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Large bird declines with increasing human pressure in savanna woodlands (Burkina Faso)

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Abstract. The impacts of human pressure, habitat changes, and efficiency of conservation measures on the non-passerine bird community were assessed in the Sudanian belt of Burkina Faso. Three regions with increasingly large protected areas and higher conservation status were compared. In each region, natural savanna woodlands were also compared to traditionally cultivated areas. Six groups of diurnal raptors and six groups of other large bird species were counted along 167 5-km transect counts during the dry season. Within savanna woodlands, the only significant and consistent declines from the little disturbed Eastern National Parks to the more populated and exploited Western forest reserves were those of the largest terrestrial game birds (Guinea fowl, Bustard, Ground Hornbill), eagles and vultures, which became virtually extinct in the least protected areas. Although some species groups maintained substantial, if not higher populations in cultivated areas (rollers, non-game terrestrial birds, several raptors), the overall abundance of both raptor and non-raptor species declined markedly (50–65%) from natural savanna woodlands to tree-dotted cultivated and fallow fields. Again large game birds, eagles and vultures were absent from every agricultural areas censused. Yet, all of them were still commonly recorded in the same natural and cultivated areas during surveys I conducted in the same regions from 1968 to 1973. The main factors correlated with large bird extinctions or declines from national parks to mere forest reserves and from natural woodlands to fields were first related to hunting, then to habitat degradation and fragmentation through intensive cattle grazing and wood cutting and extension of cultivated areas.

Introduction

The threats to tropical savanna ecosystems and their biodiversity are much less publicized than those affecting rainforests. Yet in Africa, savannas are more extensive, more densely populated and as much degraded by human activities than are dense humid forests. In West Africa, the wide savanna belt extending between the rainforest and the Sahel is increasingly drier and more sparsely wooded from south to north, but is everywhere affected at least by traditional human management including burning, hunting, grazing and clearing for cultivation, even in many protected areas. Human population growth often results in overuse of woodlands or grasslands, in large scale losses, degradation or fragmentation of large habitats, and in a spectacular decline of large wildlife (Buechner and Sauvageot 1996; Shephered et al. 2003).

The objectives of this study were to assess both the impacts of traditional anthropogenic pressure and the effectiveness of conservation status on a West African savanna bird community. Human activities have widely different environmental consequences, additive, difficult to disentangle, often at a landscape scale. Cultivation suppresses irreplaceable ecological attributes of ecosystems (Wilson et al. 1997; Sinclair et al. 2002). It results not only in the loss of natural habitats but also in the fragmentation of remaining patches, threatening the viability of populations (Harris and Silva-Lopez 1998). Annual fires have a disrupting impact and long-term effects on the structure and composition of the natural vegetation (Gillon 1983). Fuelwood removal and livestock grazing are widespread contributors to the degradation of natural grasslands and woodlands (Lamprey 1983; Duplessis 1995; Saab et al. 1995). Hunting and overfishing are important causes of wildlife impoverishment and threaten many rare taxa (Robinson and Bodner 1999).

Conservation policies, implementation and effectiveness are also variable, from habitat management, adaptation of fire schedule or grazing pressure and limitations of wood harvesting or hunting to establishment of strictly protected areas (at least on paper!). It is thus difficult to assess accurately levels of disturbance and actual conservation over large areas.

The bird community is an easy and widely used indicator of both habitat and wildlife conservation. To work on a large scale, I used only the large birds which are easier to census over extensive areas and which include a wide array of top predators, woodland specialists and game species, all likely to be sensitive to human pressure. I selected for study the three last disturbed and best protected areas of Burkina Faso, ranked from west to east along a gradient of increasing conservation status, even though even in the largest national parks, official protection was weakly enforced. Each natural area was compared with its nearby cultivated and inhabited surroundings to assess the additional consequences of cultivation and settlements.

Study areas

Burkina Faso (formerly Upper Volta) is a medium size, land-locked country (274,200 km^2), in the centre of West Africa, whose Central and South Western parts are heavily populated (11 millions in 1999). Study areas were in the south of the country, just north of the borders of Ivory Coast, Ghana and Benin (Figure 1). They were all between 11 ° and 12 ° N, in the Sudanian zone, at an elevation of 200–400 m a.s.l. The average annual rainfall is everywhere 900–1100 mm, with substantial variations between years and a decreasing trend since 1970. The rainy season extends from mid-May or June to October and mid-November, with a maximum in July–September. The hottest period (mean daily temperatures ≥34°C) is in March–May and the coolest (daily means ≤ 24°C) in December–February (average annual temperature = 27°C).

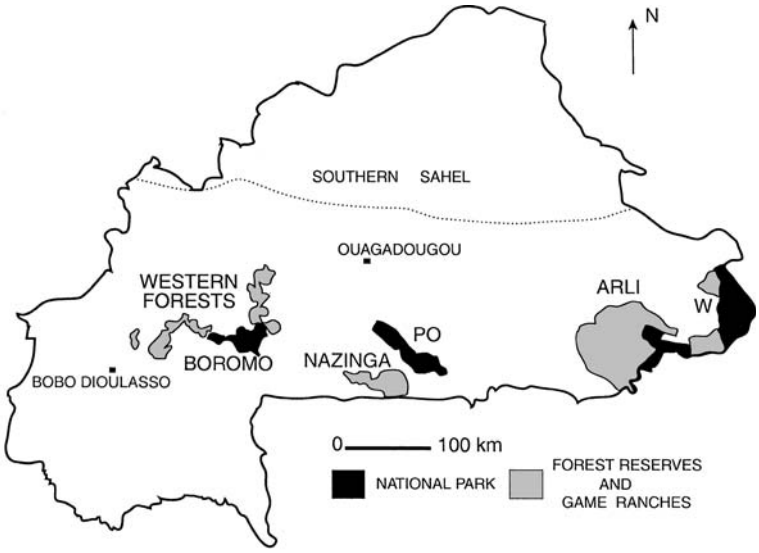

Figure 1. Study areas in Burkina Faso.

The local human population has nearly tripled during the last 30 years, partly from immigration of northern population. After massive insecticide spraying eradicated sleeping sickness and river blindness, large areas were opened to settlements and pastoralists.

Habitats

The *natural vegetation* is a mosaic of mostly deciduous dry savanna woodland ranging from some almost treeless floodplains (local), to shrubby (3–5 m high), then to denser and taller tree savanna (10–20 m) and, along streams and seasonal creeks, largely evergreen gallery forests (20–30 m). The basal area of trees usually ranges from 1–5 to 3–9 and 7–12 m^2/ha in shrubby areas, tree savannas and gallery forests, respectively, these habitats making up 5–30, 30–70 and 2–10% of the natural landscape, respectively (Devineau et al. 1997).

