Raptors in changing West African savannas : the impact of anthropogenic land transformation on populations of Palearctic and Afrotropical raptors in northern Cameroon

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Chapter 9

Raptor habitat use in the Lake Chad Basin: insights into the effect of floodplain transformation on Afrotropical and Palearctic raptors

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Abstract

West African floodplains have undergone major land-use transformations in the second half of the twentieth century. To obtain insight in the effect of floodplain development for irrigated rice cultivation on the abundance, richness, and diversity of Palearctic and Afrotropical raptors, we conducted monthly transect surveys covering dry and wet seasons in four major habitats on the Waza-Logone floodplain of Cameroon: dry grasslands, cultivated grasslands, rice fields, and seasonally flooded grasslands resembling natural floodplain vegetation. We recorded 36 raptor species among 2,533 individuals, dominated by Black Kites *Milvus migrans*, which comprised 42% of counts. Although richness and diversity was not related to land-use for Palearctic raptors, Afrotropical raptor diversity was higher on the flooded grasslands compared to the newly created cultivated habitats and dry grasslands. The abundance of Afrotropical raptors did not significantly differ across habitats but was lower in rice fields when Black Kite and Hooded Vulture *Necrosyrtes monachus* were excluded. Conversely, Palearctic raptor abundance was highest in post-harvest rice fields, demonstrating the importance of the rice fields as foraging habitat for Palearctic raptors. Further transformation of West Africa's floodplains is expected, reducing their capacity for Afrotropical raptors, while Palearctic raptors may benefit from expansion of rice fields, but more research is needed on their vulnerability to pesticide use.

Left: Long-crested Eagle in a recently harvested rice field on the Waza-Logone floodplains.

9.1 Introduction

Raptors are generally recognised as being sensitive to environmental change triggered by anthropogenic causes (Sergio *et al*. 2006, 2008), but moderate habitat alteration may positively influence raptor diversity and abundance if it coincides with increased foraging and nesting availability (Rodríguez-Estrella *et al*. 1998, Sánchez-Zapata & Calvo 1999). However, increasingly rapid processes of urbanization and agricultural intensification in developing countries may negate the adaptive response of raptors to semi-natural habitats created over longer periods by humans (Carrete & Donázar 2005). In West Africa, the seasonally flooded grasslands of the Senegal River Delta, the Inner Niger Delta, the Lake Chad Basin, and their associated river systems are prime examples of habitats which have been rapidly and dramatically altered by developments aimed at fulfilling the needs of growing human populations (Zwarts *et al*. 2009). Embankments of many West African floodplains in the second half of the twentieth century for the development of rice irrigation schemes preceded the conversion of highly productive, seasonally inundated grasslands into semi-natural habitats dominated by desiccated grasslands, cultivated fields, and human habitation. Such developments severely impacted the dynamics of the floodplains, significantly depressing their productivity and associated wildlife populations (Loth 2004, Zwarts *et al*. 2009). Raptors were correspondingly affected, their declines in the West African inundation zones being among the most severe in a vast region of central West Africa between 1973 and 2004 (Thiollay 2001, 2006a).

Despite their great importance to raptor populations, particularly Palearctic raptors (Thiollay 1989), the utilization by raptors of West Africa's floodplains and their associated cultivated habitats have been relatively little studied (Thiollay 1978b, Zwarts *et al*. 2009). In the absence of studies on habitat use, it is unclear how habitat transformation on floodplains may have impacted Afrotropical and Palearctic raptors. Our aim here was to examine habitat use by raptors on the Waza-Logone floodplain in northern Cameroon, to evaluate the effect of floodplain habitat modification on the abundance, diversity and richness of Afrotropical and Palearctic raptor assemblages. Since distribution patterns of raptor populations in West Africa are highly dynamic due to almost continuous displacements in response to seasonal rains and changes in prey availability (Thiollay 1989), our assessment included monthly counts, incorporating dry and wet seasons. Based on previous findings (Thiollay 2001, 2006b, Anadón *et al*. 2010), we predicted that the habitats least affected by development and human exploitation, i.e. the seasonally flooded grasslands and dry, protected grasslands, are preferred over cultivated habitats by Afrotropical raptors, indicated by their greater abundance, diversity and richness. Conversely, Palearctic raptors have been shown to be generally less sensitive to human exploitation, readily foraging over disturbed and cultivated habitats (Herremans & Herremans-Tonnoeyr 2000, Limiñana *et al*. 2012, this thesis). For this reason, the abundance, diversity and richness of Palearctic raptors was expected to be greater in transformed grasslands with sorghum- and rice fields, which harbour abundant and easily accessible rodent prey (Poulet 1985, Chapter 2), compared to flooded or dry grasslands.

9.2 Materials and methods

Study area

The study area was situated in the Waza-Logone floodplain of the Far North of Cameroon, on the inundation zone of the Logone River, which is part of the more extensive Lake Chad Basin (10º45'N-11º35'N and 14º34'E-15º05'E; Figure 1). The Waza-Logone floodplain is located in the transition zone between the Sudan and Sahel climatic zones in Cameroon and encompasses desiccated and flooded grasslands, open savanna woodland, and cultivation, notably rice and dry-season sorghum. The area was designated a Wetland of International Importance by the Ramsar Convention in 2006, for its important wildlife concentrations including migratory and African wetland birds. Part of the floodplain is protected in the Waza National Park, proclaimed as Biosphere Reserve in 1979 (WCMC 1983). Lake Maga, an artificial wetland resulting from the construction of the Maga dam, the Logone floodplains and Waza National Park are Important Bird Areas (BirdLife 2011a,b,c). The climate is semi-arid, with rainfall mostly occurring between June and September (*c.* 500-600 mm/annum).

