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Bird population densities along two precipitation gradients in Senegal and Niger

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Summary

Wet season densities of terrestrial birds were estimated along two 300–350 km long N–S precipitation gradients using distance sampling methods. The habitat was farmland that graded into grassland or thornbush savanna towards the north. Species richness was generally higher in Senegal than in Niger, probably due to a higher density of trees. Estimated mean densities (all species combined) varied between 475 and 862 birds per km². The most numerous species were Sudan Golden Sparrow *Passer luteus* in the northern parts of both areas, Village Weaver *Ploceus cucullatus* in S and central Senegal, and Northern Grey-headed Sparrow *Passer griseus* in S Niger. Densities of most species varied in response to precipitation differences, with very few species being evenly distributed along the gradients. In Niger, post-breeding northward displacements of large, grasshopper-eating species (Abdim's Stork *Ciconia abdimii*, Cattle Egret *Bubulcus ibis* and Yellow-billed Kite *Milvus migrans parasiticus*) were detected. Some previously under-recorded lark species were found in good numbers in Niger, where Kordofan Lark *Mirafraga cordofanica* and Dunn's Lark *Eremalauda dunnii* locally occurred at up to 6 and 7.9 birds per 10 ha, respectively. In Senegal, the highest densities of Savile's Bustard *Eupodotis savilei* (up to ten calling males per km²) were found south of 14°N. Large vultures, including Lappet-faced Vulture *Torgos tracheliotus* and White-headed Vulture *Trigonoceps occipitalis*, were recorded at mean densities of 0.51–0.58 per km² in W Senegal but were not found in the study area in Niger.

Résumé

Densités de population d'oiseaux sur deux gradients de précipitations au Sénégal et au Niger. Les densités d'oiseaux terrestres en saison des pluies ont été estimées sur deux gradients N–S de précipitations de 300–350 km de long à l'aide de méthodes d'échantillonnage à distance. L'habitat consistait en terre agricole qui passait en savane herbacée ou épineuse en allant vers le nord. La

richesse spécifique était généralement plus grande au Sénégal qu'au Niger, probablement due à une plus grande densité d'arbres. Les densités moyennes estimées (toutes espèces confondues) variaient de 475 à 862 oiseaux au km². L'espèce la plus abondante était le Moineau doré *Passer luteus* au nord de ces deux zones, le Tisserin gendarme *Ploceus cucullatus* au sud et au centre du Sénégal et le Moineau gris *Passer griseus* au sud Niger. La densité de la plupart des espèces variait selon les différences de précipitations tandis que quelques rares espèces étaient également distribuées le long de ces gradients. Au Niger, des mouvements vers le nord après la reproduction d'espèces acridophages (Cigogne d'Abdim *Ciconia abdimii*, Héron garde-boeuf *Bubulcus ibis* et Milan noir *Milvus migrans parasitus*) ont été notés. Quelques espèces d'alouettes, jusqu'à présent sous-estimées, ont été trouvées en nombre appréciable au Niger, où l'Alouette du Kordofan *Mirafra cordofanica* et l'Alouette de Dunn *Eremalauda dumni* se rencontraient localement et respectivement à raison de 6 et 7,9 oiseaux pour 10 ha. Au Sénégal, les plus fortes densités d'Outarde houpette *Eupodotis savilei* (jusqu'à 10 mâles appelant au km²) ont été trouvées au sud du 14°N. Les grands vautours, y compris le Vautour oricou *Torgos tracheliotus* et le Vautour à tête blanche *Trigonoceps occipitalis*, ont été notés à la densité de 0,51–0,58 au km² dans l'Ouest du Sénégal mais n'ont pas été trouvés dans la zone d'étude au Niger.

Introduction

In 2003 and 2004, wet season counts of terrestrial birds were carried out in W Senegal and S-central Niger. The work was part of the Préliss project (*Projet Régional de Lutte Intégrée contre les Sauteriaux au Sahel*), and the aim was to provide information on population densities of grasshopper-eating birds along two precipitation gradients, each of them 300–350 km long and stretching from the northern part of the Sudan zone into the Sahel. Although the project focused on birds preying on grasshoppers, all species were recorded.

The avifauna of Senegal is fairly well described (Morel & Morel 1990, Sauvage & Rodwell 1998), and bird population densities have been the subject of several studies in the northernmost parts of the country. Monthly counts of resident and migratory birds were carried out at Keur Mor Ibra, SE of Richard Toll, in 1960–2 (Morel 1968) and at Fété Olé 60 km further east in 1969–82 (Morel & Morel 1980 and unpubl.). Close to the former area, Keith & Mullié (1990) performed weekly bird counts in Jul–Oct 1989 as part of a study of impacts of chemical locust and grasshopper control. Densities of Palaearctic migrants have been recorded in the Ferlo Avifaunal Reserves (Ornis Consult 1997) and have also been the subject of a study in SW Mauritania (Browne 1982).

In Niger, little ornithological work has apparently been done outside the SW corner of the country and, to a lesser extent, the Aïr Mountains. The late P. Souvairan performed transect counts year-round in Makalondi district in 1991–3, but the results were never published (J. Brouwer *in litt.*, P. Giraudoux *in litt.*). According to the available information (Giraudoux *et al.* 1988, Holyoak & Seddon 1991a,b, Sauvage 1993, Debout *et al.* 2000, J. Brouwer *in litt.*) large parts of our study areas had not been visited by ornithologists since the 1930s, at least not during the rainy season. Densities of Palearctic passerines have been studied in the Sahel zone of N Nigeria (*e.g.* Jones *et al.* 1996), but data on bird densities and distribution during the rainy season do not seem to exist from this part of W Africa.

The present paper presents an overview of the bird census results. No comprehensive analysis of bird population densities in relation to land use, vegetation structure or previous findings is attempted. However, all census sites were georeferenced, and the full data set is freely available for further scientific analysis (see Methods).

Although our focus was on densities of common birds, five species new to Niger were recorded during the project (Christensen *et al.* 2005, 2006). Also, a number of range extensions and species recorded only a few times in Niger were found. Some of these findings are briefly described. We also include our records and density estimates of vultures and eagles, because dramatic population declines of these species have recently been reported from Mali, Burkina Faso and Niger (Rondeau & Thiollay 2004, Thiollay 2006).