The main savanna tres are *Burkea, Vitellaria*, *Butyrospermum*, *Crossopteryx*, *Piliostigma*, *Combretum*, *Pterocarpus*, *Prosopis*, *Lannea*, *Afzelia*, and in driest areas, *Adansonia*, *Acacia*, *Balanites*. Their mean canopy cover is between 10 and > 50%. Gallery forests are composed of rarer or larger savanna trees such as *Khaya*, *Syzygium*, *Kigelia*, *Cola*, *Manilkara*, *Parkia*, *Daniellia*, *Isoberlinia*, *Terminalia*, *Anogeissus*, *Vitex*, *Diospyros and* locally *Borassus* palms. *Mitragyna inermis* and *Acacia sieberiana* are common in seasonally inundated areas. The grass cover (mainly *Andropogon* and *Hyparrhenia*, also *Loudetia*, *Loudetiopsis*, *Schizachyrium*, *Sporobolus*, *Pennisetum*) is dense, usually

reaching 1.2–1.8 m in September–November. Because of its often park-like appearance, this Sudanian savanna, as defined by its tall grass cover, is locally an open forest, especially the least disturbed and protected areas. Scattered tree plantations (*Tectona*, *Eucalyptus*, *Gmelina*) and cotton fields are found in the western study areas, as well as natural or artificial pools, mainly in Nazinga game ranch and Arli National Park.

Cultivated fields. Most of the natural woodlands are within protected areas outside of which nearly all the countryside is densely inhabited (>50 hab./km^2) and either cultivated parkland or bush fallow. Traditional fields of millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), maize (*Zea mays*), groundnuts (*Arachis hypogea*) or yams (*Dioscorea spp*.) are dotted with family groups of huts or villages. They usually retain numerous large indigenous trees (*Butyrospermum*, *Parkia*, *Tamarindus*, *Bombax*, *Faidherbia*) at a density of 2–20/ha, giving them a parkland appearance, and where most birds were seen. During the dry season, stubbles are used by cattle and seeds remain available on the otherwise bare ground. Ploughing and seeding occur in early rains (May–June) and harvest in September–October. The former fallow rotation of about 20 years has often been reduced to 10 years or less because of land scarcity and population growth. The matrix of woodlands around fields is typically poorer in large trees (0–10/ha) and with a denser shrub cover (4000 to >9000 stems) than are natural savannas where on average 30 trees and 1960 shrubs/ha were counted on 28 1000 m^2 plots (Kiema 2001).

Cotton fields, an intensive cash-crop, with few or no trees left and pesticides spraying, are now an important feature of the landscape, especially in the western study area. They have obviously poorer bird populations than traditional farmlands, and were not studied. Locally, irrigated ricefields, gardens and orchards of Mango trees are also found. All cultivated fields sampled were of the traditional (richest) type, and near the large areas of natural protected savanna woodlands (comparative study sites), from which they probably received a lot of dispersing birds. Consequently, such fields may have had a significantly higher avian richness than most cultivated areas, typical of central Burkina Faso, that are far from extensive tracts of natural woodlands. The latter are also on average even less wooded because of the acute firewood crisis in the country and the closer huge urban markets for fuelwood.

Regions

Study sites were divided into three discrete areas, representative of a west–east gradient of increasing woodland cover, level of protection and associated large game abundance and decreasing habitat disturbance (Table 1).

1. The Western zone included 5 rather isolated and even fragmented, relatively small forest reserves, surrounded by densely populated and culti-

Table 1. Legally protected study areas : distribution, status and level of human pressure.

Region	Name	Status	Area (km^2)*	Position	Habitat disturbance
West	Mare aux Hippotames	Biosphere Reserve	163	11°35′ N–4°08′ W	Tree plantations
	Maro	Protected forest	534	11°35′ N–3°55′ W	Tree plantations fields
	Tuy	Protected forest	470	11°45′ N–3°45′ W	Road fields
	Tiogo	Protected forest	300	12°10′ N–2°45′ W	Road fields
	Deux Balé	National Park	560 (806)	11°40′ N–2°55′ W	Trails
Centre	Nazinga	Game ranch	930 (1010)	11°10′ N–1°25′ W	Roads
	Kaboré Tambi	National Park	1550	11°20′ N–1°10′ W	Road
East	Arli	National Park	760 (3700)	11°25′ N–1°10′ E	None
	W	National Park	2350 (9570)	11°40′ N–2°05′ E	None

*Figures in parentheses include surrounding buffer zones (partially protected areas or hunting reserves).

vated areas. They were severely affected by cattle grazing, wood cutting, heavy poaching and, locally, by agricultural encroachment (Tuy, Tiogo) or large tree plantations (Maro). Consequently, large game bird and mammal populations were extremely low, if not locally extinct, except elephants (Maro, Tuy, Boromo). The largest and best forested area was a national park (Deux Balé) crossed by the Mouhoun River (formerly Black Volta).

2. In the Central zone, the Nazinga game ranch and the nearby Pô, or Kaboré Tambi National Park were larger and better protected areas, less hunted than in the West, with only peripheral habitat disturbance (grazing, wood harvesting) due to tighter controls, some ecotourism and a sparser human population.
3. The Eastern zone was centred on the Arli-W National Parks, which were part of a much larger area of contiguous national parks and game reserves across the Niger–Benin–Burkina Faso border. The continuous natural woodlands were virtually undisturbed because of a low human population all around. Poaching and fishing persisted and were responsible for a dramatic decline of large game compared to the situation I observed 30 years ago. However the number of mammals counted along bird transects remained higher than in the Central area. Because of the expected relationship between large game density and large bird community, bird counts performed 30 years ago in Arli-W National Parks were used as a the highest step in our decreasing disturbance gradient.

The protected forests of South Western Burkina Faso, called 'Forêts classées' were designated in 1937–1940. National parks were officially created in 1967. All these protected areas and their surrounding buffer zones were already at that time the main, if not only large continuous patches of

natural vegetation remaining in the southern half of the country. They had long been unsettled areas because of tribal wars, Tsetse fly and onchocercosis infestation as well as low agricultural value. They were selected here because they are still the most pristine, the least populated and richest areas in wildlife. The pressure of the surrounding human population is inversely proportional to their area and remoteness which generally increases from west to east.

From western to eastern study areas, the average population density decreased from >30 to <10 inhabitants/km^2, including both largely empty protected areas and heavily settled zones. The Western sites included areas where land use was merely regulated. The Central sites were a little-patrolled national park and a well managed ranch subject to organized small and large game hunting. The Eastern sites were long-established national parks, surrounded by larger privately managed hunting reserves even less poached than the national parks. The total area under some status of protection was respectively 2273, 2560 and 13,270 km^2 divided into 5, 2 and 1 isolated blocks, i.e. increasingly larger and less fragmented from west to east (Table 1). Among them, the area of national parks, i.e. the highest level of legal protection, was respectively 560, 1550 and 3110 km^2.