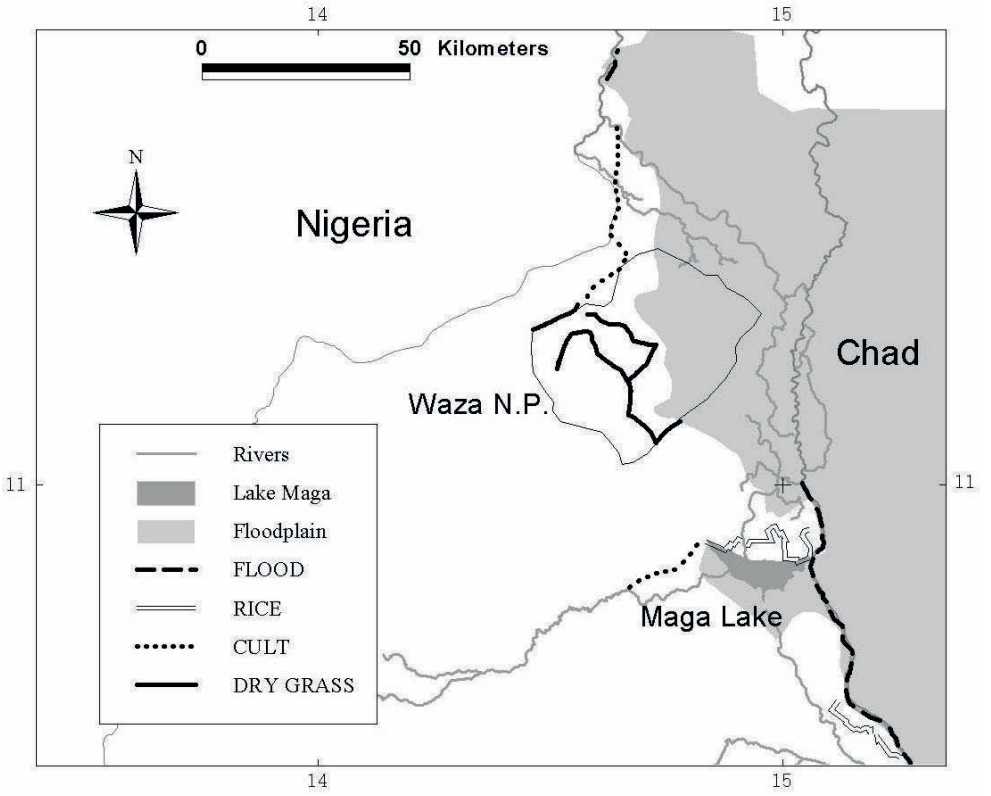

Figure 1. Location of roads used for transect surveys in the Lake Chad Basin of northern Cameroon.

The floodplains are situated along the Logone River, largely east and north of Waza National Park, with a surface area of 8000 km^2 in Cameroon. The inundation in the Waza-Logone floodplain extends from August to November in average years, and duration, depth and extent of flooding is much lower during dry years (Scholte *et al*. 2000). An earthen dam was constructed along the Logone River in 1979 to allow the development of a rice irrigation scheme with 70 km^2 rice fields, reducing flooding on 1,500 km^2 of the floodplain. The negative impact on the ecology of the plains, its grass species composition and biomass, herbivore and bird populations was partly rectified in 1994 through the breaching of the dam just north of the rice fields (Loth 2004). The ecological success from the partial re-flooding of the desiccated plains triggered human immigration into the area, leading among others to a threefold increase in livestock numbers (Scholte 2003). The dry plains are used for sorghum cultivation in the dry season (October–April), when rice fields are mostly inactive, partly burnt, and grazed by livestock. The floodplains are home to antelope populations, such as Kob *Kobus kob* and Topi *Damaliscus korrigum*, mostly inside the national park. Since the mid 1960s their numbers have declined 94 and 96%, respectively, following droughts, the damming of the Logone River, and, more recently, poaching inside the park.

Habitat types

We conducted surveys along transects in four major floodplain habitat types. Landsat MSS satellite images in combination with field observations were used to distinguish between major habitat types differing in degree of transformation and productivity:

1) Dry grasslands (DRY GRASS). Largely desiccated floodplain with woodlands on higher grounds, located entirely inside Waza National Park. The habitat is dominated (95%) by *Sclerocarya birrea* on higher ground and *Acacia seyal* on black clay soils which become saturated with water during the rainy season and which are covered in annual herbs and grasses such as *Sorghum arundinaceum*. Sections of the habitat (2–25%) are still inundated from August to November but the area affected by inundation and depth of the floodwaters declined considerably with the construction of the Maga dam. Numerous artificial and natural waterholes surrounded by *Tamarindus indica* and *Balanites aegyptiaca* trees hold water until the second half of the dry season;

2) Cultivated grasslands (CULT). Located outside the park. Similar habitat as previous, a desiccated floodplain dominated by *Acacia seyal* trees and numerous pools surrounded by stands of *Tamarindus indica* and *Balanites aegyptiaca*, and some flooded areas during the wet season. Wood cutting has reduced woody plant cover, notably *Acacia seyal*. This area is interspersed by traditionally cultivated dry-season sorghum in so-called "Karal fields" (*c.* 30% of total land cover), and few villages;

3) Irrigated rice fields (RICE). Located north of the Lake Maga dam and along the Logone River, rice fields make up > 85% of the surveyed habitat. The area is no longer subject to seasonal flooding. Reedbeds (*Typha*), small shrubs (*Mitragyna*, *Acacia*, *Ziziphus*) and annual grasses and herbs fringe the lake and the network of canals that border the irrigated

rice fields. Scattered Karal fields remain in between the rice fields (< 0.05% of the surface area). Rice is cultivated biannually, in April–June and August–October, and harvested in June and October. Rice fields are largely dry between October and March, when fires and grazing further reduce the remaining rice stubble and sparse herbaceous cover. Most trees have been removed to prevent breeding of Red-billed Queleas *Quelea quelea* apart from stands of *Azadirachta indica* and *Eucalyptus* around numerous villages and few palms (*Hyphaene thebaica*, *Borassus aethiopum*), larger *Acacia* and *Faedherbia albida* trees;