Methods

Census areas

Fig. 1 shows the location of the sites where censuses were performed. The sites were spaced along two precipitation gradients, ranging from 800 to 300 mm per year in Senegal and from 600 to 200–250 mm in Niger. In Senegal, the natural vegetation along most of this gradient is Sudanian wooded savanna and grasslands that pass into Sahelian grassland and thornbush savanna towards the north. In Niger, Sudanian open woodlands are only found south of the 500 mm isohyet, whereas the major part of the gradient lies within the Sahelian zone. Along both gradients the vegetation is heavily modified by human cultivation. The census areas generally consisted of farmland, or mixed grassland and farmland, with scattered villages. The dominant crop is millet (Niger) or millet and groundnuts (Senegal). In the south, small patches of woodland remain, particularly in Senegal, while pastoral grasslands become progressively more frequent towards the north, especially in Niger. A major difference between the two countries is the generally much higher density of trees at the Senegal sites, even within the Sahelian zone, although extensive logging has also occurred here.

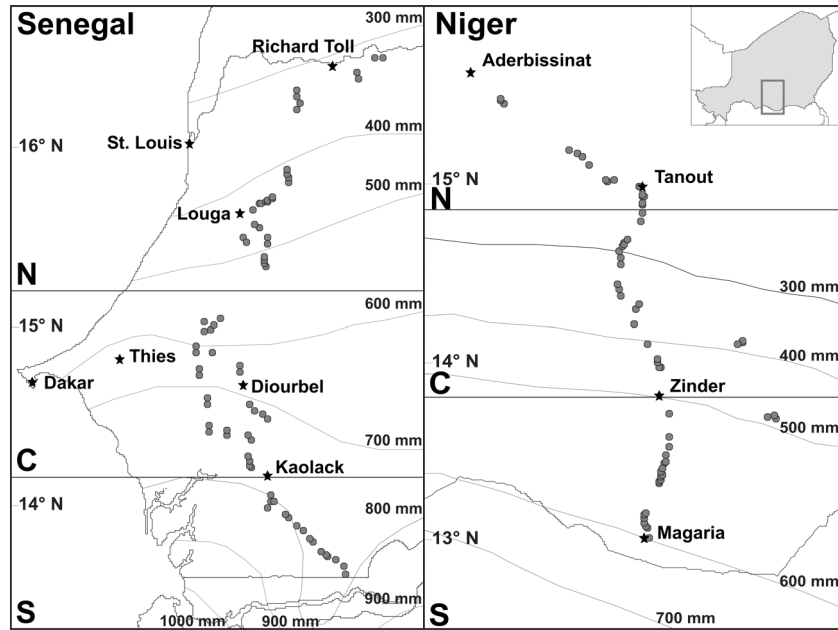


Figure 1. Map of the census areas in Senegal and Niger. Dots show where censuses were performed. Isohyets and the regions used in the data analysis are indicated (N = north, C = central, S = south).

For estimation of mean bird densities, each precipitation gradient was divided into three regions with approximately the same number of censuses (except Senegal S) and the boundaries between regions more or less corresponding to visible changes in land cover/use (cf. above). The Senegal C and Niger S regions were roughly comparable as were Senegal N and Niger C. The Senegal S region, with many large trees, did not compare with anything found along the Niger gradient. Likewise, an area corresponding to the dry, open Niger N did not occur along the Senegal gradient.

Bird counts

Bird counts were performed in 2003 and 2004, between 7 June and 20 September, corresponding to the period of main rainfall. In Senegal, 133 transects were carried out between 30 Jul and 20 Aug 2003, and 143 between 14 Jul and 4 Aug 2004 (total 276). In Niger, there were 80 transects during the period 11–21 Jul 2003, 49 during 14–20 Sep 2003, 128 during 7–24 Jun 2004 and 74 during 29 Aug to 8 Sep 2004 (total 331). Each day, two observers performed censuses independently of each other at different sites. All counts started immediately after sunrise and lasted for 4 h,

except when curtailed because of rain or, in a few cases, excessive heat. The censuses were carried out as line transects, and each morning count session consisted of four line transects of 50 min. duration. End points (start and stop) of all transects were recorded using GPS. The intended walking speed was 1.2 km.h^{-1} , and the average transect length was 1058 m. After finishing each transect, the observer walked briskly along for 8–10 minutes to make successive transects independent of each other.

The starting point for the first transect each morning was randomly selected (as number of km to be driven) along a road traversing the region to be censused. If this point happened to be inside a town or village, the starting point was displaced to *c.* 500 m after the town/village. In order to avoid looking against the sun, the direction of walking as a rule was due west. If this line was blocked by wetlands, villages etc. the observer displaced the line as appropriate to avoid the obstacle, while still recording the birds.

All birds seen or heard perched or on the ground at either side of the line were recorded and assigned to one of seven distance bands (0–25 m, 25–50 m, 50–75 m, 75–100 m, 100–200 m, 200–300 m, 300–400 m). Birds seen or heard more than 400 m off the line were not recorded, as were birds only seen flying, with the exception of birds in song-flight that were assigned to the distance band where they were first discovered. Only birds that could be identified to species were noted. Unidentified sounds were described, assigned to a distance band and later identified to species (if possible) using Chappuis (2000).

These counts were supplemented with snapshot counts of flying raptors (Bibby *et al.* 2000). Snapshot counts were performed at the beginning and in the middle of each transect, and each lasted 1 min.. During the snapshots flying raptors were recorded 400 m to each side and 500 m ahead of the observer so that the two snapshot counts together covered approximately the same area as the line-transect counts.

In addition to the censuses performed along the two gradients (Fig. 1), a number of counts (24 and 30 line transects, respectively) were carried out in Niger in the areas of Tahoua ($14^{\circ}55' \text{N}$, $5^{\circ}15' \text{E}$) and Diffa ($13^{\circ}20' \text{N}$, $12^{\circ}35' \text{E}$) in 2003. Because these counts were performed by the same observers, using the same methods and in a similar landscape as the main counts, they were included in the estimation of species-specific detection probabilities (see below).

