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EFFECT OF A ROAD ON AVIAN DIVERSITY IN THE KALAHARI WOODLAND

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Abstract. Roads may have negative or positive effects on wildlife. I surveyed birds along a c. 21 km transect alongside a road from Katima Mulilo to Ngoma bridge in the Zambezi Region, north-eastern Namibia, and on a second transect (control) parallel to the first one and 200–400 m away from the road. The habitat is Kalahari Woodland, partly transformed to cultivated fields. The number of bird species was similar on both transects (56 *vs*. 48 species; $x^2 = 0.62$, $p > 0.05$), but the number of breeding pairs (overall population density) was much higher away from the road than close to it (409 *vs*. 283 pairs; $x^2 = 22.9$, $p < 0.01$). The Shannon's Diversity Index was very similar, while Pielou's Evenness Index was identical in both transects compared. Five species (Blue Waxbill, Burchell's Starling, Cape Turtle Dove, Fork-tailed Drongo and Grey-headed Sparrow) were dominant on both transects, while the African Grey Hornbill was dominant only on the transect away from the road, whereas the Red-billed Hornbill and Grey Go-away-bird were dominant only close to the road. Four species (African Grey Hornbill, Cape Turtle Dove, Meyer's Parrot and White-browed Scrub Robin) had population densities significantly higher on the transect away from the road than close to it. However, population densities of nine other species did not differ significantly between the two transects. In general, the avian communities along and away from the road were similar, probably because traffic volume was rather low and the land cover on both transects was similar in terms of natural vegetation and degree of transformation.

INTRODUCTION

Roads are the largest artefacts on the surface of Earth (Brady and Richardson 2017). Around 2010, the global network of public roads was estimated at 50 million km, and it is still growing, especially in Eastern Europe, China and South America (van der Ree et al. 2011). In the last few decades, road ecology, a new sub-discipline of conservation biology, has documented many effects of roads on biodiversity, population densities, behaviour, physiology and other aspects of animal ecology and biology (Forman and Alexander 1998; Forman et al. 2002; Brady and Richardson 2017). The effect is usually negative (Trombulak and Frissell 2000), but roads can in fact offer both ecological costs and benefits (Fahrig and Rytwinski 2009; Underhill and Angold 2011). The negative effects include: habitat loss, habitat fragmentation, pollution (noise, light, and chemicals), increased mortality, spread and dispersal of alien and invasive species, alteration of light, wind and moisture regimes (Trombulak and Fissell 2000; Fahrig and Rytwinski 2009; Parris and Schneider 2009; Underhill and Angold 2011; van der Ree et al. 2011; Rytwinski and Fahrig 2015). However, roads may also play a positive role in the environment: they can cause release from predation (Fahrig and Rytwinski 2009), and in some cases well-planned roads may restore connectivity in an otherwise fragmented landscape (Underhill and Angold 2011).

Most studies in road ecology have focused on the mortality of individuals of particular species, while populations, communities, ecosystems and landscapes have received less attention (Trombulak and Frissell 2000; Bissonette and Rosa 2009; Fahrig and Rytwinski 2009; van der Ree et al. 2011). However, counting road casualties will not indicate whether the roads pose a genuine threat to local populations or entire species, nor will it explain how road networks affect functional relationships within and across ecosystems. To answer these questions (essential for effective nature conservation), long-term studies on the survival, mortality and population dynamics of species occurring in adjacent habitats should be undertaken. An even better approach would be to quantify selected communities within the affected ecosystem.

The purpose of this study was to investigate the effect of a road on species diversity and population density of birds, by counting resident breeding birds on two transects: one running alongside the road and the other

(control transect) parallel to the first one, but a few hundred meters away from it.

METHODS

The American version of the line transect method (Sutherland 1996; Bibby et al. 2012) has been employed in this study. All birds were counted on transects without measuring distances between the observer and a bird, i. e. the transects had no border lines on either side. Two transects, each 21 km long, were set up for this study along the road between Mafuta and Mabiza. One transect ran southwards within about 50 metres from the road, and the second (control) transect ran parallel to and on the right side of the first transect and 200–400 m from the road. The road extends from the Winela Bridge on the Zambezi River near Katima Mulilo to the Ngoma Bridge on the Chobe River, Zambezi Region, Namibia (Figure 1).