4) Seasonally flooded grasslands (FLOOD). The habitat is dominated (65%) by grassy plains, which are partly flooded from August to November and covered with perennial grasses such as *Echinochloa pyramidalis*, *Oryza longistaminata*, *Hyparrhenia rufa* and *Vetiveria nigritana* (Scholte *et al*. 2000). Part of the habitat (*c*. 35%) consists of raised and non-flooded areas with mature *Faedherbia albida*, *Hyphaene thebaica* and *Borassus aethiopum* among small-scale cultivation and scattered human settlements (permanent and temporary).

Survey methods

Raptor surveys were performed along ten transects of 2 km each, totalling 20 km in each of the four major habitat categories (Figure 1). First, the entire road network in the study area was mapped, after which dirt and tar roads which were known to be navigable at least 10 months of the year were selected. In all habitats 70–90 km of navigable roads were identified. To reduce autocorrelation between them, transects were allocated in each habitat type using randomly generated GPS locations on the navigable road network in ArcView GIS 3.2 software (Esri 1999) and the linear distance from the end of one transect to the start of the next was held at min. 2 km and max. 4 km. As raptor habitat utilization is likely to vary seasonally due to effects of cultivation, grazing, floods, fires, and rains, surveys were repeated at monthly intervals, and each transect was surveyed once per month between October 2007 to July 2008 for a total of 10 surveys for each transect (i.e. 800 km driven in total). We conducted surveys during the first ten days of each month and consisted of a combination of road surveys from a driving vehicle, and spot counts to assess raptor presence along transects, with the two observers scanning each one side of the transect. While road surveys have proven useful for comparisons of raptor community composition between habitats (Fuller & Mosher 1981, Bibby *et al*. 1992), they were combined with spot counts because these enhance detectability of raptors hunting on the wing (Herremans & Herremans-Tonnoeyr 2000). We incorporated a 2-min spot count halfway each 2-km transect, during which both observers scanned for raptors. To standardise count efforts, the total time spent surveying a 2-km transect was held at *c*. 15 min. Surveys were conducted only with fine weather, i.e. clear or slightly clouded skies with low to moderate winds, starting at 06:30 to 07:30 depending on the season (and the increase in air temperature). Transect surveys for a single habitat type were always conducted within 3 hours including time to traverse distances between transects, thus covering peak activity hours of all recorded species. All diurnal raptors perched or flying within eyesight range, on either side of the road and during spot counts were recorded with a GPS and identified with 10 x 42 binoculars. GPS positions were taken of birds perpendicular to the transect line, thus raptors

detected beyond either end of the transect were not included. The perpendicular distance from the road to each perched or flying raptor at the location of initial detection was measured with a calibrated rangefinder, which enabled estimation of the effective strip width (ESW; Buckland *et al*. 1993) to evaluate potential differences in raptor detectability between habitat categories which would confound comparisons of relative abundance between habitats. To examine changes in herbaceous cover which affects foraging site selection in raptors by influencing prey accessibility (Preston 1990), the percentage cover of the rooted herbaceous vegetation along transects was characterised at 1-km intervals using a nested 2-ha plot centred on the road.

Palearctic and Afrotropical raptors

Data were pooled for Palearctic migrants and Afrotropical species according to the breeding range of the majority of individuals making up the populations in the region (Thiollay 1977a). Palearctic migrants are species which breed in Eurasia or Northern Africa and spend the Palearctic non-breeding season in sub-Saharan Africa (juveniles of various species also spend the northern breeding season in the Sahel; Thiollay 1977a). Afrotropical species were recorded in the area during a large part of the year (timing different per species) and many were recorded breeding, including those species with long- (e.g. Wahlberg's Eagle *Aquila wahlbergi*; Meyburg *et al*. 1995) and short-distance seasonal displacements (Grasshopper Buzzard *Butastur rufipennis*), and/or nomadic movements (e.g. Black-winged Kite *Elanus caeruleus*; Thiollay 1977a). Black Kite *Milvus migrans* populations were composed of Afrotropical Yellow-billed Kites (*M. m. parasitus/aegyptius*; Johnson *et al*. 2005) and Palearctic Black Kites (*M. m. migrans*) and the two races could not be safely distinguished most of the time. However, the majority of individuals identified (> 98%) referred to *M. m. parasitus/aegyptius* and Black Kite was therefore treated as an Afrotropical raptor.

Statistical analyses

To determine whether detectability of raptors differed between habitat categories, we calculated ESW for raptors in each habitat category using Distance 6.0 software (Thomas *et al*. 2006). Raptors were grouped to three size categories based on mean adult body mass (small: < 300 g, medium-sized: 300–800 g, large: > 800 g; Ferguson-Lees & Christie 2001) assumed to have approximately comparable detectability. To determine ESW separately for each raptor size category, six combinations of key functions with expansion series were used to model the detection functions: the half-normal key function with cosine and hermite polynomial adjustment terms, the hazard-rate key function with cosine and simple polynomial, and the uniform key function with cosine and simple polynomial. Following Buckland *et al*. (1993), models with the lowest Akaike Information Criterion (AIC) value was selected for estimation of ESW and significant differences of ESW between habitats for each size category were based on overlap of 95% confidence intervals.