Agricultural encroachment inside protected areas was common in West, rare in Centre and non-existent in East.

Birds and mammals

Over the three study areas, at least 300 species of birds have been recorded, of which 41 Falconiforms and 35 other non-passerines were studied (Green and Sayer 1979; Koster and Grettenberger 1983; Thonnérieux 1989; Weesie and Belemsobgo 1997; Borrow and Demey 2001).

Large mammals were formerly a spectacular component of all these savannas. They have declined dramatically during the last century and have disappeared from cultivated areas. Even in the national parks, I counted in 2002 barely 10% on average of the large mammals I recorded along similar transects in 1972. In Nazinga ranch (Legemaat and DeBries 1990) and Arli National Park (Green 1979), the (former) large mammal biomass was estimated at 2 tons/km^2. They include antelopes (*Hippotragus*, *Kobus*, *Redunca*, *Alcephalus*, *Damaliscus*, *Tragelaphus*, *Ourebia*, *Cephalophus*, *Sylvicapra*), Buffalo, *Syncerus Caffer*, Elephant, *Loxondota africana*, Wharthog, *Phacochoerus aethiopicus*, Hippotamus, *Hippotamus amphibius*, and now rare, if not extinct, large carnivores, as well as still frequent smaller mammalian predators (jackal, civet, Ratel, genets, mongooses) and monkeys (*Erytrhocebus*, *Cercopithecus*, *Papio*). Only elephants apparently did not decrease during the last 30 years in all study areas (pers. obs.), probably because of reduced ivory trade.

Human uses of natural habitats and threats

Rural populations still rely, or have a significant impact on savanna woodlands.

Fire is the most widespread form of human pressure, since all savannas, even in the remote areas, are burnt every year between November–March and few, if any of these fires are natural. This occurs since a very long time and has probably resulted in the selection of fire resistant tree species. Increasing human presence may have increased the frequency of burning of the fire-sensitive gallery forests. Early fires are prescribed, and usually implemented, in protected areas. They have a lower intensity and leave some unburnt coarse grasses and this minimizes their negative impact.

Wood cutting has an important impact on natural woodlands. It goes far beyond the gathering of dead wood for fire and involves both local use and commercial exploitation of larger trees cut specifically, and charcoal. Cutting poles for construction and high grass for roofs is also common. At least, firewood collection was practised on a large scale almost throughout the Western study areas, but much more locally, on the margins of Central and Eastern areas.

Cattle grazing involves both local and transhumant herds of cows (also sheep, goats and donkeys) which penetrate even far into protected areas. In the dry season, herdsmen set fire for pasture, cut trees for fodder, and interfere with wildlife around ponds and gallery forests. Cattle was observed everywhere in the Western region, in one of the two Central study areas, and rarely in the Eastern region (where large mammals have also decreased dramatically).

Collection of non-timber products, such as honey, palms, fruits, medicinal plants, has probably a minor and local impact.

Impoundment of water for use in the dry season, by building numerous small dams, has been an active policy throughout Burkina Faso during the last decades. Some valuable gallery forests has been destroyed as a result, as well as significant areas of the most humid woodlands. These water stretches have favoured some birds dependent on drinking water in the dry season, but they have increased agricultural and grazing pressures over large areas.

Exotic tree plantations (Teak, *Tectona grandis*, *Eucalyptus* sp., ..) were sometimes extensive in the western study area. Their avifauna was strikingly poorer than that of natural woodlands.

Subsistence and commercial hunting, either legal or illegal, may have an ever stronger effect on animal populations that habitat degradation. Hunting is done largely by shooting (rarely snaring) and targets all middle-size or big mammals, and here-called game birds. Other birds involved in this study are usually not hunted. Poachers regularly occur even in the most remote parts of protected areas, even though there is little organized bush-meat trade in Burkina Faso.

Fishing is the last detrimental activity affecting every suitable area. All drying pools or streams are heavily fished even far from any road, as well as all permanent rivers during the dry season even in national parks.

Overgrazing by cattle is a problem in many unprotected areas. Conversely, large open grasslands of Arli National Park appeared more wooded (bushy encroachment) that 30 years ago. However the respective consequences of climate or faunal changes on ecosystems and bird populations have not been documented and remain conjectural.

Methods

Bird censuses

All counts were performed from 9 December 2002 to 5 January 2003 in the early dry season. Raptor surveys in Eastern National Parks were also compared with those made in January 1972 and 1973, exactly on the same circuits, in a similar way by the same observer, to give an appreciation of long term changes.

Censuses were made, once each on unpaved roads and small trails, divided into separate 5-km transects, either by foot, or by car driving slowly with frequent stops, by fine weather at any time between sunrise and sunset, except in the hot early afternoon hours when some birds are hidden. They were balanced among habitats and regions with respect to hourly periods.

All birds seen were counted on either side of the trail, the raptors within 1 km, and all other birds within 100 m to account for their lower detectability. Species were grouped into homogenous categories according to their behavioural or ecological similarities and expected responses to habitat features. Comparisons of abundances were made between regions and habitats within but not between species because of likely differences in detectability. Results were expressed in mean number of individuals per 5-km transect in each habitat type and region to take into account the between-transect variability in statistical comparisons. Because the full set of species recorded in fields of a given region were always seen in the first 10 counts or less, sample sizes were smaller in fields (15–16 transects/region) than in savanna woodlands (30 transects), but were similar between regions.

Study site selection

All transect counts in natural habitats were within protected areas or their immediate surroundings. To allow a direct comparison with protected areas, all transects in fields were within a few kilometres from these natural woodlands. As a result, their avifauna may have been augmented, both qualitatively and quantitatively, by birds spilling over from nearby undisturbed habitats. Therefore, the differences between the two habitat types were likely to be minimized by this relative proximity (landscape connectivity) compared with similar fields much further from large patches of little disturbed woodlands.

Environmental variables

To assess habitat or landscape structure and various consequences of human pressure likely to affect habitat quality or food availability for birds, I measured semi-quantitative variables along every transect counts.

Tree cover. In natural savannas, I attributed to each transect an average index of tree height and density. At one random point in each 1-km segment of the transect, the dominant habitat feature was scaled as follows: 0 = open, almost treeless grass savanna; 1 = shrub savanna with low trees (5–20 m); 2 = savanna woodland with tall trees (15–25 m); 4 = dense, tall gallery forest, often narrow and fragmented. The sum of the 5 scores gave an overall index of tree cover for each transect (0–20, in fact all from 3 to 17). The grass cover was not taken into account because it was dry, hence lowered or more often recently burnt at the time of the survey.