Both transects were divided into five sections, about 4 km long each (Figure 1). Birds were counted while walking in the morning by one and the same observer all the time. Observations were aided with 10 × 50 binoculars. Since there is not much seasonal difference in the structure of breeding bird communities in the Kalahari Woodland (Kopij 2017, 2020b, c), birds were counted in each section once in the dry season in 2013 (Table 1). For more precise and less biased results, counts should be repeated and conducted both in the dry and wet season, and over several years. The results obtained in the presented study should be therefore treated as preliminary.

The land cover, composition of natural vegetation and the degree of its human transformation were visually assessed and deemed to be similar on both transects (Figure 1). The natural vegetation represents the Kalahari Woodland. *Terminalia sericea* is the dominant tree species, while *Baikiaea plurijuga*, *Colophospermum mopane*, *Acacia* spp. and other species constitute an admixture. In some places the woody vegetation is fairly dense forming a forest, in others it is sparse with rich grassy undergrowth forming sort of savanna. It is interlaced with shallow flooded areas covered mainly with grasses. It is partly converted to cultivated fields, mainly maize and sorghum, and small human settlements (Figure 2).

Table 1. Location of the transects (in pairs, i.e. for A, B, C, D, E, both the transect close to the road and that away from it are included) and dates of survey.

No.	Co-ordinates (beginning and end)	Date of survey
A	S17.31.95 E24.20.09 – S17.33.23 E24.20.99	06 July 2013
B	S17.33.23 E24.20.99 – S17.35.51 E24.22.53	08 July 2013
C	S17.35.51 E24.22.53 – S17.37.10 E24.23.83	20 July 2013
D	S17.37.10 E24.23.83 – S17.39.02 E24.25.88	28 July 2013
E	S17.39.02 E24.25.88 – S17.40.68 E24.27.49	10 August 2013

Figure 1. Location of the transects: the transect along the road is indicated with a yellow line; the transect away from the road (control) – with a red line. The frame with a white broken line is shown enlarged on the left side. Dark green shows dense natural woody vegetation; grey green – natural sparse woody vegetation; light brown – arable fields with small human settlements.

Figure 2. Natural (left) and partly transformed (right) vegetation on the transect.

Traffic volume was measured by counting the number of vehicles while counting birds along the road. Attention was also given to road collisions; none was however recorded during the counting. The proportion of heavy vehicles was rather low but was not measured.

Dominance was expressed as a percentage of the total number of pairs of a given species in relation to the total number of all pairs of all species recorded on the whole transect. A dominant species was defined as the one comprising 5% or more of all pairs of all species recorded, while subdominant species were considered to be those constituting 2.0–5.0%. The following guilds were distinguished:

A. Diet: G – granivorous, I – insectivorous, F – frugivorous, N – nectarivorous, V – herbivorous, C – carnivorous.

B. Nesting: TS – in trees or shrubs, H – in holes, B – in/on buildings, V – in herbaceous vegetation.

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

1) Shannon's Diversity Index: $H' = -\sum p_i \ln p_i$,

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

2) Pielou's Evenness Index: $J' = (-\sum p_i \ln p_i) / \ln S$,

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

3) Community Dominance Index: $DI = (n_1 + n_2)/N$,

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

4) Sørensen's Coefficient: $I = 2C/A + B$,

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

As recommended for the line transect method (Sutherland 1996; Bibby et al. 2012; Kopij 2016), a pair, not an individual, was a census unit. For each species, the number of pairs on each transect was calculated as a sum of the number of pairs on each section of the transect. For statistical purposes, the sum of all species and counts was calculated for each transect and differences between these values were calculated with a Chi-squared test. Systematics and nomenclature of bird species (Appendix) follow those in Hockey et al. (2005), updated by Chittenden et al. (2016).

RESULTS

In total, 64 bird species were recorded – slightly more away from than along the road (56 *vs*. 48 species; $x^2 = 0.62$, $p > 0.05$). However, the number of breeding pairs (overall population density) was much higher away from the road than close to it (409 *vs*. 283 pairs; $x^2 = 22.9$, $p < 0.01$).