For comparing richness and diversity of the raptor assemblage between habitat categories, we used sample-based rarefaction, which allowed for the statistically robust comparisons based on equivalent numbers of individuals and samples (Colwell *et al*. 2004). Sample-based rarefaction computes the expected number of species when samples are drawn at random (without replacement) from a set of samples that are collectively representative of an assemblage (Gotelli & Colwell 2001). We used the cumulative species number on the 2-km transects (n = 10 in each category) as our units of replication. The Mau Tau estimator of rarefied species richness (Mao *et al*. 2005) was used to compute rarefaction curves in EstimateS Version 8.0 software (Colwell 2006). Samples were randomised 50 times for each dataset. We standardised comparisons by comparing expected species numbers at equal effort (i.e. similar number of individuals observed; Gotelli & Colwell 2001). Differences in species diversity were compared in EstimateS using Shannon diversity estimates, which weighs species proportionately to their frequencies in the sample rather than favoring common or rare species such as species richness or other diversity indices (e.g. Simpson's index; Jost *et al*. 2006). We used sampling with replacement which allowed estimation of confidence intervals and comparisons of diversity between habitats sampled at equal effort. The criterion used to determine whether the richness and diversity estimations were significantly different ($P < 0.05$) was the absence of overlap among the 95% confidence intervals for richness estimates (Colwell *et al*. 2004).

Generalized Estimated Equations (GEEs) with binomial errors were used to analyze the distribution of the most common species among the four main habitat types in SPSS 19.0 (SPSS Inc, Chicago, IL, USA). GEEs are an extension of Generalized Linear Models that allow the analysis of correlated data arising from repeated measures (in the binomial model: monthly species presence on 2-km transect segments; Hardin and Hilbe 2003). Thus, habitat (four categories: DRY GRASS, CULT, RICE, FLOOD) was fitted as predictor variable and binomial presence data for each species as dependent variables. The 2-km segments in each habitat category were taken as subject variables with months (n = 10) as within-subject variables. We specified independent or first-order autoregressive (AR-1) covariance types to account for potential temporal autocorrelation between subsequent transects surveys, and selected the final model based on the lowest QICC value. Apart from binomial models to test species presence, we investigated associations between habitat and the abundance of all raptors, Afrotropical raptors, and Palearctic raptors on 2-km transects using GEEs with Poisson and Negative Binomial errors and log link functions. Final model selection was based on quasi-likelihood under the independence model criterion (QIC; Hardin & Hilbe 2003). Differences between habitats for all models were tested using pair-wise comparisons in GEE and considered significant at $P < 0.05$ but adjustments were made for Type I error using Bonferroni correction. Kruskal-Wallis tests were used to explore differences in mean monthly grass cover values between the four main habitat types.

9.3 Results

A total of 36 species were recorded during surveys (Table 1). Thirty-six percent of those (13 species) were Palearctic migrants, which constituted 19% of the total number of raptors

observed (n = 2533). The most commonly recorded species, the Black Kite, comprised 42% of total numbers and 51% of Afrotropical raptors. Species diversity had clear patterns related to habitat categories only for Afrotropical raptors (Figure 2a), with a significantly higher diversity on seasonally flooded grasslands compared to other habitats. Grass cover also differed between habitat categories ($\chi^2_3 = 8.48$, $P < 0.05$), and was significantly higher in the floodplain than in the other habitats. Conversely, Palearctic raptor diversity, and the diversity of the entire raptor assemblage, did not differ significantly across habitats. No significant differences in species richness were recorded between habitat categories for overall, Afrotropical, and Palearctic raptor richness (Figure 2b).

Table 1. Total number of raptors detected on ten 2-km transects surveyed at monthly intervals between October 2007 and July 2008 in the partly cultivated grasslands (CULT), dry grasslands (DRY GRASS), rice fields (RICE), and seasonally flooded grasslands (FLOOD). Numbers are presented separately for the wet (W; 4 counts; May-Oct) and dry season (D; 6 counts; Nov-April).

	CULT		**DRY GRASS**		**RICE**		**FLOOD**		
	D	W	D	W	D	W	D	W	**Tot**
Palearctic raptors									
Eurasian Marsh Harrier *Circus aeruginosus*	13	13	18	8	94	3	49	0	198
Booted Eagle *Hieraaetus pennatus*	7	0	11	0	62	0	11	0	91
Common Kestrel *Falco tinnunculus*	16	0	11	0	13	0	5	0	45
Steppe Eagle *Aquila nipalensis*	1	0	3	0	33	0	3	0	40
Long-legged Buzzard *Buteo rufinus*	2	0	1	0	20	0	3	0	26
Montagu's Harrier *Circus pygargus*	6	0	3	0	12	0	5	0	26
Pallid Harrier *Circus macrourus*	2	0	2	1	16	0	1	0	22
Short-toed Eagle *Circaetus gallicus*	3	1	6	0	5	0	2	0	17
Lesser Kestrel *Falco naumanni*	2	0	2	0	0	0	0	0	4
Osprey *Pandion haliaetus*	0	0	0	0	1	0	3	0	4
Barbary Falcon *Falco pelegrinoides*	2	0	0	0	0	0	0	0	2
Red-footed Falcon *Falco vespertinus*	0	1	0	0	0	0	0	0	1
Egyptian Vulture *Neophron percnopterus*	0	0	1	0	0	0	0	0	1
Afrotropical raptors									
Black Kite *Milvus migrans*[1]	191	22	299	45	388	3	78	27	1053
Hooded Vulture *Necrosyrtes monachus*	1	0	0	1	15	3	170	91	281
Grasshopper Buzzard *Butastur rufipennis*	97	66	43	28	1	0	4	0	239
Dark Chanting Goshawk *Melierax metabates*	9	2	16	3	10	12	35	25	112
African White-backed Vulture *Gyps africanus*	1	0	3	0	1	0	37	18	60
African Swallow-tailed Kite *Chelictinia riocourii*	13	1	39	0	1	0	3	0	57
Black-winged Kite *Elanus caeruleus*	2	1	7	1	22	8	5	10	56
Tawny Eagle *Aquila rapax*	4	3	12	5	2	1	4	3	34
Gabar Goshawk *Micronisus gabar*	3	2	5	2	0	4	10	8	34
Lanner Falcon *Falco biarmicus*	13	4	6	3	1	0	0	2	29
Wahlberg's Eagle *Aquila wahlbergi*	0	1	3	5	5	3	10	0	27
Red-necked Falcon *Falco chicquera*	1	0	1	0	4	1	11	9	27
Rüppell's Vulture *Gyps rueppellii*	0	0	0	2	2	0	7	1	12

