African Hoopoe	3.8	0.0
Yellow-bellied Apalis	3.0	0.0
Southern Masked Weaver	2.4	0.0
Long-billed Crombec	1.8	0.0
Helmeted Guineafowl	1.7	0.0
White-bellied Sunbird	1.3	0.0
Striped Kingfisher	1.1	0.0

*Species marked with an asterisk are those with the densities lower ($p < 0.05$) in the pristine Kalahari Woodland than in the neighbouring farmland.

influenced by the differential rainfall. However, contrary to expectations, population densities of most bird species (at least the more numerous ones) were higher in the year with lower than in the year with higher rainfall.

Appendix 1. Avian community in two consecutive years in the Kalahari Woodland converted to a farmland. Explanations: n — number of breeding pairs, d — density (pairs per 1 km), % d — dominance

Species	2014						2015					
	Transects			Total			Transects			Total		
	A	B	C	n	d	%d	A	B	C	n	d	% d
Acacia Pied Barbet, *Tricholaema leucomelas*	0	1	0	1	0.2	0.6	0	0	0	0	0.0	0.0
African Golden Oriole, *Oriolus auratus*	0	1	0	1	0.2	0.6	0	0	0	0	0.0	0.0
African Grey Hornbill, *Lophoceros nasutus*	3	0	1	4	0.9	2.6	2	1	1	4	0.9	2.2
Arrow-marked Babbler, *Turdoides jardineii*	3	0	0	3	0.7	1.9	0	0	0	0	0.0	0.0
Bearded Woodpecker, *Dendropicos namaquus*	0	0	0	0	0.0	0.0	2	1	0	3	0.7	1.6
Black-backed Puffback, *Dryoscopus cubla*	2	1	0	3	0.7	1.9	0	1	0	1	0.2	0.5
Black-chested Prinia, *Prinia flavicans*	0	0	0	0	0.0	0.0	2	0	0	2	0.4	1.1
Blue Waxbill, *Uraeginthus angolensis*	7	3	3	13	2.9	8.4	16	6	3	25	5.6	13.6
Bradfield's Hornbill, *Lophoceros bradfieldi*	0	0	0	0	0.0	0.0	1	0	0	1	0.2	0.5
Brown-crowned Tchagra, *Tchagra australis*	0	0	0	0	0.0	0.0	0	2	1	3	0.7	1.6
Brubru, *Nilaus afer*	1	0	0	1	0.2	0.6	1	0	0	1	0.2	0.5
Burchell's Starling, *Lamprotornis australis*	1	0	0	1	0.2	0.6	0	0	0	0	0.0	0.0
Cape Starling, *Lamprotornis nitens*	1	3	0	4	0.9	2.6	3	1	0	4	0.9	2.2
Cape Turtle Dove, *Streptopelia capicola*	17	8	5	30	6.7	19.5	14	8	1	23	5.1	12.5
Cardinal Woodpecker, *Dendropicos fuscescens*	0	1	0	1	0.2	0.6	0	0	0	0	0.0	0.0
Chinspot Batis, *Batis molitor*	1	1	0	2	0.4	1.3	3	1	2	6	1.3	3.3
Cisticola, *Cisticola* sp.	0	0	0	0	0.0	0.0	1	0	0	1	0.2	0.5
Crested Francolin, *Peliperdix coqui*	0	0	0	0	0.0	0.0	1	1	0	2	0.4	1.1
Crimson-breasted Shrike, *Laniarius atrococcineus*	2	1	1	4	0.9	2.6	2	1	1	4	0.9	2.2
Dark-capped Bulbul, *Pycnonotus tricolor*	2	0	0	2	0.4	1.3	2	1	0	3	0.7	1.6
Emerald-spotted Dove, *Turtur chalcospilos*	8	2	4	14	3.1	9.1	6	1	0	7	1.6	3.8
Fork-tailed Drongo, *Dicrurus adsimilis*	4	1	0	5	1.1	3.2	3	3	0	6	1.3	3.3
Golden-tailed Woodpecker, *Campethera abingoni*	1	0	0	1	0.2	0.6	0	0	0	0	0.0	0.0
Green Wood Hoopoe, *Phoeniculus purpureus*	0	0	0	0	0.0	0.0	2	5	0	7	1.6	3.8
Grey Go-away-bird, *Corithaixoides concolor*	4	2	0	6	1.3	3.9	3	2	0	5	1.1	2.7
Grey-backed, Camararoptera, *Camaroptera brevicaudata*	1	0	1	2	0.4	1.3	4	1	1	6	1.3	3.3
Jacobin Cuckoo, *Clamator jacobinus*	0	1	0	1	0.2	0.6	0	0	0	0	0.0	0.0
Laughing Dove, *Streptopelia senegalensis*	7	1	1	9	2.0	5.8	1	2	0	3	0.7	1.6
Lilac-breasted Roller, *Coracias caudatus*	1	2	0	3	0.7	1.9	2	1	0	3	0.7	1.6
Magpie Shrike, *Urolestes melanoleucus*	2	0	1	3	0.7	1.9	1	2	0	3	0.7	1.6
Marico Flycatcher, *Melaenornis mariquensis*	0	0	0	0	0.0	0.0	1	0	1	2	0.4	1.1
Meyer's Parrot, *Poicephalus meyeri*	3	3	1	7	1.6	4.5	2	1	0	3	0.7	1.6
Orange-breasted Bushshr, *Chlorophoneus sulfureopectus*	1	0	0	1	0.2	0.6	0	1	1	2	0.4	1.1
Purple Roller, *Coracias naevius*	0	0	0	0	0.0	0.0	0	1	0	1	0.2	0.5
Rattling Cisticola, *Cisticola chiniana*	2	1	0	3	0.7	1.9	1	0	0	1	0.2	0.5
Red-eyed Dove, *Streptopelia semitorquata*	2	2	2	6	1.3	3.9	3	0	0	3	0.7	1.6