Five species (Blue Waxbill, Burchell's Starling, Cape Turtle Dove, Fork-tailed Drongo and Southern Grey-headed Sparrow) were dominant on both transects, the African Grey Hornbill was dominant only on the transect away from the road, while the Red-billed Hornbill and Grey Go-away-bird were dominant only close to the road (Appendix).

The Shannon's Diversity Index was very similar, while Pielou's Evenness Index was identical in both transects compared (Table 2).

Four species (African Grey Hornbill, Cape Turtle Dove, Meyer's Parrot and White-browed Scrub Robin) had population densities significantly higher on the transect away from the road than close to it. However, population

densities of nine other species did not differ significantly between the two transects (Table 3).

The differences in the proportions of the main feeding and nesting guilds between the assemblage away from the road and the one close to it were not statistically significant (Figures 3 and 4).

DISCUSSION

Animals are affected by roads in different ways, depending on the species and habitat. However, it is important to point out that not all animals are affected by roads negatively. In general, species vulnerable to collisions with cars, e.g. reptiles, amphibians, or large and medium-size mammals, are negatively affected. Species with large territories/home ranges, low reproductive rates and low population density, e.g. carnivores, will also suffer negative effects, whereas species with small territories and high reproductive rates, e.g. small mammals, that are not disturbed by traffic but avoid collisions and whose predators avoid both traffic disturbance and roads, may benefit (Gerland and Bradley 1984; Bellamy et al. 2000; Newmark et al. 2006; Bissonette and Rosa 2009; Fahring and Rytwinski 2009).

Birds are also affected by roads in different ways. Grassland passerines are neutral in this regard (Forman et al. 2002; Fahring and Rytwinski 2009; Lee and Wright 2019). In this study, granivorous birds, most of which are associated with grasses, were equally abundant

Table 2. Characterisation of breeding bird community in a mixed woodland away from the road (A) and along the road (B).

Parameter	A	B
Number of species and pairs		
Number of species	56	48
Number of breeding pairs	409	283
Dominance		
Number of dominant species	6	7
Cumulative dominance (%)	50.8	59.7
Community dominance (DI)	0.23	0.23
Indices		
Shannon's Diversity Index (H')	3.31	3.19
Pielou's Evenness Index (J')	0.82	0.82

Table 3. Number of breeding pairs in a mixed woodland away from the road and along the road.

Species	Away from the road	Along the road	x^2- value	Level of significance
African Grey Hornbill	22	7	7.76	$p < 0.01$
Blue Waxbill	41	36	0.32	$p > 0.05$
Burchell's Starling	41	29	2.06	$p > 0.05$
Cape Turtle Dove	54	25	10.65	$p < 0.01$
Fork-tailed Drongo	25	17	1.52	$p > 0.05$
Green Wood Hoopoe	8	7	0.07	$p > 0.05$
Grey Go-away-bird	14	20	1.06	$p > 0.05$
Southern Grey-headed Sparrow	25	18	0.14	$p > 0.05$
Meyer's Parrot	15	4	6.37	$p < 0.05$
Red-billed Buffalo-Weaver	7	10	0.53	$p > 0.05$
Red-billed Hornbill	15	24	2.08	$p > 0.05$
White-bellied Sunbird	8	7	0.07	$p > 0.05$
White-browed Scrub Robin	19	7	5.54	$p < 0.05$

Figure 3. Proportion of the main feeding guilds on transects close to and far from the road.