Table 1. (Continued).									
African Fish Eagle *Haliaeetus vocifer*	0	0	6	2	0	0	1	1	10
Bateleur *Terathopius ecaudatus*	0	0	2	6	0	0	2	0	10
Long-crested Eagle *Lophaetus occipitalis*	0	1	1	0	0	1	3	0	6
Shikra *Accipiter badius*	0	0	1	1	0	0	1	0	3
Beaudouin's Snake Eagle *Circaetus beaudouini*	1	0	0	0	0	0	0	0	1
Brown Snake Eagle *Circaetus cinereus*	0	0	0	1	0	0	0	0	1
Grey Kestrel *Falco ardosiaceus*	0	0	0	0	0	0	0	1	1
African Harrier Hawk *Polyboroides typus*	1	0	0	0	0	0	0	0	1
Secretary Bird *Sagittarius serpentarius*	0	0	0	0	0	0	0	1	1
Lappet-faced Vulture *Torgos tracheliotus*	0	0	1	0	0	0	0	0	1
Total individuals	391	118	503	114	708	39	462	198	2533
Species number	23	13	26	16	21	10	25	14	36

[1]A proportion of Black Kites *Milvus migrans* (*c.* 1-2% of numbers between October-March) was identified as the Palearctic subspecies *migrans*, the bulk constituted by the Afrotropical subspecies *M. m. parasitus/aegyptius* (Yellow-billed Kite).

Prior to examinations of species-habitat associations, estimation of ESW using Distance 6.0 showed these did not significantly differ ($P < 0.05$) between the four habitat categories for the three raptor size categories, dismissing the need for corrections of relative abundance estimates due to differences in detectability between habitats. GEE model results indicated that raptor abundance did not differ among habitats for the 10-month survey period ($\chi^2_3 = 1.81$, $P = 0.61$), which remained the case when the most abundant species, Black Kite and Hooded Vulture, to a different degree commensal with humans, were excluded from the analysis. Also, the abundance of Afrotropical species did not differ among habitats ($\chi^2_3 = 1.16$, $P = 0.76$). However, Afrotropical raptors were significantly less abundant in rice fields compared to other habitats when Black Kite and Hooded Vulture were excluded ($\chi^2_3 = 32.7$, $P < 0.001$). Conversely, Palearctic migrants were significantly more abundant in rice fields compared to other habitats ($\chi^2_3 = 51.8$, $P < 0.001$). This was mirrored by species-specific binomial models for most common Palearctic migrants (Table 2), although no significant habitat effect on presence was detected for Montagu's Harrier *Circus pygargus* ($\chi^2_3 = 3.87$, $P = 0.27$), Common Kestrel *Falco tinnunculus* ($\chi^2_3 = 4.30$, $P = 0.23$), and Short-toed Eagle *Circaetus gallicus* ($\chi^2_3 = 3.19$, $P = 0.36$). Raptors significantly associated with rice fields over other habitats (Table 2) were regularly observed capturing rodents (*Arvicanthis* spp. and *Mastomys* spp.). Inspection of the combined monthly counts for these five Palearctic migrants showed that rice fields were favoured from November (Figure 3), corresponding with a decrease in herbaceous cover. Monthly counts appeared to follow a similar pattern on flooded grasslands, although numbers were lower here compared to rice fields. In comparison, numbers of these Palearctic migrants peaked earlier in the dry season in cultivated and dry grasslands, which compared to rice fields and flooded grasslands experienced a strong decline in herbaceous cover early in the dry season (Oct–Dec; Figure 3).