Eight different observers took part in the censuses. All of them had previous experience with systematic bird census work and a good knowledge of African birds. To standardize the methodology, harmonize estimation of distances etc., two observers worked together on the first one or two days of each counting period.

Data analysis

Based on the field counts, density estimates were calculated for each bird species. For each of the 37 most abundant species (all species with > 200 records or > 400 recorded individuals), absolute densities were estimated with Distance 4.1 software (Thomas *et al.* 2003) fitting a species-specific detection function model to the distribution of records across distance bands. The probability of detection was

assumed not to differ significantly between regions, so for each species a common detection function was fitted to data from all regions, including the counts from the Tahoua and Diffa areas. Choice of model was performed following the recommendations of Buckland *et al.* (1993) and was mainly based upon a low value of Akaike's Information Criterion and a good visual fit to the distribution of records. In most species a hazard-rate model fitted the data well, but in a few species a half-normal model or a uniform model with cosine series expansion provided a better fit. The computed Effective Strip Width (ESW, the distance where the number of birds overlooked inside the strip equals the number recorded outside the strip) varied between 35 m (*Ploceus luteolus*: see Appendix for English names not mentioned in the text) and 400 m (*Eupodotis savilei* advertisement call) for these 37 species.

For the less numerous species, detection function models were not fitted in Distance and field count data were converted to absolute densities using an estimated ESW. For each of these 195 species, the choice of ESW was based upon similarity to one or more of the 37 abundant species with respect to the distribution of records across distance bands or, in species with few records, similarity in visibility and/or vocal behaviour. The estimated ESWs varied between 25 m (species with almost all records inside the innermost band, *e.g.* Quail-plover *Ortyxelos meiffrenii*, Pearl-spotted Owlet *Glaucidium perlatum*, silent warblers, *Petronia dentata*) and 300 m (species with almost equal distribution of records across distance bands, *e.g.* large raptors).

Densities of flying raptors at each line transect were calculated by dividing the total number of each species seen on the two snapshot counts by the area covered by these counts ($2 \times 0.4 \text{ km}^2$). Raptor density data from line transect counts and snapshot counts were combined by using, for each line transect, the maximum of the two density estimates (in most cases the estimate from the line transect count).

Depending on the species, the number of birds recorded may represent the number of territories or advertising males (*e.g.* *Eupodotis savilei*, singing warblers) or the number of individuals present (*e.g.* *Bubulcus ibis*, *Lamprotornis* starlings) or may fall somewhere in between these two extremes. Given the uncertainties involved, we did not attempt to adjust for these differences.

Taxonomy and nomenclature follow Borrow & Demey (2001).

Data availability

A summarized version of the original data set has been placed on the W.A.O.S. web site at <http://malimbus.free.fr/suppindex.htm>. This data set gives the coordinates of all 607 transects and the number of individuals of each bird species recorded on each, plus the computed or estimated ESWs for all 232 species. More detailed data or density estimates are available for further scientific analysis upon request to the authors.

Sources of bias

The study was designed with the purpose of estimating average densities of common birds during the rainy season in representative areas of farmland and grassland in W

Senegal and S-central Niger. For obvious reasons villages and towns were avoided by the observers as were areas more than 5 km from easily drivable roads. This led to an under-representation of species associated with human settlements (*e.g.* Common Bulbul *Pycnonotus barbatus*) or with very remote areas (*e.g.* bustards Otidae). Apart from these constraints, the random selection of starting points and fixed direction of walking probably ensured representative sampling of the different habitats and their associated avifauna.

One of the main assumptions of distance sampling is that all individuals within the innermost band are recorded. Violation of this assumption leads to an underestimation of density. This may occur if birds flee from the observer before detection or if birds are overlooked or cannot be identified. Evasive movements may, if frequent, be detected by inspection of the distribution of records across distance bands (Buckland *et al.* 1993). Only one of the 37 species analysed in Distance (*Eupodotis savilei*) showed clear signs of evasive movements, which in this case was handled by merging all records in the four innermost bands (0–100 m).

The probability of overlooking a bird depends, apart from its size and coloration, on its behaviour, which varies during the breeding cycle. Thus, densities of skulking and nocturnal species and of some dry season breeders not showing advertising behaviour during the census period were probably underestimated. During the counts the observer must proceed as steadily as possible, deviations from the line must be kept to a minimum, and it is generally not allowed to approach a bird for identification. Even if all observers were fairly skilled, the latter constraint almost certainly caused an under-recording of species such as Yellow-bellied Eremomela *Eremomela icteropygialis* and Northern Crombec *Sylvietta brachyura* (which have very similar songs), some weavers *etc.* Because birds not identified to species were not recorded, total densities are surely underestimated.

Along some parts of the transects, especially in the southern parts of the census areas, the observer's view was restricted by woody vegetation or by high-grown millet plants. This certainly violated the assumption of equal probability of detection across sites, but data from such areas were too sparse to allow separate modelling of the detection functions. As a consequence, densities in Niger S and (especially) Senegal S are probably underestimated.

Bias in distance estimation may also affect the estimation of densities, but control measuring of distances estimated by the observers revealed no obvious biases. If anything, distances were probably overestimated, leading to an underestimation of densities.

Overestimation of densities may result if individual birds are recorded more than once. This is the main reason for proceeding steadily along the line, keeping track of individuals of common species and not diverting too much effort into species identification. All observers had a thorough understanding of the rationale of the method and previous experience with systematic counts of terrestrial birds, so it is believed that bias due to double counting was negligible.

Results

The total number of species and the mean densities (birds per km²) in each of the six regions are shown in Table 1. A total of 232 species was recorded on the transects, but many of them too infrequently to allow a reasonable estimation of densities. The Appendix gives densities of all species with more than ten records that fulfil one of the following criteria: (1) mean density > 1 per km² in either Senegal or Niger; (2) density > 2 per km² in at least one of the six regions. To give an impression of the variation, local densities of two species with different distribution patterns are shown in Fig. 2.

