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VULTURES IN GUINEA-BISSAU: ESTABLISHING BASELINE DATA ON DISTRIBUTION AND ABUNDANCE, ASSESSING CONSERVATION STATUS AND LAUNCHING BASES FOR POPULATIONS MONITORING

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Resumo

Os abutres são os necrófagos mais bem-sucedidos da natureza e os únicos a apresentar atualmente uma dieta quase exclusivamente baseada em animais mortos. Existem atualmente 23 espécies de abutres descritas globalmente, 11 das quais ocorrem em África. Como um grupo relativamente diverso no que concerne ao comportamento alimentar, os abutres do Velho Mundo apresentam diferentes estratégias de alimentação. Alguns foram até capazes de se adaptar a ambientes modificados pelo homem, desenvolvendo uma relação comensal. Fisiologicamente os abutres desenvolveram níveis de pH extremamente baixos no seu trato digestivo, uma adaptação fulcral para destruir a maior parte dos microrganismos e reduzir fortemente a probabilidade de constituírem fontes de infeções e transmissão de doenças.

As populações de abutres enfrentam atualmente um dos declínios mais rápidos jamais registados para espécies de aves e são hoje o grupo funcional de aves mais ameaçado globalmente. Como espécies-chave, o seu desaparecimento acarreta um vasto leque de consequências a nível socioeconómico, cultural e na biodiversidade, principalmente sobre a saúde humana, custos para a indústria, custos de eliminação de desperdícios pelas comunidades, sobre os valores culturais e religiosos e outros impactos sobre a biodiversidade.

Declínios dramáticos têm sido reportados no continente africano, especialmente no Oeste e no Este. Na África Ocidental, contagens realizadas no Sahel demostraram declínios na ordem dos 98% fora das áreas protegidas, num período de 35 anos. Na África Oriental mais declínios foram reportados, como foi o caso no centro do Quénia, onde contagens de 3 anos reportaram declínios de 70% das aves necrófagas. No ecossistema do Masai Mara, várias espécies de abutres sofreram também declínios de 44 a 62% num período de 30 anos. A principal causa subjacente a estes declínios é o envenenamento intencional e não intencional. Outras causas propostas incluem a perseguição humana para partes do corpo para feitiçaria, declínio de ungulados selvagens, caça para fonte de alimento humano, a evolução das condições sanitárias, com a introdução de sistemas fechados de abate de gado, ou a evolução das condições de tratamento de lixo em alguns centros urbanos de África. Todos estes declínios reportados e respetivas causas sugerem um problema à escala continental.

Apesar de ainda haverem muitas lacunas relativamente ao estado das populações de abutres africanos, trabalhos recentes já motivaram várias atualizações no estatuto de ameaça destes necrófagos, havendo presentemente apenas 2 espécies que não figuram na Lista Vermelha da UICN como ameaçadas (abutre-das-palmeiras *Gypohierax angolensis* e o grifo europeu *Gyps fulvus*). Ainda assim, para muitas áreas e países, virtualmente nada se sabe sobre o estado das populações, tendências e ameaças.

A Guiné-Bissau alberga 5 espécies de abutres, a maior parte delas listadas como ameaçadas globalmente pela UICN. Pelo menos três (*Necrosyrtes monachus, Gyps africanus e Gypohierax angolensis*) são ainda abundantes.

Este estudo tem por objetivo avaliar o estado das populações de abutres na Guiné-Bissau, estabelecer dados de referência relativamente à abundancia e distribuição de todas as espécies por todo o território e providenciar as primeiras indicações sobre possíveis ameaças que possam estar a afetar os abutres. Está dividido em 3 capítulos, os quais descrevemos sumariamente abaixo.