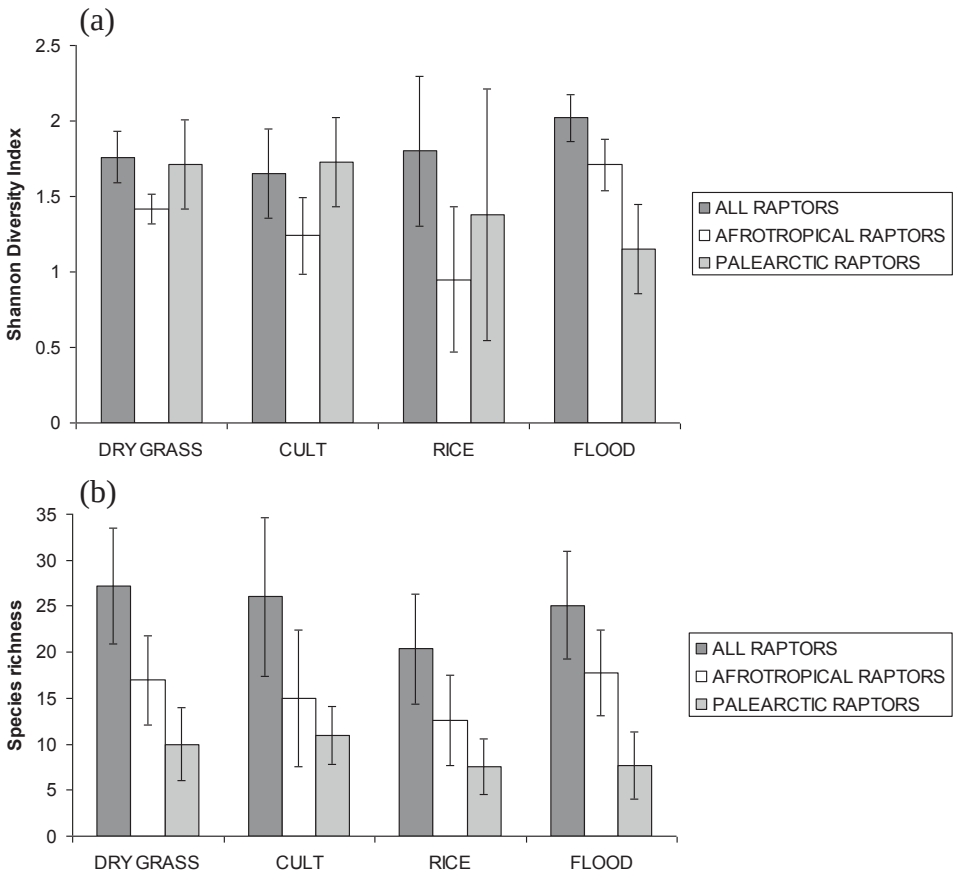

Figure 2. Raptor diversity and richness in four habitat types on the Waza-Logone floodplain. Shannon diversity indices (a) and species richness (b) are presented for all raptors, Afrotropical raptors, and Palearctic raptors. Indices were estimated at equal sampling effort. Values are presented with 95% CIs.

Habitat associations for common Afrotropical raptors were more variable compared to Palearctic raptors (Table 2). Seasonally flooded grassland was favoured by generalists (Dark Chanting Goshawk *Melierax metabates*), bird specialists (Gabar Goshawk *Micronisus gabar*, Red-necked Falcon *Falco chicquera*), and vultures (White-backed *Gyps africanus* and Hooded Vulture). Conversely, dry and cultivated grasslands were more attractive than flooded grasslands and rice fields for Lanner Falcon and Grasshopper Buzzard (Table 2), whereas Black Kite was more strongly associated with dry grasslands than other habitats. Distribution patterns for Tawny Eagle *Aquila rapax* ($\chi^2_3 = 5.92$, $P = 0.12$), Wahlberg's Eagle ($\chi^2_3 = 3.45$, $P = 0.33$), and African Swallow-tailed Kite *Chelictinia riocourii* ($\chi^2_3 = 2.56$, $P = 0.46$) were indifferent to land-use. The Black-winged Kite, a

Table 2. Relationship between raptor presence and habitat, for (a) Afrotropical and (b) Palearctic raptors. Generalized Estimating Equations with binomial errors and a logit link function were used with habitat (four categories: CULT: cultivated grasslands; DRY GRASS: dry grasslands; RICE: rice fields; FLOOD: floodplain) fitted as predictor variable and binomial presence data for each species as dependent variables. Model fit and mean differences (± S.E.) between habitat categories are presented after pairwise comparisons and Bonferroni correction for Type I errors. Only species for which habitat was significantly associated ($P < 0.05$) with presence are reported.

(I) habitat	(J) habitat	Black Kite (I-J)	Grasshopper Buzzard (I-J)	Dark Chanting Goshawk (I-J)	African White-backed Vulture (I-J)	Black-winged Kite (I-J)
CULT	DRY GRASS	-0.22±0.06**	0.08±0.07	-0.09±0.05	-0.01±0.02	-0.03±0.03
	RICE	0.02±0.06	0.40±0.05***	-0.08±0.04	0.00±0.01	-0.17±0.04***
	FLOOD	0.04±0.06	0.37±0.05***	-0.32±0.06***	-0.15±0.04**	-0.05±0.02
DRY GRASS	RICE	0.24±0.06***	0.32±0.06***	0.01±0.05	0.01±0.02	-0.14±0.04**
	FLOOD	0.26±0.06***	0.29±0.06***	-0.23±0.08*	-0.14±0.04*	-0.02±0.03
RICE	FLOOD	0.02±0.06	-0.03±0.02	-0.24±0.06**	-0.15±0.04**	0.12±0.04*
	Model fit	$\chi^2_3 = 26.2$, $P < 0.001$	$\chi^2_3 = 54.6$, $P < 0.001$	$\chi^2_3 = 27.4$, $P < 0.001$	$\chi^2_3 = 21.2$, $P < 0.001$	$\chi^2_3 = 21.7$, $P < 0.001$

	(J) habitat	Gabar Goshawk (I-J)	Lanner Falcon (I-J)	Red-necked Falcon (I-J)	Hooded Vulture (I-J)
CULT	DRY GRASS	0.00±0.02	0.03±0.04	0.00±0.01	0.00±0.01
	RICE	0.03±0.02	0.11±0.03**	-0.03±0.02	-0.08±0.02***
	FLOOD	-0.06±0.03	0.11±0.03**	-0.13±0.02***	-0.49±0.06***
DRY GRASS	RICE	0.03±0.02	0.08±0.02**	-0.03±0.02	-0.08±0.02***
	FLOOD	-0.06±0.03	0.08±0.02**	-0.13±0.02***	-0.49±0.06***
RICE	FLOOD	-0.09±0.03*	0.00±0.01	-0.10±0.03**	-0.41±0.06***
	Model fit	$\chi^2_3 = 8.47$, $P < 0.05$	$\chi^2_3 = 12.8$, $P < 0.01$	$\chi^2_3 = 23.2$, $P < 0.001$	$\chi^2_3 = 79.8$, $P < 0.001$