Table 1. Summary data on the line transects carried out in each country and region.

	Senegal				Niger			
	Total	S	C	N	Total	S	C	N
No. of line transects	276	62	103	111	331	115	115	101
No. of species recorded	170	112	109	104	168	122	97	87
Mean bird density per km ²	663	475	670	762	639	477	862	566
Mean density excluding <i>Passer luteus</i>	565	475	666	528	470	473	500	430

A comparison of counts performed early and late in the rainy season in Niger revealed significant differences in densities of species such as *Bubulcus ibis* and *Milvus migrans parasiticus* (Table 2). The latter species occurred in fairly high numbers north of Zinder (14°–14°25'N) in July and further north (around 14°55'N) in September. Also *Ciconia abdimii* occurred in high densities in the northern part of the Niger study area in September but not in Jun–Jul. On 19 Sep 2003, the following mean densities were recorded along four 1 km transects a few km south of Tanout: *Ciconia abdimii* 384, *Bubulcus ibis* 164 and *Milvus m. parasiticus* 94 per km². Grasshopper densities along these transects were high (average 7 per m²) but not exceptional.

Table 2. Estimated mean densities (no./km²) of Cattle Egret *Bubulcus ibis* and Yellow-billed Kite *Milvus migrans parasiticus* in the Niger study areas Jun–Sep.

	<i>Bubulcus ibis</i>			<i>Milvus m. parasiticus</i>		
	S	C	N	S	C	N
June	61.5	10.0	3.4	0.4	0	0
July	30.2	0.5	5.0	0.7	11.0	2.5
August–September	0	0	34.9	0	0.2	12.4

In addition to the common lark species, some rare or uncommon larks were recorded on the transects. In some areas, one or more of these species were even

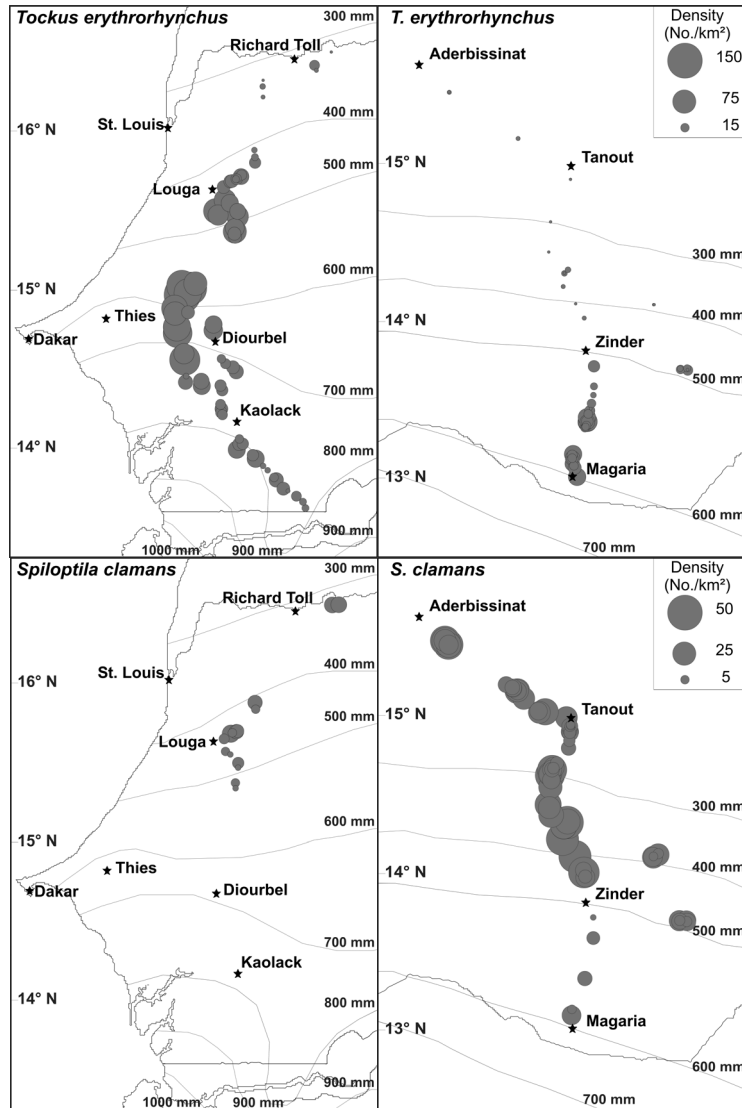


Figure 2. Estimated densities of Red-billed Hornbill *Tockus erythrorhynchus* and Cricket Warbler *Spiloptila clamans* along the precipitation gradients in Senegal and Niger. Dot area indicates estimated density (the key does not show all possible dot sizes). Each dot represents one morning count (mean of four 1-km transects). Apparent gaps in distribution may reflect lack of censuses, cf. Fig. 1.

sufficiently frequent to allow a tentative estimation of densities. Because good views are generally needed for identification, most of these lark species have narrow ESWs (30–65 m), sometimes resulting in fairly high density figures if expressed per km², as generally used in this paper. This may be misleading if a species is only locally common, so the densities below are reported as number per 10 ha (which also keeps the density figures well below the actual number of individuals recorded).

***Mirafra cordofanica* Kordofan Lark** (58 records). Niger: common between Zinder and Tanout (13°58'–14°47'N), 16–19 Jul 2003, with mean density 1.1 per 10 ha and maximum density 6 per 10 ha; not seen further north; less common 16–20 Sep 2003 in the same area (mean 0.2, max. 2.2 per 10 ha); also recorded NE of Tahoua (15°5'N, 5°37'E) 25 Jul 2003 (0–4 per 10 ha); much rarer in 2004, single birds recorded 12 and 13 Jun in the same belt between Zinder and Tanout as in 2003. Senegal: no records in 2003; one record of a single bird NE of Louga (15°41'N, 16°7'W) 30 Jul 2004.