In cultivated areas, habitat structure was so different from natural vegetation that a similar index was not applicable. So, I measured a mean tree density in bare fields (number of isolated trees within a 100 m-radius at four random points) and a proportion of fallow scrub crossed or skirted by the whole transect trail (in four classes, from 0–25 to 75–100%).

Woodcutting. Number of areas with signs of (mostly firewood) exploitation, i.e. people carrying wood or an axe, piles of cutwood and/or trees cut, along each 5-km transect.

Cattle grazing. Number of herds (groups of any domestic animals, even free roaming) and/or areas with fresh dungs (<1 month) within sight along each transect.

Hunting pressure. I used the number of people carrying a gun met with along transects, and discarded cartridges found, only as an indication of hunting pressure, but both were too elusive and easily missed to be reliably quantified. Therefore, the index chosen was the number of medium size to large mammals seen along each transect (small and large antelopes, warthogs and elephants). Smaller game (e.g. hares, mongooses) were too little detectable to be quantified.

The above four environmental variables were assessed in savanna woodlands only, because in cultivated areas the tree cover was measured differently, wood cutting was rare (lack of trees to be cut), livestock was everywhere in the dry season, and hunting was very occasional (lack of game).

Density of *human population* or villages was not assessed because people and settlements were seen along every transect in cultivated areas and none of them on natural savanna transects.

Bird community

Large birds were selected because they are conspicuous and easy to count over large open areas, even outside the breeding season and early morning hours.

Conversely passerines were wandering in flocks and drab plumages, or they were too secretive. Therefore all medium size and large land birds (non-passerines) were counted, except the rarely seen kingfishers (*Halcyon*) and the Glossy Starlings (*Lamprotornis*), pigeons and doves (Columbidae) which were too numerous everywhere and moving in flocks over long distances.

This segment of the bird community represented a wide array of habitat and foraging requirements, including both specialists and generalists, and was likely to be indicative of habitat changes. They were divided into subsets of ecologically similar species, i.e. six groups of non-raptor landbirds (35 species) and six groups of diurnal birds of prey (Falconiforms), hereafter called raptors (41 species). Their natural history traits were derived from field observations, previous experience and data in Borrow and Demey (2001).

Landbirds included (Appendix 1) 1/9 *game birds*, i.e. the most regularly hunted species, ground-living and usual prey of eagles, 2/5 other *terrestrial*, or at least ground-feeding species, not hunted; 3/10 *arboreal*, frugivorous or insectivorous species associated with trees, woodlands or gallery forests; 4/5 aerial, flycatching *bee-eaters*; 5/4 perch-to-ground hunting *rollers* and 6/2 tree-living but often ground-feeding small *hornbills*.

Raptors were highly diversified (41 species, Appendix 2). Resident species were breeding, sahelian and palearctic migrants were present, while many intra-African migrants (*Milvus*, *Aquila*, *Butastur*, etc …) had not yet departed (Thiollay 1978). They were divided, according to their ecology and usual habitat requirements, as follows:

1. Two *scavengers*, i.e. Black Kite and Hooded Vulture, are more commonly and permanently associated with human settlements and refuse than with natural savannas and food resources (wild fires, carcasses, ponds). They were expected to be the species most positively associated with densely inhabited areas.
2. Five larger *vultures* (78% were White-backed) are mostly dependent on carcasses of large mammals, both wild and domestic. They are not molested by local people and can breed on any large tree (except the cliff-nesting Rüppells' Griffon). So they were expected to be as abundant in cattle-rich inhabited areas than in game-poor natural savannas.
3. Because they are feeding almost exclusively on reptiles, the four *Snake Eagles* were set apart from other eagles, together with the small *Booted Eagle*, a European migrant, active predator of medium-sized birds and the only eagle frequent in cultivated, even sometimes suburban, areas.
4. All eight *larger eagles* were grouped, together with the odd Secretary Bird, because of their reliance on little disturbed habitats.
5. Thirteen other *Accipitrids*, i.e. small and medium-size hawks, kites, harriers and buzzards, reasonably tolerant to disturbance and habitat degradation, were pooled into a single category.
6. The three *kestrels*, sit-and-wait hunting small ground prey, and the four larger *falcons*, mostly hunting birds in flight, were grouped on the basis of their taxonomic affinities and common open habitats.

Data analysis

No attempt was made to estimate detection probabilities and resulting biases because 1. specific differences were assumed to be similar among regions, 2. comparisons were made only within, not between, groups of behaviourally similar species, 3. the use of groups minimized the effect of possible undetected species, and 4. birds were more likely to be missed in denser natural woodlands than in open fields. This potentially strengthened the often lower abundances observed in the fields.

The hypothesis was that the bird community composition was formerly the same in all three regions because of geographical proximity, habitat, latitudinal and climatic similarity. Indeed, all species had been recorded in all three areas during personal surveys in 1968–1973. Therefore only species abundances were expected to change with habitat degradation and were compared among regions and habitats.

Data did not always meet normality assumptions (Shapiro–Wilks statistics performed). Therefore, I used non-parametric Mann–Whitney U tests to assess the significance of differences in mean numbers of birds per transect between two habitats or years. To assess differences in abundances across regions, I used ANOVAs on log $(x + 1)$ transformed data in savannas, because some samples had no record and parametric ANOVAs produced more conservative levels of significance than non-parametric tests. When comparing regional abundances in cultivated fields however, Kruskal–Wallis ANOVAs were used instead because some species groups had null variances (absences), which prevented the use of parametric ANOVAs. A Spearman rank-order correlation coefficient was used to assess the relationships between environmental variables and regional abundances of species groups. The significance of r_s was computed using critical r_s values for calculated z values and sample sizes of $n = 30$ (Siegel and Castellan 1988). The most significant of these variables was identified in a multiple linear regression using species abundance as the dependent variable and tree cover, grazing, wood cutting and hunting as independent variables.

Results

Regional abundances of birds in savanna woodlands

All *non-raptors*, together, were significantly less numerous in the Central region (22.5 per transect) than in Eastern and Western regions (31.4–39.3, KW ANOVA, $H = 10.30$, $p = 0.006$, Table 3). Among them, arboreal species and Hornbills were significantly more abundant in the more forested Western region (Table 3). The overall abundance of game birds was lowest but not significantly so (Table 2) in the Central study area. This may be indicative of sport hunting pressure in the otherwise, little disturbed natural habitats of the Nazinga game ranch. Interestingly, the rather secretive Francolins remained

Table 2. Bird abundances (mean number of individuals ± SE) per 5-km transect count across regions and years in natural savannas.