(I) habitat	(J) habitat	Pallid Harrier (I-J)	Booted Eagle (I-J)	Eurasian Marsh Harrier (I-J)	Long-legged Buzzard (I-J)	Steppe Eagle (I-J)
CULT	DRY GRASS	0.00±0.02	-0.04±0.03	0.00±0.04	0.01±0.02	-0.02±0.02
	RICE	-0.07±0.03*	-0.24±0.04***	-0.22±0.04***	-0.12±0.03***	-0.15±0.04**
	FLOOD	0.01±0.02	-0.04±0.02	-0.05±0.05	0.00±0.02	-0.01±0.02
DRY GRASS	RICE	-0.07±0.03*	-0.20±0.04***	-0.22±0.04***	-0.13±0.03***	-0.13±0.04**
	FLOOD	0.01±0.02	0.00±0.03	-0.05±0.05	-0.01±0.02	0.01±0.02
RICE	FLOOD	0.08±0.02**	0.20±0.04***	0.17±0.05***	0.12±0.03***	0.14±0.04**
	Model fit	$\chi^2_3 = 12.5$, $P < 0.01$	$\chi^2_3 = 51.5$, $P < 0.001$	$\chi^2_3 = 34.4$, $P < 0.001$	$\chi^2_3 = 23.2$, $P < 0.001$	$\chi^2_3 = 19.1$, $P < 0.001$

***$P < 0.001$ **$P < 0.01$ *$P < 0.05$.

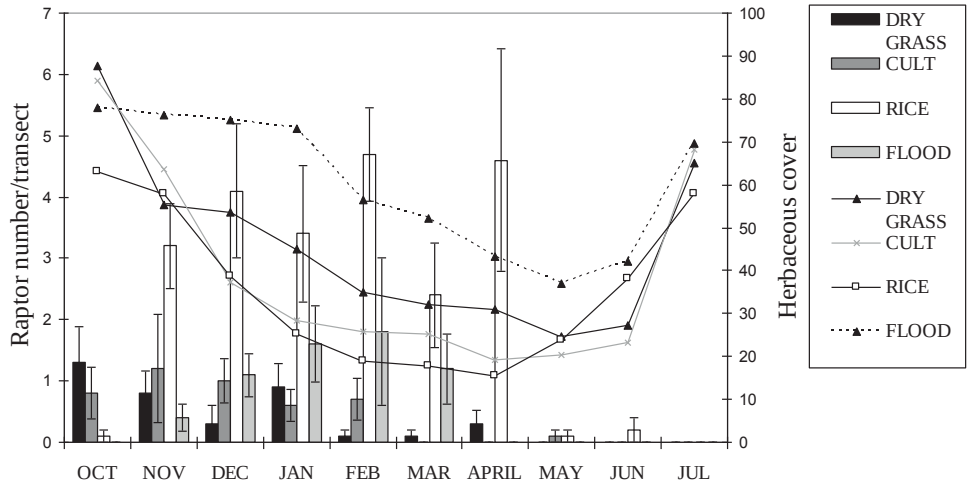

Figure 3. Mean raptor numbers ±S.E. on 2-km transects of five Palearctic raptors (Booted Eagle, Eurasian Marsh Harrier, Steppe Eagle, Long-legged Buzzard, Pallid Harrier) favoring rice cultivation (RICE) over cultivated grassland (CULT), dry grassland (DRY GRASS), and seasonal floodplains (FLOOD), from October 2007 to July 2008 in the Waza-Logone floodplain of northern Cameroon. Lines represent the mean herbaceous layer cover on 2-km transects in each of four habitat categories during the same period.

rodent specialist, was the only Afrotropical species with a preference for rice fields (Table 2), and at least three pairs were recorded breeding in *Faedherbia albida* trees in rice fields.

9.4 Discussion

Our data revealed a strikingly different distribution pattern in terms of abundance of Afrotropical and Palearctic raptors with regard to rice fields, which were generally avoided by Afrotropical raptors but preferred by Palearctic raptors. The attractiveness of rice fields to Palearctic raptors augments reports of raptors converging on post-harvest rice fields in Europe (Boano & Toffoli 2002, Lourenço 2009), Asia (Fujioka *et al*. 2010), and the Americas (Remsen *et al*. 1991, Petit *et al*. 1999, Elphick 2004, Pandolfino *et al*. 2011). Evidently, the attractiveness of different habitat types may shift over the course of the winter season (cf. Figure 3), and the accessibility of rodents in rice fields increased from November with decreasing herbaceous cover. Rodents are similarly common in sorghum fields (Chapter 2), but these were localized in dry, unproductive grasslands, probably lowering their attractiveness to Palearctic raptors compared to rice-dominated habitats. Intensive tree-pruning, -logging, and human exploitation of tree-lined canals for fishing and bushmeat (rats, frogs) leading to high levels of human disturbance detrimental to breeding raptors (Newton 1979), explained the lack of suitability of rice fields to Afrotropical raptors.

Furthermore, rice fields were flooded and cultivated from April, well before the arrival of the seasonal floods (August–September), limiting prey accessibility for sedentary raptors

during an eight month period. Interestingly, Black-winged Kites, which are known to profit from rodent outbreaks with prolonged or variable breeding seasons (Ferguson-Lees and Christie 2001) and prefer cultivated landscapes with few trees for breeding (Balbontin *et al*. 2008), were the only raptors breeding among rice fields and the only Afrotropical raptor species which increased in the area following irrigation rice scheme development (Thiollay 2001).