***M. rufocinnamomea* Flappet Lark** (79 records). Only recorded in Senegal between 14°N and the Gambian border. Mean densities in this area 0.4 per 10 ha (30 Jul to 2 Aug 2003) and 0.6 per 10 ha (14–18 Jul 2004), max. densities 2.3 and 3.4 per 10 ha in 2003 and 2004, respectively.

***M. rufa* Rusty Bush-lark**. Three records from Niger, north and east of Zinder, in 2004: one (14°6'N, 9°24'E) 11 Jun; one (14°19'N, 8°48'E) 12 Jun; four (13°41'N, 9°34'E) 19 Jun.

***Pinarocorys erythropygia* Rufous-rumped Lark**. Three records from Niger in 2003: one S of Tanout (14°47'N 8°50'E) 20 Sep; two single individuals near Diffa (13°18'N, 12°33'E) 23 Sep.

***Ammomanes deserti* Desert Lark** (9 records, 16 individuals). Only recorded in Niger. Southernmost record 33 km S of Tanout (14°41'N, 8°46'E), density 0.4 per 10 ha, 18 Sep 2003. More numerous, albeit patchy, only 35–40 km further north; mean density 6 per 10 ha, 25 km WNW of Tanout, 8 Sep 2004.

***Eremalauda dunnii* Dunn's Lark** (41 records, 66 individuals). Only recorded in Niger. Frequent along the road between Zinder and Aderbissinat from 14°7'N northwards, mean densities: 0.17 per 10 ha, 17–21 Jul 2003; 0.9 per 10 ha, 11–24 Jun 2004; 0.4 per 10 ha, 3–8 Sep 2004. Maximum densities were found in the northernmost part of this area: 7.9 and 6.6 per 10 ha at 15°27'N, 8°4'E, 16 and 24 Jun 2004, respectively. Also recorded NE of Tahoua: two at 15°17'N, 5°56'E, 23 Jul 2003; one at 15°4'N, 5°36'E, 25 Jul 2003; four SW of Diffa (13°17'N, 12°31'E), 23 Sep 2003.

All four species of large vulture breeding in W Africa were recorded in Senegal between 14°14' and 15°51'N, but none was seen on Senegal S or any transect in Niger. Estimated densities (no./km²) are: African White-backed Vulture *Gyps africanus* Senegal C 0.27, Senegal N 0.09; Rüppel's Griffon *G. rueppellii* Senegal C 0.24, Senegal N 0.37; Lappet-faced Vulture *Torgos tracheliotus* Senegal N 0.12, found only in a narrow belt around Louga (15°30'–15°42'N). White-headed Vulture *Trigonoceps occipitalis* was recorded just once, 10 km NNW of Diourbel (10 Aug

2003). Hooded Vulture *Necrosyrtes monachus* was recorded in mean densities of 0.15 per km² in Senegal and 0.04 per km² in Niger, but due to its association with towns and villages these mean densities almost certainly underestimate the true density. Egyptian Vulture *Neophron percnopterus* was seen once, in Niger, 35 km S of Tanout, 13 Jun 2004.

Three species of savanna or woodland eagles were recorded in Senegal. Tawny Eagle *Aquila rapax* was seen twice, 25 km SSE of Kaolack and 30 km E of Richard Toll, respectively. A single African Hawk Eagle *Hieraaetus spilogaster* was seen 10 km ENE of Louga (15°40'N, 16°10'W, the first record in this atlas square), 30 Jul 2004, and a Martial Eagle *Polemaetus bellicosus* was seen 30 km SSE of Louga, 20 Aug 2003. None of these species was found in the Niger census areas, where the only eagle recorded was a Wahlberg's Eagle *Aquila wahlbergi* half-way between Magaria and Zinder (13 Jun 2003).

Discussion

Species richness was generally higher in Senegal than in Niger, probably due to the higher structural diversity of the vegetation. The low number of transects in Senegal S (about half the number conducted elsewhere, cf. Table 1) probably explains the comparatively few species recorded in that region, which otherwise would be expected to hold the highest number of species. Given that densities in the southern regions are almost certainly underestimated (cf. Sources of bias, above), total densities were fairly constant across regions if the flocks and colonies of *Passer luteus* are excluded.

The gradient of decreasing precipitation from south to north is the major factor affecting the distribution of species in this part of Africa. Table 3 shows our interpretation of the distribution of 67 species along this gradient during the rainy season, based upon the density estimates given in the Appendix. The following example illustrates how species were placed along the gradient: *Streptopelia vinacea* occurred at its highest densities in Senegal C and Niger S and was therefore placed in the Senegal C–Niger S group, whereas *S. senegalensis* was most numerous in Senegal N and Niger S and was therefore placed in an intermediate position between Senegal C–Niger S and Senegal N–Niger C. Only ten of the species included in the Appendix could not reasonably be placed along this gradient. Some of these were mainly associated with locally occurring habitats (e.g. *Bubulcus ibis*, *Ploceus melanocephalus*) and very few species, if any, were almost equally distributed across the area.

The north-south distribution patterns revealed here are generally well known, and only a few findings deserve further discussion. *Eupodotis savilei* was only recorded in Senegal, where it occurred all along the precipitation gradient. We found it to be clearly more numerous in the Sudanian zone than in the Sahel, reaching its highest

Table 3. Location of the highest densities of 67 species in Jun–Sep along the N–S gradient. Data from Senegal and Niger have been combined. The precipitation ranges are rough indications of the annual rainfall in each region. Each species was placed in one of the seven groups according to the region(s) where it was most numerous (see text); three of the groups take up intermediate positions between the regions/precipitation ranges defined. See Appendix for English names.