	Samples 2002			*p* (1) between regions	Samples 1972 East	*p* East (2) 1972/2002
	West	Centre	East			
Game birds	7.5 (±1.8)	4.0 (±1.2)	8.3 (±1.8)	0.053		
Other terrestrial species	1.6 (±1.1)	0.4 (±0.2)	1.5 (±1.1)	NS		
Arboreal species	12.6 (±1.9)	6.1 (±1.1)	6.3 (±0.8)	0.007		
Bee-eaters	4.3 (±0.8)	5.2 (±1.0)	5.4 (±1.1)	NS		
Rollers	2.3 (±0.7)	1.5 (±0.1)	2.4 (±0.3)	NS		
Hornbills	11.0 (±1.3)	5.3 (±0.8)	7.5 (±0.9)	*		
Scavengers	1.3 (±0.5)	0.6 (±0.2)	1.9 (±0.5)	(0.064)	2.7 (±0.5)	NS
Large vultures	0.0	0.5 (±0.2)	2.8 (±1.1)	*	4.7 (±0.8)	*
Snake-booted eagles	0.6 (±0.2)	0.2 (±0.1)	0.4 (±0.1)	NS	0.6 (±0.2)	NS
Large eagles + secretary bird	0.2 (±0.1)	1.6 (±0.3)	2.3 (±0.4)	*	3.2 (±0.4)	*
Other accipitrids	3.3 (±0.8)	1.7 (±0.4)	2.2 (±0.3)	0.045	2.6 (±0.5)	NS
Kestrels and falcons	0.6 (±0.3)	1.0 (±0.2)	0.5 (±0.1)	(0.096)	1.4 (±0.3)	**

Number of samples = 30 in each area and year.
NS is the non-significant difference between regions ($p > 0.100$); p in bracket, is the marginal significance * ≤ 0.05, ** ≤ 0.01.
(1) ANOVAs on log ($x + 1$) transformed data $F_{2,87}$.
(2) Paired t test.

Table 3. Bird abundances (mean number ±SE) per 5-km transect counts in cultivated fields (left half of the table) and significance of differences with abundances in natural savannas (see Table 2).

	Samples 2002			*p* fields (1) between regions	*p* savanna/fields (2)			
	West	Centre	East		Within regions			Regions pooled
					West	Centre	East	
Game birds	0.2 (+0.3)	0.0	0.0	NS	*	*	*	*
Other terrestrial species	4.1 (±1.6)	1.7 (±0.6)	1.8 (±0.8)	NS	*	0.005	NS	*
Arboreal species	3.5 (±0.9)	1.3 (±0.4)	1.6 (±0.3)	NS	*	*	*	*
Bee-eaters	1.6 (±0.7)	1.3 (±0.3)	1.4 (±0.5)	NS	0.007	*	*	*
Rollers	3.1 (±0.9)	1.3 (±0.2)	1.5 (±0.3)	NS	NS	NS	NS	NS
Hornbills	4.1 (±1.1)	1.3 (±0.3)	1.4 (±0.4)	(0.094)	*	*	*	*
Scavengers	0.7 (±0.4)	1.0 (±0.4)	3.1 (±0.8)	0.006	NS	NS	NS	NS
Large vultures	0.0	0.0	0.0	A	A	(0.067)	*	*
Snake + Booted Eagles	0.3 (±0.2)	0.7 (±0.7)	0.1 (±0.1)	NS	NS	NS	NS	0.045
Large eagles + Secretary Bird	0.0	0.0	0.1 (±0.1)	A	A	*	*	*
Other accipitridae	3.9 (±1.2)	0.9 (±0.3)	1.2 (±0.3)	0.042	NS	NS	(0.056)	(0.061)
Kestrels and falcons	0.9 (±0.3)	0.3 (±0.1)	0.3 (±0.2)	NS	NS	0.026	NS	NS

Number of samples : 15 (Centre) to 16 (West and East).
NS is the non-significant (>0.10); *p* in brackets is marginally significant; *highly significant (<0.005).
A is the absent or nearly so, in both areas.
(1) Kruskal–Wallis ANOVAs.
(2) Mann–Whitney *U* tests.

numerous in the West where local subsistence hunting does not primarily target medium-sized birds, whereas the bigger and more conspicuous and vulnerable Guinea fowls exhibited a 58% decrease compared to the Eastern protected areas. The most spectacular decline among game birds, only matched by that of vultures and eagles, was that of Bustards. During this month-long survey, I saw only a single (small) bustard, whereas 30 years ago, bustards of two species were encountered almost daily in all three regions. Bustards are much sought after game birds and highly sensitive to both hunting, disturbance and over-grazing. Ground Hornbills, another conspicuous big target for hunters, were also never recorded in 2002 in the West, whereas I saw them many times 30 years ago.

All species pooled, *raptors* were significantly more numerous in the Eastern zone (10.1 per transect) than in the Central and Western areas (5.6–6.0, Kruskal–Wallis ANOVA, $H = 9.13$, $p = 0.010$, Table 2). The number of species recorded increased from 24 in West to 30 in the Centre and 34 in East (Appendix 2). Their abundance and richness were even higher 30 years ago in Eastern National Parks (15.0 birds/transect, 39 species).

This West–East decrease, however, was significant (Table 2) only for large vultures and eagles which are probably the most sensitive raptors to habitat disturbance, persecution, hunting pressure or game abundance. Together they were 26 times less abundant in West than East in 2002, and even 40 times less than in national parks in 1972. The complete lack of records of the very conspicuous vultures and Bateleur in the Western section, in spite of careful searches, was especially striking, all the more because they still were seen daily in the same area and season 30 years ago (pers. obs.).

All other raptor species occurred in every region, even if they were not seen on transects from each of them (pers. obs.). Some species were recorded more frequently in the West because they were associated with more numerous gallery forests along western transects (Banded Snake Eagle, Harrier Hawk, Shikra, Lizard Buzzard). Others were significantly more frequent (ANOVA, $p < 0.05$) in Western (Booted Eagle, Marsh Harrier, Black Kite, Grasshopper Buzzard), or Eastern savannas (Hooded Vulture, Gabar Goshawk), but they were mostly concentrated on a few suitable, transects. None of the 17 remaining species was significantly more abundant in one region (too rare or local, or seasonal migrants).

Comparative bird populations in cultivated fields

No significant difference was found between fields of the three regions: the tree cover was variable but on average similar; cattle occurred on every transect; there was no evidence of wood cutting and hunting anywhere because of lack of dead wood and game. At the landscape scale, cotton fields were more frequent in the West and areas of degraded bushy savanna between fields tended to be larger in the East, but they were not (or marginally) included in samples.

The avian community of agricultural areas was everywhere an impoverished subset of that of savanna woodlands, but some species survived in fields much better than others.