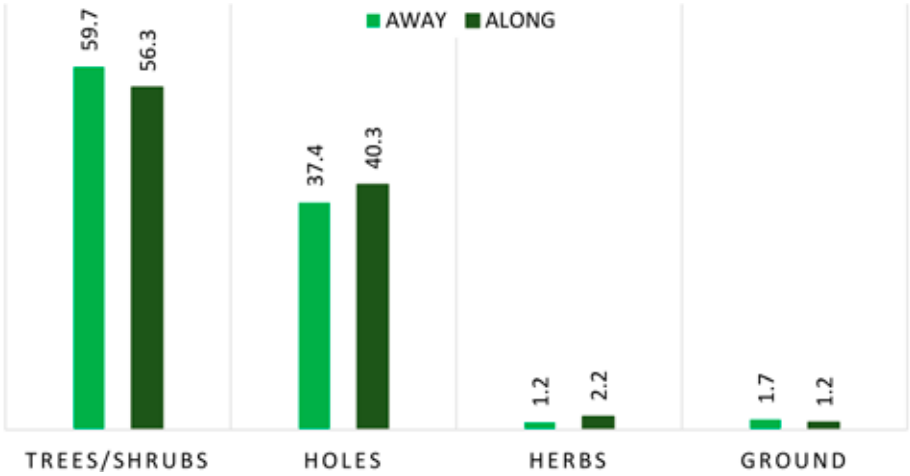

Figure 4. Proportion of the main nesting guilds on transects close to and far from the road.

close to and further from the road (Figure 3, Appendix). Fahring and Rytwinski (2009) have shown that some granivorous birds may even be attracted to roads, probably as a result of spillage from grain transport. In this study, such an effect has not been demonstrated. However, the Cape Turtle Dove and Emerald-spotted Dove, typical granivorous birds, were apparently affected negatively (Table 3), possibly because they are tree-nesting species (Hockey et al. 2005). It is interesting to note that the Laughing Dove, so common in disturbed habitats all over southern Africa (Kopij 2006, 2014a, b, 2019, 2020a, b, c, d), was not recorded at all on either transect (Appendix).

Singing passerines are usually affected negatively because of noise pollution (Rheindt 2003; Parris and Schneider 2009). In southern Africa, many of them rely both on acoustic and visual signs, hence most singing passerines were not affected negatively by the road in this study. The only exception was the White-browed Scrub Robin. It is however a very active singer, mostly dependent on acoustic signals for communication (Hockey et al. 2005).

Large species with extensive territories may be negatively affected by roads. Certainly, they are negatively impacted by urbanization in Africa (Lee et al. 2021). In this study, the group was represented by six raptor species (Appendix). Five such species were recorded away from the road, and only three along it (Appendix), and the overall linear density of raptors was significantly higher away from the road (10 *vs*. 3 pairs). On the other hand, some raptor species may be attracted to roads for food (carcasses), e.g. crows, vultures, and kites. Although not recorded in this study, the Pied Crow *Corvus albus* and Yellow-billed Kite *Milvus aegyptius* are good examples. They are common in northern Namibia, especially in the Cuvelai Drainage system in Ovamboland, north-central Namibia (Kopij 2014a, b), where they are often seen feeding on carcasses of animals (mainly donkeys and sheep) killed by cars on the roads. Despite this, these scavenging birds are seldom hit by vehicles (G. Kopij, pers. observ.).

Large terrestrial birds, such as francolins, guinea fowls and sand grouses may be negatively affected. They may frequently cross the roads, risking collisions with vehicles. However, in this study, only two such species were recorded, the Crested Francolin and Swainson's Spurfowl, which clearly avoided the vicinity of roads (Appendix).

In general, the avian communities along and away from this road in Kalahari Woodland in NE Namibia were similar. This is probably because the road traffic was rather low (1–2 vehicles per 5–10 minutes) and the land cover on transects close to the road (0–50 m) and 200–400 m away from it was similar both in terms of the composition of natural vegetation and degree of its transformation (Figure 1). However, the results are based on single counts by means of the line transect method in the dry season only. They may be biased and not robust statistically. Further studies should be conducted both in the dry and wet seasons, with repeated counts in each season to further elucidate the effect of roads on birds.

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Appendix. Results of bird counting (number of breeding pairs) in a mixed forest on a transect running away from and close to the road. Abbreviations: n – number of breeding pairs, d – linear density (pairs per 10 km), %D – dominance. Dominant species are indicated with bold case.