Niger N	
<300 mm	<i>Eremalauda dumni, Oenanthe (bottae) heuglini, Turdoides fulvus</i>
Intermediate	<i>Burhinus capensis, Cursorius temminckii, Pterocles exustus, Streptopelia roseogrisea, Urocolius macrourus, Merops albicollis, Upupa epops, Galerida cristata, Eremopterix leucotis, E. nigriceps, Cercotrichas podobe, Amadina fasciata</i>
Senegal N/ Niger C	<i>Vanellus tectus, Oena capensis, Mirafra cantillans, M. cordofanica, Cercotrichas galactotes, Cisticola aridulus, Spiloptila clamans,</i>
300–500 mm	<i>Lanius meridionalis, L. senator, Lamprotornis pulcher, Passer luteus, Quelea quelea</i>
Intermediate	<i>Streptopelia senegalensis, Halcyon chelicuti, Bubalornis albirostris, Sporopipes frontalis, Ploceus velatus, Lonchura cantans</i>
Senegal C/ Niger S	<i>Streptopelia vinacea, Psittacula krameri, Halcyon senegalensis, Coracias abyssinicus, Phoeniculus purpureus, Tockus erythrorhynchus, Lybius vielloti,</i>
500–750 mm	<i>Chalcomitra senegalensis, Cinnyris pulchellus, Ptilostomus afer, Lamprotornis chalybaeus, Passer griseus, Ploceus luteolus, Uraeginthus bengalus, Serinus leucopygius</i>
Intermediate	<i>Eupodotis savilei, Turtur abyssinicus, Streptopelia decipiens, Centropus senegalensis, Merops pusillus, Tockus nasutus, Cisticola juncidis, Prinia subflava, Camaroptera brachyura, Tchagra senegala, Lamprotornis caudatus, Petronia dentata, Ploceus cucullatus, Euplectes franciscanus, Lagonosticta senegala</i>
Senegal S >750 mm	<i>Francolinus bicalcaratus, Mirafra rufocinnamomea, Laniarius barbarus, Lamprotornis chloropterus</i>

densities (up to ten calling males per km²) between the Gambian border and 14°N. The species was classified as restricted to the Sahel biome by Fishpool & Evans (2001), and Sauvage & Rodwell (1998) described it as frequent between 14° and 16°N, but apparently not further south. It may recently have expanded southwards, and good numbers could possibly also occur south of the Gambian border where it was first discovered in 1994 (Borrow 1997, Payne *et al.* 1997). The other Sahelian biome-restricted species (*sensu* Fishpool & Evans) all occurred most frequently in the northern part of the study areas.

The high densities of *Bubulcus ibis*, *Ciconia abdimii* and *Milvus m. parasiticus* recorded in September in Niger N, coinciding with the virtual disappearance of these

species from the southern parts of the study area, indicate that significant northward movements occur towards the end of the breeding season. These post-breeding movements are most probably an adaptation to utilization of the seasonal abundance of grasshoppers, especially *Oedaleus senegalensis*, in the northern grasslands.

In addition to the north-south differences, several differences between Senegal and Niger are apparent (cf. Appendix). Many of these are related to the higher density of trees found in Senegal, even in the drier parts of the country. Common arboreal species such as *Urocolius macrourus*, *Halcyon senegalensis*, *H. helicuti*, *Coracias abyssinicus*, *Tockus erythrorhynchus*, *Lybius vieilloti*, *Lamprotornis* starlings (except *L. pulcher*), *Bubalornis albirostris* and *Ploceus* weavers (except *P. luteolus*) all occurred in higher numbers in Senegal than in Niger. On the other hand, many species associated with open, dry country, with or without scattered bushes, were more frequent in Niger than in areas receiving a similar amount of rainfall in Senegal (e.g. *Oena capensis*, *Eremopterix leucotis*, *E. nigriceps*, *Cercotrichas galactotes*, *Cisticola aridulus*, *Spiloptila clamans*, *Lanius meridionalis* and *Sporopipes frontalis*). A few exceptions from this general trend are mentioned in the following.

Despite their arboreal habits, all sunbird species were more numerous in Niger than in Senegal. This was the case even in *Chalcomitra senegalensis*, which was recorded at a mean density of 6.4 per km² between the Nigerian border and Zinder, and Copper Sunbird *Cinnyris cupreus*, of which we had three records (north to 13°22'N). There have been less than ten previous records of *Chalcomitra senegalensis* in Niger, and our records of *Cinnyris cupreus* are the first ones outside "W" National Park (Giraudaux *et al.* 1988, J. Brouwer *in litt.*). All four sunbird species recorded are rains migrants at the northern limit of their range, so their occurrence varies from year to year and from place to place, depending on the northward extension of the rains and on local differences in rainfall.

Among the dry country species, the three common waders *Burhinus capensis*, *Cursorius temminckii* and *Vanellus tectus* were more frequent in Senegal than in Niger. A possible reason for this could be the higher incidence of bush fires in Senegal, creating suitable habitat. Also *Mirafraga cantillans* occurred in higher densities in northern Senegal than in most similar areas in Niger. However, mean densities of 40 per km², comparable to those in Senegal N, were recorded at the additional counts in the Tahoua area in Niger. Generally, the regional mean densities shown in the Appendix may conceal large local variations (cf. Fig. 2), especially in colonial species and species whose optimum habitat is patchily distributed. For instance, whereas the mean density of *M. cantillans* in Senegal N was 44 per km², maximum densities regularly recorded along 1-km transects were as high as 200–250 per km². The latter figure compares well with the 22–37 singing males per 10 ha found by Mullié & Keith (1991).

Our records of *Mirafraga cordofanica* and *M. rufa* from Niger are the first records since 1931 (Giraudoux *et al.* 1988, J. Brouwer *in litt.*). At least in some years, *M. cordofanica* seems to be fairly common in a belt between Zinder and Tanout, but the

paucity of records in 2004 may indicate a rather erratic occurrence. *Eremalauta dunni* (less than ten previous records from Niger) proved surprisingly common too, mainly north of the *M. cordofanica* belt. Also *Ammomanes deserti* was found in fairly high densities south of the area where it had previously been recorded (*i.e.* north of 15°18'N, cf. Giraudoux *et al.* 1988). The novelty of these findings from Niger may simply reflect that very little ornithological work has been done during the rainy season in the areas in question, but the records may also represent southward range extensions (cf. the recent discovery of Golden Nightjar *Caprimulgus eximius* in Cameroon (Sinclair *et al.* 2003)). In Senegal, our record of *M. cordofanica* seems to be the first south of 16°N (Morel & Morel 1990, Sauvage & Rodwell 1998). *M. rufocinnamomea* proved unexpectedly common in Senegal S, but all our records (except one west of 16°W) fall within the known range of the species.