Within fields alone, *non-raptor* species, altogether, were significantly less abundant in the Central and Eastern than the Western regions (6.9–7.7 vs 16.6 per transect, KW ANOVA, $H = 7.7$, $p = 0.022$, Table 3). All species pooled, *raptors* were least abundant in Central (2.9 birds/transect) than in Eastern and Western fields (4.8 and 5.8/transect, respectively), but not significantly so (KW ANOVA, $p = 0.116$). However, there was no significant difference in abundance of raptors in fields between the three regions for any species group, except the scavengers which were more numerous in East (Table 2).

Forty per cent of all raptors recorded in fields were the two human-associated scavengers (Black Kite and Hooded Vulture, Appendix 2). Another 25% were Grasshopper Buzzard, an African migrant mostly spending the dry season south of Burkina Faso, but coming back in March–April to breed commonly in and around cultivated areas (pers. obs.). Large trees scattered in fields and around villages were crucial for the maintenance of falcons, goshawks and Shikras. Fields were also a regular foraging habitat for wintering Palearctic migrants (Booted Eagle, Harriers, Common Kestrel).

Compared with natural savannas, the abundance of non-raptor species groups was either significantly much lower (game birds, arboreal species, bee-eaters, hornbills), or not significantly different (rollers), or significantly higher (terrestrial birds) in fields (Table 3). Overall, the abundance of non-raptors declined by 65% from savanna to cultivated areas and their species richness by 33%.

Overall, I counted on average 3.5–4 times less arboreal species, Bee-eaters and Hornbills in fields than in the savanna woodlands but almost as many Rollers and twice as much terrestrial birds (Table 2). The only game birds left were a few francolins. No bird was found in fields alone and only three species were significantly more abundant there (Cattle Egret, Black-headed Plover and Pied Crow), all of them commonly associated with cattle and human-made habitats.

Among *raptors*, the difference in abundance between fields and savannas (Table 2) was barely significant (slight decrease) for Snake- and Booted Eagles, as well, as for most medium-sized species (Appendix 2). Scavengers, Common Kestrel and Lanner Falcon were even more numerous in fields than in all savanna woodlands but the Eastern National Parks. Conversely, I did not record a single large vulture or eagle in cultivated areas, where they were still not uncommon 30 years ago (pers. obs.).

Correlates of population changes in savanna woodlands

The mean ($\pm$SE) tree cover index was slightly, but significantly lower in the Central area (7.07 ± 0.58) than in the West (9.40 ± 0.62) and East (9.03 ± 0.49) KW ANOVA, $H = 9.33$, $p = 0.009$), and similar between West

and East ($p = 0.732$). This may have contributed to a consistent trend of lower abundances in the Central region. The Spearman rank correlation coefficient of species abundance with this cover index was however different among species groups. It was highly significant ($p < 0.001$) only for arboreal species ($r_s = 0.781$) and hornbills ($r_s = 0.681$), and lower ($r_s = 0.310$–0.416), but still significant ($p = 0.003$), for Bee-eaters, game birds and the other Accipitrids category (Table 2). Conversely, there was no correlation between tree cover index and the abundance of any of the remaining seven species groups.

Observed grazing pressure (dry season) by domestic livestock decreased from West (mean index $= 2.0 \pm 0.7$) to East (0.1 ± 0.1), as also did the evidence of woodcutting (3.5 to 0/5 km-transect). There was a significant ($p < 0.06$) negative correlation between grazing or wood cutting and the abundance of large vultures and eagles, but not with any of the ten other species groups.

There was a similar relationship between hunting pressure and species group abundances: only the number of large vultures and eagles increased with that of wild mammals recorded along transects (considered to be inversely correlated with hunting pressure), from 1.1 ± 0.3 in Western protected areas to 25.3 ± 7.2 in Eastern National Parks. Hunting pressure also affected significantly the abundance of Guinea fowls, singled out of other, less sensitive, game birds. In a multiple linear regression, using the four environmental variables above as independent variables, the hunting pressure was the most significant determinant of large vulture and eagle abundance ($p < 0.001$).

Discussion

The surveys were extensive and numerous enough to give a representative picture of the local avifauna. They included some intra-African and Palearctic migrants, whose abundance may change between seasons (Thiollay 1978), but most species sampled were not known to perform seasonal movements. Many species survived in traditional fields with large trees but few of them ($< 20\%$) retained in cultivated areas a density as high as in natural savannas and woodlands.

In natural savannas, the relationship between tree cover and the abundance of birds was significant only for the most arboreal groups, including those often feeding on the ground (hornbills, small raptors, game birds). Otherwise the three study areas had similar enough habitats to be compared on the basis of anthropogenic impacts indicated by the increasing protection status and size of protected areas from West to East.

Human pressure

Different forms of nature resource exploitation usually occur together in the same area. Their effects are difficult to disentangle and to measure accurately.

They may affect each species differently according to its specific requirements, and they collectively account for what may be called human pressure.

Hunting is probably the most widespread activity, and it is likely to be inversely related to the strength of protected status or reserve size. It was the most significant environmental variable negatively correlated with the abundance of large game birds, vultures and eagles. Other species groups were not affected significantly and other human pressure components were less, or not obviously involved. Mammals are the first targets but also increasingly every large birds when mammals are disappearing. It is why big game extinction rate in West African reserves was better explained by surrounding human population size (an index of hunting pressure) than by reserve size alone (Bradshares et al. 2001). It is probably a major factor in the observed extinction of at least Guinea fowls and Bustards outside national parks, and through the decline of game birds, a contributing factor in the disappearance of eagles.

Bush fires are set everywhere, except in fields, usually as soon as the grass cover is dry enough, without detectable difference between study areas. Many species are attracted by fires and recently burnt savannas. But they rarely stay for long and have to move extensively during the dry season. The long-term benefit of fires for species, which are not fire-followers, is questionable.

Timber and firewood harvesting effects depend on the proportion of stems removed and habitat selection of the birds involved (Aigner et al. 1998). The decrease of large trees in gallery forests may be a threat for cavity nesting birds or some frugivorous species (Du Plessis 1995).

Livestock grazing also may have several negative effects (Saab et al. 1995) through persistent disturbance, trampling, reduction of grass cover, pruning or cutting trees for fodder and repeated burning of savannas. Many nests are robbed by shepherds.

In *agricultural areas*, compared to adjacent natural habitats, the decrease of bird species richness and abundance, and shift in community structure are well known (Wilson et al. 1997). In Tanzania, more than 50% of both insectivorous and granivorous birds were not recorded in cultivated fields where the density of the remaining species was on average 28% of their abundance in their native savanna (Sinclair et al. 2002). In the traditional fields studied here, most birds were associated with the large trees left throughout, together with the proximity of natural savannas, if not forest patches. The increasingly widespread cotton fields (not censused) were much poorer probably because they were more intensive monocultures, with heavy pesticides spraying and few trees left.