No primeiro capítulo apresentamos uma visão alargada sobre a distribuição, a abundância relativa, e as ameaças a todas as espécies de abutres do país, descrevendo a sua relação com outras aves necrófagas facultativas. Realizámos 1,733 km de transectos de carro e registámos 4,313 *Necrosyrtes monachus* (326 aves/100 km), 160 grifos (8.65/100 km, dos quais 80% eram *Gyps africanus*, 2% *Gyps rueppelli* e 18% grifos não identificados), 24 *Gypohierax angolensis*, 3 *Trigonoceps occipitalis*, 275 *Milvus migrans parasitus* (18.65/100 km), e 274 *Corvus albus* (22.31/100 km). Paralelamente realizámos pontos de contagem de 2 minutos em áreas abertas que permitiram amostrar o arquipélago dos Bijagós e as áreas com vegetação mais densa, e a partir dos quais medimos índices pontuais de abundância (média do

número de aves por ponto de contagem, por 2 minutos de contagem). Por este meio confirmámos a ausência de grifos nas ilhas. Os restantes valores de abundância obtidos forneceram informação semelhante à dos transectos de estrada. Estudámos quais os preditores da distribuição das abundâncias dos abutres e das outras aves necrófagas facultativas, em conjugação com uma análise preliminar sobre o uso do habitat e os ambientes antrópicos demostraram ser o fator mais importante para todas as espécies, menos para os grifos. Neste capítulo, as conclusões mais relevantes foram: (1) a abundância relativa de *Necrosyrtes monachus* é das maiores reportadas em toda a sua distribuição, enquanto os *Gyps africanus* também se apresentam em números importantes; (2) não há indícios de competição entre os *M. m. parasitus* e os abutres, enquanto os *Corvus albus* apresentam um perfil mais competitivo nos centros urbanos ao *Necrosyrtes monachus*; (3) os ambientes antrópicos parecem desempenhar uma função importante no padrão de uso de habitat destas aves necrófagas; (4) relatos provenientes de entrevistas informais com criadores de gado, comerciantes de carne, veterinários, líderes religiosos e das aldeias, curandeiros tradicionais e feiticeiros indicam que as ameaças reportadas noutros países para os abutres têm ainda uma expressão limitada na Guiné-Bissau. No entanto, parecem existir zonas do país onde há casos de envenenamento, de forma indireta, e que a perseguição para uso na medicina tradicional e feitiçaria tem uma expressão alegadamente crescente.

No segundo capítulo focamo-nos na espécie mais abundante no país, *Necrosyrtes monachus*, avaliando a sua abundância total a nível nacional. Estudámos os padrões de atividade diária destes abutres no centro urbano de Bissau, permitindo refinar as metodologias desenvolvidas para o censo de abutres durante este estudo. Estas observações demostraram que estas aves estão activas entre as 9:20h e as 17:10h. Para estimar a abundância total em toda o país, amostrámos 21 povoações usando dois métodos: transectos de bicicleta com banda de largura fixa, com o qual amostrámos as cidades de Bissau e Gabú, e contagens de carro em períodos de baixa atividade de abutres, para amostrar as restantes povoações de tamanho médio e pequeno. Os dois métodos foram executados de manhã cedo e ao final da tarde. Estimámos 7,335 abutres para Bissau, e 809 para Gabú, usando as distâncias de avistamento calcular densidades e extrapolar para a área de cada cidade. Usámos os resultados das contagens de abutres nas 19 povoações numa regressão linear com a quantidade de pessoas em cada povoação, seguindo a premissa da forte associação dos *Necrosyrtes monachus* às pessoas. Somando o resultado das predições às estimativas das duas maiores cidades, estimámos entre 67,908 e 88,323 aves, correspondente a 34 – 44% da população global da espécie. As principais conclusões tiradas deste estudo foram: (1) a conjugação destes dois métodos providencia uma alternativa válida para estimar a população total desta espécie no país, com potencial para replicação noutras áreas; (2) esta é a primeira estimativa populacional de *Necrosyrtes monachus* realizada para o país, e das poucas materializadas na África Ocidental. A importância da Guiné-Bissau para esta espécie criticamente ameaçada fica bem salientada.