No large vultures and eagles were recorded on the transects in Niger. In Senegal, large vultures were absent from the southern and northernmost parts of our study area but were elsewhere found in fair numbers. *Gyps rueppellii* and *G. africanus* were most frequent, but also *Torgos tracheliotus* was regularly seen on the transects and a few large eagles were recorded as well. According to W. Mullié (*in litt.*), flocks of 100 vultures, or rarely up to 600, are regularly seen on carcasses along the main road between Thies and Louga (with typically 40–50% *G. rueppellii*, 35–45% *G. africanus*, 10–15% *Necrosyrtes monachus* and 0–5% *T. tracheliotus*) whereas vultures are now very rare in the northernmost part of Senegal and also in Mauritania.

W African raptor populations have plummeted during recent decades. In Mali, Burkina Faso and Niger, numbers of large vultures and eagles outside protected areas have been reduced by 98% and 86–93%, respectively, since 1969–73 (Thiollay 2006). Our lack of records from Niger fits well into this picture. By contrast, fair numbers of large raptors still seem to survive in Senegal, at least in the W part of the country. Raptor populations have undoubtedly also declined here, and poisoning is known to occur (W. Mullié *in litt.*), but, for unknown reasons, the decline has apparently been less dramatic than in countries further east.

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Appendix.

Densities (no./km²) of the 77 species fulfilling the abundance criteria for inclusion (see text). Estimated mean densities are given for Senegal and Niger as well as for each of the six regions.

	Senegal				Niger			
	Mean	S	C	N	Mean	S	C	N
Ardeidae								
<i>Bubulcus ibis</i> Cattle Egret	10.6	14.5	6.9	11.6	17.7	28.9	9.7	14.2
Ciconiidae								
<i>Ciconia abdimii</i> Abdim's Stork					5.7	0.8	0.5	17.2
Accipitridae								
<i>Milvus migrans parasiticus</i> Yellow-billed Kite	0.1	0.1	0.1		2.9	0.3	3.2	5.4
Phasianidae								
<i>Francolinus bicalcaratus</i> Double-spurred Francolin	1.3	4.7	0.2	0.2				
Otididae								
<i>Eupodotis savilei</i> Savile's Bustard	1.2	2.4	0.8	0.7				
Burhinidae								
<i>Burhinus capensis</i> Spotted Thick-knee	1.1		0.2	2.6	0.7			2.2
Glareolidae								
<i>Cursorius temminckii</i> Temminck's Courser	1.3	0.7	0.3	2.4	0.2		0.2	0.4
Charadriidae								
<i>Vanellus tectus</i> Black-headed Lapwing	13.8	15.6	7.9	17.9	1.8	1.7	2.8	0.8
Pteroclididae								
<i>Pterocles exustus</i> Chestnut-bellied Sandgrouse	4.1			10.0	0.4	0.2		1.0
Columbidae								
<i>Turtur abyssinicus</i> Black-billed Wood Dove	1.3	4.4	0.8		0.4	1.1		
<i>Oena capensis</i> Namaqua Dove	4.7		1.2	10.3	9.5	3.7	19.4	4.8
<i>Columba guinea</i> Speckled Pigeon	1.6	2.1	1.1	1.9	0.2	0.3	0.2	0.1

	Senegal				Niger			
	Mean	S	C	N	Mean	S	C	N
<i>Streptopelia decipiens</i> African Mourning Dove	0.7	2.0	0.2	0.3	0.1	0.3		
<i>S. vinacea</i> Vinaceous Dove	7.4	6.3	14.2	2.2	6.4	18.1	0.2	0.1
<i>S. roseogrisea</i> African Collared Dove	3.4		0.6	7.6	2.0	1.4	2.1	2.4
<i>S. senegalensis</i> Laughing Dove	34.8	5.2	31.8	53.9	7.9	16.7	5.2	0.8
Psittacidae								
<i>Psittacula krameri</i> Rose-ringed Parakeet	1.3	1.7	1.7	0.7	2.7	7.8		0.1
Cuculidae								
<i>Chrysococcyx caprius</i> Didric Cuckoo	1.7	1.1	1.7	2.1				
<i>Centropus senegalensis</i> Senegal Coucal	2.0	6.7	0.7	0.5	1.6	4.7		
Coliidae								
<i>Urocolius macrourus</i> Blue-naped Mousebird	2.5		2.2	4.1	0.3		0.3	0.6
Alcedinidae								
<i>Halcyon senegalensis</i> Woodland Kingfisher	4.4	4.8	9.2	0.2	0.1	0.2		
<i>H. chelicuti</i> Striped Kingfisher	2.4	0.2	1.7	4.1	0.2	0.4	0.1	
Meropidae								
<i>Merops pusillus</i> Little Bee-eater	1.1	1.8	0.8	1.0	0.3	0.8		
<i>M. albicollis</i> White-throated Bee-eater	1.1			2.7	9.7	0.6	9.9	19.8
<i>M. orientalis</i> Little Green Bee-eater	1.1	3.7	0.6	0.1	0.2			0.6
Coraciidae								
<i>Coracias abyssinicus</i> Abyssinian Roller	16.9	10.9	19.0	18.4	7.5	16.7	3.6	1.6
Phoeniculidae								
<i>Phoeniculus purpureus</i> Green Wood-hoopoe	1.0	0.5	2.3	0.3	1.3	3.2	0.3	0.2
Upupidae								
<i>Upupa epops</i> Hoopoe	1.1		1.3	1.6	0.4	0.3	0.3	0.6
Bucerotidae								
<i>Tockus erythrorhynchus</i> Red-billed Hornbill	35.0	17.7	56.4	26.3	7.4	20.0	0.9	0.4