Species declines

The main significant declines, from the Eastern Uninhabited national parks to the Western more exploited forest reserves, were those of the largest and most conspicuous terrestrial game birds (Guinea fowls, bustards, Ground Hornbill) as well as vultures and eagles. It is well known that such species more often

survive in protected areas (Herremans 1998). Their decrease or disappearance from large areas of West Africa has also been documented in Ivory Coast and Cameroon (Thiollay 1998, 2001).

The decline of large raptors within natural savannas was perceptible in the comparison between the counts of 1972 and 2002 in Arli and W National Parks (Appendix 2) and from former published data (Green and Sayer 1979; Thonnérieux 1989). Accurate raptor counts in Nazinga game ranch made in December 1991 produced a higher frequency of White-backed Vulture, large eagles and also Chanting Goshawk Weesie and Belemsobgo 1997). The downturn of eagle populations may be related to the impoverishment of their prey base due to overhunting, to habitat degradation and to the fragmentation of their populations more and more isolated in protected areas. Conversely, direct persecution is unlikely to be widespread and is rarely mentioned by local people. The indirect effect of the extinction of large predators, through the subsequent increase of smaller predators, is a well known threat to bird communities (Berger et al. 2001) but there is still no evidence of such a phenomenon in West Africa.

The decline of vultures has no obvious cause. Although wild ungulates are disappearing, cattle is still abundant, if not increasing everywhere, and carcass availability should not be a limiting factor. Incidental killing of vultures during poisoning operations of jackals or hyenas has been mentioned and indiscriminate uses of pesticides, rodenticides or veterinary medicines, that are now provided freely by international aid, are additional threats.

The equally dramatic decline of large terrestrial birds may be primarily attributed to overhunting. However, increasing disturbance by cattle and woodcutters and habitat disturbance or impoverishment by increasing human activities (population growth) may be decisive additional factors. Moreover, their ground-nesting habits make them especially vulnerable to disturbance.

The loss of large species occurred during the last decades over all the savannas of Burkina Faso (personal extensive surveys), even though it was more marked in the densely populated areas of the Western region. In natural habitats, only the largest species (game and raptors) were visibly affected, a typical pattern of early biodiversity decline.

Patterns of habitat use

Many of the species studied had their highest frequency in stands of high trees, used as foraging, nesting or roosting sites, from where they readily foraged in surrounding more open savanna woodlands. Thus the richest natural habitat was the association of gallery forests and open park-land savanna. Habitat degradation and loss of species richness and abundance occurred when clearings for cultivation, cattle grazing and wood cutting reduced large trees and

grass cover, which together were the preferred foraging sites of a majority of large birds.

Indigenous cultivated fields, dotted with large trees, often free of pesticides and surrounded with bushy long-term fallow areas, were suitable, if not sometimes optimal habitats for a few bird species, including rollers and several raptors, let alone crows, plovers and Cattle Egret, traditionally associated with farmlands. Both ploughing and grazing reduce grass and tree cover, favouring open grassland and generalist species as long as pesticides and hunting do not impact insect and bird populations. Large trees, like paddock trees in Australian pastures (Fischer and Lindenmayer 2002) also maintain forest or arboreal species and potentially enhance connectivity between natural woodland patches. Bird diversity however decreased even in such wooded fields, because many of the woodland taxa were specialists, sensitive to habitat disturbance (Petit and Petit 2003; Söderström et al. 2003).

Protected area management and conservation

The results suggest that the multiple use of Western forest reserves (be it legal or not) is less effective in conserving bird diversity, than the lower human pressure provided by the national park status or at least by larger, more remote uninhabited natural woodlands. It was not possible to single out the most critical factor likely to be responsible for the loss of biodiversity, but comparative patterns of habitat and avifaunal changes gave some clues.

The general decline of many species from natural savannas to cultivated areas is an indication that habitat structure, or composition, or the food supply associated with them, were a significant factor. The total area of natural habitat may be less of a problem than its fragmentation and associated increase of human disturbance into smaller core areas. The Western region has a similar area of savanna woodlands than the other regions, but divided into several small patches, instead of two larger blocks in the Centre and a single wide continuous area in the East. There is however no specific study on the critical size of little disturbed habitat necessary to maintain viable populations of large game birds, eagles or vultures.

Prescribed burning in early dry season seemed to be implemented widely, since most areas surveyed in December were already burning or recently burnt. This is done to prevent later and stronger fires and to promote an early regrowth of grass for ungulates. The overall effect of burning has been (Gillon 1983) and is still much debated.

Cattle probably had not the same impact as wild ungulates in parks. It usually has a more patchy grazing pressure, more concentrated on grass and often reaches higher densities. Shepherds also cut many branches or trees to feed cattle and often rob many bird nests. Moreover, they increasingly sell animals before they die, reducing carcass availability for vultures.

Fuelwood cutting was obvious from the many women, donkeys or carts, loaded with wood, going out daily from Western forests. This pressure was proportional to the proximity of villages, roads and markets, which strikingly decreased from West to East. Together with some logging for timber of big trees, fuel wood collection may have had a severe impact on woodlands.

Hunting, which is independent of habitat degradation, may occur anywhere but was probably heavier in the West, where mammals had been exterminated, and in the Central game ranch, than in the Eastern region where it was better controlled. It may be a major, if not the main cause for the decline of game birds and probably a negative factor for large eagles.

Maintaining biodiversity at patch and landscape scales requires a detailed monitoring of the dynamic of these changing habitats (Szaro 1996). The next step is to prevent habitat degradation, unsustainable use and unregulated hunting and to define management rules and even a restoration strategy. The most sensitive birds may be used as surrogates and indicators for testing habitat quality and management options (Caro and O'Doherty 1999). The range of protected areas surveyed here has proved to have different conservation results, but none of them was able to fully stop a continuing erosion of biodiversity.

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Appendix 1. Non-raptor species recorded in 30 5-km transect counts in each region and habitat types in Burkina Faso.