No terceiro capítulo apresentamos um pequeno estudo sobre a abundancia sazonal dos *Gypohierax angolensis* no Parque Nacional Marinho João Vieira e Poilão (PNMJVP), no arquipélago dos Bijagós, Guiné-Bissau. Realizámos transectos de praia a pé, ao redor das 4 ilhas que compõem o PNMJVP, e contámos todos os indivíduos adultos e imaturos avistados. As contagens foram realizadas na época seca e época das chuvas. Calculámos a média para cada época, por ilha, e obtivemos um resultado de 265 aves (SD = ±9.8, n = 5) na época seca, e 305 (SD = ±38.9, n = 10) na época das chuvas. A ilha com maior número de abutres nas duas épocas é João Vieira. Contámos 8 aves/km em todo o PNMJVP (num total de 36.2 km), com Poilão a apresentar a maior abundância relativa (16.3 aves/km), assim como a maior variação no número de aves imaturas entre a época seca e a chuvosa (de 5 para 23 aves). Meio apresentou também uma importante variação percentual de aves imaturas (aumento em 11.4%). Em Poilão contámos 5x mais abutres na época chuvosa do que na seca, o que poderá ser explicado pelo *input* de aves nascidas na época de reprodução anterior (durante a época seca) ou pela presença de aves vindas de outras ilhas do arquipélago, atraídas pela colónia de reprodução de tartarugas marinhas, que tem o seu pico na época chuvosa. Estas contagens indicam apenas um número mínimo de aves existentes na área protegida. Com base na nossa experiência da área de estudo, estimamos grosseiramente que o número de abutres-das-palmeiras no PNMJVP andará entre as 355 e as 525 aves. Isto fornece indicações que suportam a premissa da importância desta população a nível nacional e regional.

Este estudo permitiu estabelecer uma situação de referência sobre as populações de abutres, o que irá ser importante para estabelecer comparações futuras e avaliar tendências populacionais. O desenvolvimento de protocolos metodológicos no decurso deste trabalho poderá ser uma base importante para a implementação de um programa de monitorização de abutres no país. As estimativas populacionais para duas espécies de abutres, uma a nível nacional, e outra para uma área protegida, são importantes no desenvolvimento de planos de gestão e no estabelecimento de prioridades de conservação.

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General Introduction

Vultures are nature's most successful scavenging vertebrates (Ogada et al. 2012a) and the only ones among extant vertebrates having a diet based almost exclusively on carrion (Ruxton & Houston 2004). This group is divided in two quite distinct lineages but that are an example of convergent evolution: the Old World vultures, included into the Accipitridae family, and New World vultures, the Catarthidae family, being the former distributed across Africa, Asia and Europe and the later confined to the American super-continent (Houston 1985; Seibold & Helbig 1995; Lerner & Mindell 2005; O'Neal Campbell 2016). Both lineages share the general traits that characterize vultures: large body size (compared to other groups of birds), hooked bill, naked or downy head, food-holding crop, plumage patterns, common dependence on souring on air currents, among others. They differ essentially in the type of habitat of occurrence (Old World vultures are mainly confined to open habitats such as savannahs, grasslands and semi-deserts, in opposition to their New World counterparts, with several species adapted to closed forested environments), and in the foraging strategy (New World vultures developed a keen sense of smell, which they use to locate carcasses in dense forest, while Old World vultures rely mainly on eyesight to do so) (Houston 1985; Ogada et al. 2012a; O'Neal Campbell 2016). There are 23 species of vultures described globally, of which 16 occurs in the Old World. Vulture-rich regions include Central and South America (n = 6 spp.), South Asia (n = 10 spp.), and Africa (n=11 spp.) (Mundy et al. 2001; O'Neal Campbell 2016).

As a relatively diversified group when it comes to feeding behaviour, Old World vultures present different foraging strategies (Houston 1985). This is the case for griffons, known to forage collectively for carrion and sometimes congregate in several hundred (up to a thousand) over carcasses of dead large animals in the wild (Mundy et al. 2001; O'Neal Campbell 2016). By keeping visual contact with conspecifics, griffons manage to benefit from a local enhancement effect following other vultures that descends to carcasses (Houston 1974a; Kane et al. 2014). Some vultures could even adapt to human-modified environments, such as livestock farming areas, slaughter-houses or rubbish dumps in highly urbanised areas, which is the case of the hooded (*Necrosyrtes monachus*) and the Egyptian (*Neophron percnopterus*) vultures, who developed a commensal relationship with humans (Gangoso et al. 2013; O'Neal Campbell 2016). Physiologically vultures developed very low pH levels in their digestive tracts (pH 1-2), which is of most importance to destroy most microorganisms and greatly reduce the probability of vultures to act as sources of infection at carcasses. As a result of this adaptation, their gastric acid is extremely corrosive, allowing vultures to easily digest rotting carcasses infested with many potentially dangerous bacteria. Therefore, the digestive tract of vultures is likely to destroy all except the most resistant of organisms. (Houston 1974b; Houston & Cooper 1975; Turnbull et al. 2008; Chung et al. 2015; Buechley & Şekercioğlu 2016).