Senegal Coucal, *Centropus senegalensis*	1	0	0	1	0.2	0.6	0	0	0	0	0.0	0.0
Southern Black Tit, *Melaniparus niger*	0	0	0	0	0.0	0.0	1	0	0	1	0.2	0.5
Southern Grey-headed Sparrow, *Passer diffusus*	0	0	0	0	0.0	0.0	0	1	0	1	0.2	0.5
Southern Yellow-billed Hornbill, *Tockus leucomelas*	0	0	1	1	0.2	0.6	0	0	0	0	0.0	0.0
Sunbirds Nectarinidae	2	0	0	2	0.4	1.3	3	0	4	7	1.6	3.8
Swamp Boubou, *Laniarius bicolor*	1	1	1	3	0.7	1.9	4	0	1	5	1.1	2.7
Terrestrial Bulbul, *Phyllastrephus terrestris*	2	0	1	3	0.7	1.9	2	0	1	3	0.7	1.6
Yellow-bellied Greenbul, *Chlorocichla flaviventris*	2	0	0	2	0.4	1.3	5	0	0	5	1.1	2.7
Yellow-fronted Canary, *Crithagra mozambica*	0	0	0	0	0.0	0.0	10	0	3	13	2.9	7.1
Yellow-fronted Tinkerbird, *Pogoniulus chrysoconus*	0	0	0	0	0.0	0.0	0	1	0	1	0.2	0.5
Violet-backed Starling, *Cinnyricinclus leucogaster*	0	0	0	0	0.0	0.0	1	0	0	1	0.2	0.5
Violet-eared Waxbill, *Granatina granatina*	0	0	0	0	0.0	0.0	1	1	0	2	0.4	1.1
White-browed Robin-Chat, *Cossypha heuglini*	6	1	3	10	2.2	6.5	4	4	2	10	2.2	5.4
Zitting Cisticola, *Cisticola juncidis*	0	1	0	1	0.2	0.6	0	0	0	0	0.0	0.0
Total	90	38	26	154	34.2	100	110	51	23	184	40.9	100

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