	Group	Natural woodlands			Cultivated fields
		West	Centre	East	
Double-spured Francolin, *Francolinus bicalcaratus*	G	126[a]	41	52	3
Stone Partridge, *Ptilopachus petrosus*	G	14	8	19	
Helmeted Guinea fowl, *Numida meleagris*	G	64	51	136	
White-bellied Bustard, *Eupodotis senegalensis*	G	1			
Senegal Thick-knee, *Burhinus senegalensis*	G	2[b]	10	6	

Appendix 1. Continued

	Group	Natural woodlands			Cultivated fields
		West	Centre	East	
Four-banded Sandgrouse, *Pterocles quadricinctus*	G	133	16	25	
Ground Hornbill, *Bucorvus abyssinicus*	G		7	3	
Cattle Egret, *Bubulcus ibis*	T	31		2	48
Black-headed Plover, *Vanellus tectus*	T	4	1		12
Senegal Wattled Plover, *Vanellus senegalus*	T	3	10	34	
Black Magpie, *Ptilostomus afer*	T	3		9	2
Pied Crow, *Corvus albus*	T	8			13
Senegal Parrot, *Poicephalus senegalus*	A	145	85	80	25
Rose-winged Parakeet, *Psittacula krameri*	A	51	22	13	10
Grey Turaco, *Crinifer piscator*	A	95	27	25	17
Violet Turaco, *Musophaga violacea*	A	22		2	
Striped and Grey Cuckoos, *Clamator levaillanti* and *Cuculus gularis*	A	1		1	
Senegal Coucal, *Centropus senegalensis*	A	12	7	7	2
Hoopoe, *Upupa epos*	A	3	1	3	
Senegal Wood-Hoopoe, *Phoeniculus purpureus*	A	48	42	53	13
Lesser Wood-Hoopoe, *Rhinopomastus aterrimus*	A		2	7	
European Bee-eater, *Merops apiaster*	B	31		2	5
Little Green Bee-eater, *Merops orientalis*	B	65	41	49	40
Carmine Bee-eater, *Merops nubicus*	B	13	4	31	2
Little Bee-eater, *Merops pusillus*	B		2	2	
Red-throated Bee-eater, *Merops bulocki*	B	18	102	79	
Abyssinian Roller, *Coracias abyssinica*	R	58[c]	32	55	46
Rufous-crowned Roller, *Coracias naevia*	R	11	8	17	15
Grey Hornbill, *Tockus nasutus*	H	89	46	63	31
Red-beaked Hornbill, *Tockus erythrorhynchus*	H	241	115	159	36
Total individuals		1172	680	933	321
Total species		31	23	26	18

[a]Including 2 *Francolinus albogularis*.
[b]Including 1 *Burhinus capensis*.
[c]Including 6 *Coracias cyanogaster* and 1 *Eurystomus glaucurus*.
G – game birds; A – arboreal species; T – terrestrial (or ground feeding) birds; B – *Meropidae*; R – Coraciidae; H – small *Bucerotidae*.

Appendix 2. Dry season abundance of raptors in Southern Burkina Faso.

	Group	Natural woodlands				Cultivated fields
		West	Centre	East	1972*	
Black Kite, *Milvus migrans* (A)	S	18	2	5	23	15
Hooded Vulture, *Necrosyrtes monachus*	S	21	16	53	58	34
Palm-nut Vulture, *Gypohierax angolensis*	V			1	1	
African White-backed Vulture, *Gyps africansu*	V		9	58	115	
Rüppell's Griffon *Gyps rueppellii*	V			17	11	
Lappet-faced Vulture, *Aepypius. tracheliotus*	V			1	4	

Appendix 2. Continued

	Group	Natural woodlands				Cultivated fields
		West	Centre	East	1972*	
White-headed Vulture, *Trigonoceps occipitalis*	V		4	5	9	
Short-toed Snake Eagle, *Circaetus gallicus* (P)	E				2	
Beaudouin's Snake Eagle, *Circaetus beaudouini*	E	3	1	7	9	1
Brown Snake Eagle, *Circaetus cinereus*	E	1	1	3	3	
Smaller Banded Snake Eagle, *Circaetus cinerascens*	E	4	1	1	1	
Booted Eagle, *Hieraaetus pennatus* (P)	E	10	3	3	2	4
African Fish-Eagle, *Haliaeetus vocifer*	L	1	2	9	11	
Bateleur, *Terathopius ecaudatus*	L		44	41	52	
Tawny Eagle, *Aquila rapax*	L		1	5	6	
Wahlberg's Eagle, *Aquila wahlbergi* (A)	L		2	10	13	
African Hawk-eagle, *Hieraaetus spilogaster*	L	4	1	1	3	
Ayres's Hawk-eagle, *Hieraaetus ayresii*	L			1		
Long-crested Eagle, *Lophaetus occipitalis*	L				4	
Martial Eagle, *Polemaetus bellicosus*	L	+	+		1	
Secretary Bird, *Sagittarius serpentarius*	L				4	
African Cuckoo-hawk, *Aviceda cuculoides*	O		1			
Black-shouldered Kite, *Elanus caeruleus*	O			1	2	
African swallow-tailed Kite, *Chelictinia riocourii*	O				10	
African Harrier-hawk, *Polyboroides typus*	O	6	2	3	6	
Pallide Harrier, *Circus macrourus* (P)	O	2			2	
Montagu's Harrier, *Circus pygargus* (P)	O	2	1	7	16	2
Marsh Harrier, *Circus aeruginosus* (P)	O	14	8	9	3	3
Gabar Goshawk, *Micronisus gabar*	O	3	2	6	5	7
Dark Chanting Goshawk, *Melierax metabates*	O	8	3	7	7	3
Shikra, *Accipiter badius* (A)	O	25	16	14	9	5
Grasshopper Buzzard, *Butastur rufipennis*	O	23	16	14	11	31
Lizard Buzzard, *Kaupifalco monogrammicus*	O	15	4	2	3	2
Red-necked Buzzard, *Buteo auguralis* (A)	O	2		2	2	
Common Kestrel, *Falco tinnunculus*	F	2	3	3	22	5
Fox Kestrel, *Falco alopex*	F		4	3	2	
Grey Kestrel, *Falco ardosiaceus*	F	15	17	6	6	6
Red-necked Falcon, *Falco chicquera*	F	+	+	1	2	
African Hobby, *Falco cuvieri*	F	1	2	1	3	
Lanner Falcon, *Falco biarmicus*	F	1	1	1	6	5
Peregrine Falcon, *Falco peregrinus*	F		2	1	2	
Total individuals		181	169	302	451	124

Numbers of individuals recorded in 30 5-km transect counts in each region in 2002 (see Study areas) and on the same eastern transects in 1972*. The 47 counts in cultivated fields (15–16/region) were pooled, and, for comparison with woodlands, results were given as mean numbers per 30 counts (rounded to the nearest unit). The piscivorous migrant Osprey, *Pandion haliaetus*, was recorded on a single transect (Mare aux Hippopotames, Western Region).

Species groups: S – scavengers; V – large vultures; E – Snake and Booted eagles; L – large eagles; O – other, smaller accipitridae; F – falcons (Falconidae).

+ = recorded once outside transect counts; (P) = palearctic migrants. *Falco tinnunculus* and *F. peregrinus* may also include wintering migrants; (A) = most typical African migrants (Thiollay 1978).

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