<i>T. nasutus</i> African Grey Hornbill	4.1	12.2	2.4	1.2	7.8	21.3	1.1	0.2
Capitonidae								
<i>Lybius vieilloti</i> Vieillot's Barbet	1.6	0.4	3.3	0.9	0.3	0.7	0.2	
Alaudidae								
<i>Mirafra cantillans</i> Singing Bush-lark	24.5		17.6	44.1	10.9	1.0	16.4	16.0
<i>M. cordofanica</i> Kordofan Lark	0.0			0.1	1.1		3.1	
<i>M. rufocinnamomea</i> Flappet Lark	1.1	4.7						
<i>Eremalauda dunni</i> Dunn's Lark					2.8		3.0	5.8
<i>Galerida cristata</i> Crested Lark	1.1		1.0	1.8	0.9	0.1	1.2	1.4
<i>Eremopterix leucotis</i> Chestnut-backed Sparrow Lark	6.1			14.6	44.2	3.1	55.4	78.4
<i>E. nigriceps</i> Black-crowned Sparrow Lark	7.3			17.7	53.1		46.1	122.0
Turdidae								
<i>Cercotrichas galactotes</i> Rufous Scrub Robin	0.1	0.2		0.2	1.5	0.5	2.6	1.2
<i>C. podobe</i> Black Scrub Robin	0.9		0.3	2.0	1.0		1.4	1.7
<i>Oenanthe (bottae) heuglini</i> Heuglin's Wheatear					1.1		0.5	3.2
Sylviidae								
<i>Cisticola juncidis</i> Zitting Cisticola	7.0	20.1	5.7	0.9	1.1	1.6	0.9	0.7
<i>C. aridulus</i> Desert Cisticola	1.1	0.2	1.1	1.5	8.9	4.4	16.5	5.4
<i>Prinia subflava</i> Tawny-flanked Prinia	14.5	24.2	23.0	1.9	0.6	1.7		
<i>Spiloptila clamans</i> Cricket Warbler	1.6			3.8	14.7	3.5	22.9	18.1
<i>Camaroptera brachyura</i> Grey-backed Camaroptera	2.2	5.8	1.8	0.5	0.1	0.3		
Timaliidae								
<i>Turdoides fulvus</i> Fulvous Babbler					1.3		1.3	2.9
Nectariniidae								
<i>Chalcomitra senegalensis</i> Scarlet-chested Sunbird	0.6	0.8	0.9	0.1	2.3	6.4	0.1	
<i>Hedydipna platura</i> Pygmy Sunbird	0.1	0.2	0.2		4.6	11.0	0.7	1.8
<i>Cinnyris pulchellus</i> Beautiful Sunbird	0.8	0.3	1.1	0.8	2.3	6.0	0.3	0.5

	Senegal				Niger			
	Mean	S	C	N	Mean	S	C	N
Laniidae								
<i>Lanius meridionalis</i> Southern Grey Shrike	2.2			5.4	10.3	3.1	17.7	10.0
<i>L. senator</i> Woodchat Shrike	1.8		0.2	4.1	2.0	0.4	3.1	2.6
Malaconotidae								
<i>Tchagra senegala</i> Black-crowned Tchagra	1.2	1.9	0.3	1.6	0.8	2.2	0.1	
<i>Laniarius barbarus</i> Yellow-crowned Gonolek	0.5	2.3						
Corvidae								
<i>Corvus albus</i> Pied Crow	0.8		2.4		1.6	1.0	0.2	3.6
<i>Ptilostomus afer</i> Piapiac	1.9	2.2	3.8		2.6	7.5		
Sturnidae								
<i>Lamprotornis chalybaeus</i> Greater Blue-eared Starling	9.8	4.5	15.6	7.7	2.4	3.8	1.5	1.7
<i>L. chloropterus</i> Lesser Blue-eared Starling	3.1	7.8	3.7					
<i>L. caudatus</i> Long-tailed Glossy Starling	6.2	13.2	8.7		1.3	3.8		
<i>L. pulcher</i> Chestnut-bellied Starling	20.7	0.9	26.0	27.2	20.3	11.1	38.6	9.7
Passeridae								
<i>Passer griseus</i> Northern Grey-headed Sparrow	29.0	10.4	69.6	4.7	32.6	64.1	24.7	5.7
<i>P. luteus</i> Sudan Golden Sparrow	98.0		3.8	233.7	168.9	3.5	361.8	135.9
<i>Petronia dentata</i> Bush Petronia	0.8	3.5			1.3	3.8		
Ploceidae								
<i>Bubalornis albirostris</i> White-billed Buffalo Weaver	82.0	21.1	73.9	123.1	8.0	13.1	5.3	5.3
<i>Sporopipes frontalis</i> Speckle-fronted Weaver	2.0		5.7		32.2	43.9	46.4	2.5
<i>Ploceus luteolus</i> Little Weaver	5.2	3.6	10.9	1.4	7.7	18.0	3.8	0.4
<i>P. velatus</i> African Masked Weaver	18.0	9.2	17.8	23.2	7.1	10.2	10.0	0.2
<i>P. cucullatus</i> Village Weaver	73.6	130.4	115.9	5.4	0.8	1.8	0.5	
<i>P. melanocephalus</i> Black-headed Weaver	2.0			4.9				
<i>Quelea quelea</i> Red-billed Quelea	1.3		0.3	2.9	37.4	17.0	70.1	22.9

<i>Euplectes franciscanus</i> Northern Red Bishop	17.7	40.2	22.5	1.1	2.5	6.6	0.5	
Estrildidae								
<i>Lagonosticta senegala</i> Red-billed Firefinch	0.2	0.8			1.1	2.3	0.6	0.3
<i>Uraeginthus bengalus</i> Red-cheeked Cordon-bleu	9.5	8.4	21.0	0.3	1.6	4.0	0.6	
<i>Lonchura cantans</i> African Silverbill	15.4	0.8	16.8	22.3	18.7	28.4	22.2	3.8
<i>Amadina fasciata</i> Cut-throat	2.6		2.2	4.4	7.4	3.4	9.4	9.7
Fringillidae								
<i>Serinus leucopygius</i> White-rumped Seedeater	2.6	0.5	6.6	0.4	2.3	5.2	1.4	
Emberizidae								
<i>Emberiza tahapisi</i> Cinnamon-breasted Rock Bunting					2.8	2.9	2.4	3.3