The situation on the original floodplain, with its abundant wildlife and prey resources, may not be duplicated today, since the diminished productivity of the former grasslands were only partially compensated by floodplain rehabilitation (Scholte 2005). At the same time, growing human populations, increased livestock numbers, and agricultural expansion have greatly intensified pressure on natural resources in the area (Scholte 2003), with potentially important consequences for raptor prey resources. In the absence of the original habitat, we focused our comparison on existing habitats, including the habitat most resembling the original floodplain. This habitat differed from the newly created cultivated habitats and dry grasslands by a significantly higher grass cover, which is among the most important determinants of prey availability and foraging distribution of many raptors (Thiollay 1978a), and characterized the original floodplain (Scholte *et al*. 2000). The surveyed floodplain habitat thus retained an essential component of the original grasslands, at least to foraging raptors, justifying our comparisons.

Our results revealed a greater diversity of Afrotropical raptors on the floodplain compared to the newly created cultivated habitats and dry, protected grasslands, underlining the importance of the floodplain to Afrotropical raptors. We found a preference for floodplain habitat by five Afrotropical raptors, three of which (Dark Chanting Goshawk, African White-backed Vulture, Hooded Vulture) declined significantly in the area between 1973 and 2000 (Thiollay 2001), while two other raptors (Gabar Goshawk, Red-necked Falcon) were either too infrequently recorded to evaluate population trends, or remained stable. Although wide-ranging vultures (Kendall & Virani 2011) are likely to have been affected by practices that affected the wider region (e.g. traditional medicine trade; R. Buij unpubl. data), these results suggest that the observed raptor declines might have at least partly been related to floodplain embankment, which greatly reduced the extent of floodplain habitat.

Contrary to expectations, Afrotropical raptor abundance, richness and diversity on the dry, protected grasslands was comparable to the cultivated grasslands, suggesting that the moderately cultivated grasslands still supported suitable habitat for many raptors. However, species-specific models did show variable responses, e.g. Black Kite preferred protected, dry grasslands over cultivated grasslands, whereas Lanner Falcon and Grasshopper Buzzard equally preferred dry and cultivated grasslands. These discrepancies corresponded with differences in long-term population trends between Black Kite populations (strong decrease; Thiollay 2001), and Lanner Falcon and Grasshopper Buzzard (stable), perhaps pointing to differences in species-specific sensitivity to anthropogenic impact. The observed preference for dry grasslands over floodplain by Black Kite, Grasshopper Buzzard, and Lanner Falcon may be related to limitations on the number of breeding sites and prey availability on the floodplain. Grasshopper Buzzard and Black Kite breed at

relatively high densities during the transition from the dry to wet seasons (March–July; Chapter 5, R. Buij unpubl. data) and require adequate tree cover for nesting, thus favouring well-wooded dry grasslands over the partly treeless floodplain. In addition, prey accessibility is compromised when grass cover is high (Thiollay & Clobert 1990), as is the case during much of the year on the floodplain.

Implications for floodplain management

Despite their importance to Palearctic and Afrotropical birds and wildlife in general (Zwarts *et al*. 2009), only a small proportion of the West African floodplains have received protected status. Waza National Park protects < 10% (700 km^2) of the Waza-Logone floodplain, while regional protection of other floodplain systems is limited to Djoudj and Diawling National Parks in the Senegal River Delta and various small reserves in Nigeria, Chad, and Mali. As a result, floodplains have been vulnerable to development initiatives, and rice irrigation schemes have become a common feature of floodplains the past 50 years (Zwarts *et al*. 2009). During this period, the area harvested with rice increased from 4000 to 31,000 km^2 in six Sahelian countries with large floodplain systems (FAOSTAT 2012) and such growth is not likely to stop any time soon (Zwarts *et al*. 2009). Their convergence on rice fields implies that Palearctic migrants are vulnerable to aspects pertaining to the management of the rice fields. Firstly, any positive effect of increased prey availability can be drastically altered by changes to the flooding regime, which may negatively affect the abundance and richness of raptors (Elphick 2004). Secondly, application of harmful pesticides in rice is hardly supervised and likely to affect raptors through secondary poisoning (Mullié *et al*. 1991), as reported from neighbouring Chad (Keith & Bruggers 1998), but little is known about pesticide impact on raptors in the region. Deliberate, large-scale poisoning of birds for food, as reported in some East African rice schemes (Odino 2010), has not been observed in Cameroon. However, poisoning of small waterholes, already reported from the region in the 1970s (Green & Sayer 1979), is a frequently used method to harvest birds (particularly passerines) for consumption, and also kills raptors (R. Buij pers. obs.). An important recommendation emanating from this study would be a strict ban on the use of pesticides highly toxic to birds from rice fields. Instead, raptors could be promoted as valuable predators of crop-pests and assisted through supplementation of perches (Sheffield *et al*. 2001).

Habitat quality for Afrotropical raptors is further affected by the intensive exploitation of the Waza-Logone floodplains and surrounding woodlands, where human disturbance, wood extraction and tree pruning progressively limit nest site availability. Poaching in Waza National Park has been on the increase since the late 1990s and has decimated large wildlife populations (De Iongh *et al*. 2009), to the detriment of shy scavengers (e.g. Tawny Eagle, Bateleur *Terathopius ecaudatus*). Raptors are poached for meat and persecuted for trade (R. Buij unpubl. data), which has contributed to declining vulture and possibly Secretary Bird *Sagittarius serpentarius* populations. Floodplain rehabilitation triggered a 34% increase in sedentary fisherman in two years which intensively utilise the fish resources in the park (Scholte 2003), which together with the reduced flooding extent led to declining fish stocks, weakening the prey base for few remaining African Fish Eagle *Haliaeetus vocifer* pairs in

the far north. Limitations to any of these exploitative utilizations will benefit raptor populations and other wildlife using the floodplains, underlining the importance for improved protection of Waza National Park and restrictions on developments that stimulate further human immigration into the area.