Species	Transect away from the road								Transect close to the road							
	Transect sections (Table 1)					Total			Transect sections (Table 1)					Total		
	A	B	C	D	E	n	d	%d	A	B	C	D	E	n	d	%d
African Eagle Owl *Bubo africanus*			1			1	0.5	0.2						0	0.0	0.0
African Grey Hornbill *Tockus nasutus*	4	9	4	3	2	22	10.5	**5.4**		3	1	1	2	7	3.3	2.5
African Hawk-Eagle *Hieraaetus fasciatus*	1					1	0.5	0.2						0	0.0	0.0
African Hoopoe *Upupa africana*	2		1		3	6	2.9	1.5					1	1	0.5	0.4
African Pipit *Anthus cinnamomeus*				1		1	0.5	0.2			1			1	0.5	0.4
Arrow-marked Babbler *Turdoides jardineii*	1	3			2	6	2.9	1.5			1		7	8	3.8	2.8
Bateleur *Terathopius ecaudatus*		1	2	1	1	5	2.4	1.2	1		1			2	1.0	0.7
Black-backed Puffback *Dryoscopus cubla*						0	0.0	0.0				1	1	2	1.0	0.7
Black-chested Prinia *Prinia flavicans*	1	1	1	2		5	2.4	1.2		1				1	0.5	0.4
Black-collared Barbet *Lybius torquatus*	1	1				2	1.0	0.5						0	0.0	0.0
Black-crowned Tchagra *Tchagra senegala*	1	1				2	1.0	0.5	1					1	0.5	0.4
Black-eyed Bulbul *Pycnonotus barbatus*		2	1		1	4	1.9	1.0		2			2	4	1.9	1.4
Black-throated Canary *Crithagra atrogularis*	1					1	0.5	0.2						0	0.0	0.0
Blue Waxbill *Uraeginthus angolensis*	14	8	8	6	5	41	19.5	**10.0**	5	7	6	3	15	36	17.1	**12.7**
Brubru *Nilaus afer*			1		1	2	1.0	0.5			1	2	1	4	1.9	1.4
Burchell's Starling *Lamprotornis australis*	2	8	5	20	6	41	19.5	**10.0**	6	4	7	4	8	29	13.8	**10.2**
Cape Starling *Lamprotornis nitens*	1	1				2	1.0	0.5						0	0.0	0.0
Cape Turtle Dove *Streptopelia capicola*	7	11	6	16	14	54	25.7	**13.2**	1	5	4	5	10	25	11.9	**8.8**
Cardinal Woodpecker *Dendropicos fuscescens*				1	1	2	1.0	0.5						0	0.0	0.0
Chin-spot Batis *Batis molitor*	3	1		1		5	2.4	1.2	3					3	1.4	1.1
Common Scimitar *Rhinopomastus cyanomelas*	1					1	0.5	0.2	1				1	2	1.0	0.7
Crested Barbet *Trachyphonus vaillantii*	1			1	3	5	2.4	1.2					1	1	0.5	0.4
Crested Francolin *Francolinus sephaena*		1			1	2	1.0	0.5		1				1	0.5	0.4
Orange-breasted Shrike *Telophorus sulfureopectus*		1				1	0.5	0.2						0	0.0	0.0
Emerald-spotted Dove *Turtur chalcospilos*	2	2	1	1		6	2.9	1.5			1		1	2	1.0	0.7
Fork-tailed Drongo *Dicrurus adsimilis*	7	5	2	7	4	25	11.9	**6.1**	2		7	6	2	17	8.1	**6.0**
Golden-tailed Woodpecker *Campethera abingoni*	1	2		1		4	1.9	1.0					1	1	0.5	0.4
Greater Striped Swallow *Hirundo cucullata*				1	1	2	1.0	0.5						0	0.0	0.0
Green-winged Melba *Pytilia melba*	1				1	2	1.0	0.5	1			1		2	1.0	0.7
Green Wood Hoopoe *Phoeniculus purpureus*			1	6	1	8	3.8	2.0		3	2		2	7	3.3	2.5
Grey Go-away-bird *Corythaixoides concolor*	3	3	3	4	1	14	6.7	3.4	3	1	3	8	5	20	9.5	**7.1**
Southern Grey-headed Sparrow *Passer diffusus*			8	10	7	25	11.9	**6.1**	1	5	1	3	8	18	8.6	**6.4**
Grey Penduline Tit *Anthoscopus caroli*				1		1	0.5	0.2				1		1	0.5	0.4

Species	Transect away from the road								Transect close to the road							
	Transect sections (Table 1)					Total			Transect sections (Table 1)					Total		
	A	B	C	D	E	n	d	%d	A	B	C	D	E	n	d	%d
Ground Hornbill *Bucorvus leadbeateri*						0	0.0	0.0				1		1	0.5	0.4
Groundscraper Thrush *Turdus litsitsirupa*	1					1	0.5	0.2						0	0.0	0.0
Hawk *Accipiter* sp.						0	0.0	0.0				1		1	0.5	0.4
Lesser Striped Swallow *Hirundo abyssinica*	1		3			4	1.9	1.0						0	0.0	0.0
Lilac-breasted Roller *Coracias caudata*		1		2	2	5	2.4	1.2		1	1	1	1	4	1.9	1.4
Lizard Buzzard *Kaupifalco monogrammicus*			1		1	2	1.0	0.5		1				1	0.5	0.4
Long-billed Crombec *Sylvietta rufescens*		1	1	2		4	1.9	1.0				1	2	3	1.4	1.1
Marico Sunbird *Nectarinia mariquensis*	1					1	0.5	0.2	1			1		2	1.0	0.7
Meyer's Parrot *Poicephalus meyeri*	1	7	4	2	1	15	7.1	3.7			2	1	1	4	1.9	1.4
Namaqua Dove *Oena capensis*	1					1	0.5	0,2						0	0.0	0.0
Rattling Cisticola *Cisticola chiniana*						0	0.0	0.0		2	2	1		5	2.4	1.8
Red-billed Buffalo-Weaver *Bubalornis niger*			2	3	2	7	3.3	1.7		5	1	4		10	4.8	3.5
Red-billed Firefinch *Logonosticta senegala*				2		2	1.0	0.5				1		1	0.5	0.4
Red-billed Hornbill *Tockus erythrorhynchus*	1	2	3	6	3	15	7.1	3.7	1	2	9	5	7	24	11.4	**8.5**
Red-billed Oxpecker *Buphagus erythrorhynchus*						0	0.0	0.0				2		2	1.0	0.7
Red-eyed Dove *Streptopelia semitorquata*					1	1	0.5	0.2				1		1	0.5	0.4
Red-faced Mousebird *Urocolius indicus*					4	4	1.9	1.0						0	0.0	0.0
Scarlet-chested Sunbird *Nectarinia senegalensis*						0	0.0	0.0					1	1	0.5	0.4
Southern Black Tit *Parus niger*	1		1			2	1.0	0.5					3	3	1.4	1.1
Southern Masked Weaver *Ploceus velatus*	2	4				6	2.9	1.5		2	2			4	1.9	1.4
Southern Yellow-billed Hornbill *Tockus leucomelas*		1				1	0.5	0.2						0	0.0	0.0
Striped Kingfisher *Halcyon chelicuti*					1	1	0.5	0.2						0	0.0	0.0
Sunbird *Nectarinia* sp.		4				4	1.9	1.0		1				1	0.5	0.4
Swainson's Spurfowl *Pternistis swainsonii*		2	2			4	1.9	1.0					1	1	0.5	0.4
Tawny Eagle *Aquila rapax*	1					1	0.5	0.2						0	0.0	0.0
Tchagra *Tchagra* sp.						0	0.0	0.0				1		1	0.5	0.4
White-bellied Sunbird *Cinnyris talatala*	2		2	1	3	8	3.8	2.0	1		3		3	7	3.3	2.5
White-browed Robin *Cossypha heuglini*						0	0.0	0.0			1	1		2	1.0	0.7
White-browed Scrub Robin *Erythropygia leucophrys*	10	2	2	4	1	19	9.0	4.6		1	3	3		7	3.3	2.5
White-crowned Shrike *Eurocephalus anguitimens*				1		1	0.5	0.2						0	0.0	0.0
Yellow-billed Oxpecker *Buphagus africanus*		1				1	0.5	0.2				1		1	0.5	0.4
Total	77	86	66	106	74	409.0	194.8	100.0	28	47	60	61	87	283.0	134.8	100.0