Vultures soar over large distances in search of food. However, during the breeding season, which may span well over half a year, these birds must necessarily concentrate their activities around nesting sites (Monadjem & Garcelon 2005). Nesting habitat requirements can vary among species but, in general, well conserved areas are needed for them to successfully breed (open wooded savannah, tall tree areas, riparian vegetation or cliffs) (Monadjem & Garcelon 2005; O'Neal Campbell 2016).

Vultures have some of the lowest reproductive rates among birds (often laying a mean of less than one egg per year, and showing delayed maturity), and their populations are particularly vulnerable to high mortality, whether by natural or human causes (Ogada et al. 2012a). Currently, vulture populations face some of the most rapid declines ever recorded for any bird species and are the most threatened foraging guild of birds globally (Askew 2014; Buechley & Şekercioğlu 2016).

As scavengers, vultures play an important ecological role and these declines have a range of socio-economic, cultural and biodiversity impacts, mainly on human health, costs to industry, disposal costs to local communities, cultural and religious values and other biodiversity impacts, among others (Sekercioğlu et al. 2004; Markandya et al. 2008; Buechley & Şekercioğlu 2016). Vultures are often the firsts to arrive at carcasses (Houston 1974a; Hunter et al. 2007; Kendall 2013). Therefore, their absence may affect the community composition of scavengers, altering scavenging rates for individual species (Hunter et al. 2007; Ogada et al. 2012b; Barton et al. 2013; Moleón et al. 2015). This can result in rapid increase of opportunistic species like feral dogs and rats and promote more contact between potentially infected individuals. Thus, the absence of vultures will more likely increase the probability of the transmission of diseases like rabies and bubonic plague (Markandya et al. 2008; Ogada et al. 2012b). Finally, some species of vultures have adapted to human-altered environments and provide ecosystem services of much importance to urban areas like the disposal of waste in towns. This is the case for the Egyptian and hooded vultures (Ogada & Buij 2011; Gangoso et al. 2013). Markadya et al. (2008) estimated the cost of vulture declines in India for human health over the period of 1992 to 2006 to be up to around €15.5 billion.

Following the "Asian vulture crisis" (more than 99% decline of Gyps vultures in just 15 years in the Indian sub-continent due to poisoning from the non-steroidal anti-inflammatory drug diclofenac) (Green et al. 2004; Pain et al. 2008), the alarm was launched for African vultures as well. Some dramatic declines have been reported recently in Africa, but nevertheless the African vulture crisis is still poorly documented. For example, in the Western region, surveys conducted in the Sahel showed 98% population declines outside protected areas in a 35-year period (Rondeau & Thiollay 2004; Thiollay 2006a, 2006c, 2007a; Ogada et al. 2015a). In East Africa, more declines have been highlighted by researchers, as is the case for Central Kenya, where the 3-year survey results conducted on raptors between 2001-2003 suggest an overall decline rate of approximately 50% per year for scavenging birds (total of 70% over the study period) (Ogada et al. 2013) and in the Masai Mara ecosystem, where considerable declines in several vulture species where detected in a 30-year period (hooded vulture (62%), Gyps vultures (52%), lappet-faced vulture *Torgos tracheliotus* (50%), white-headed vulture *Trigonoceps occipitalis* (44%)) (Virani et al. 2011). More recently, in western Kenya, Odino et al. (2014) reported some evidences of declines of hooded vultures in dumpsites and slaughterhouses since 2000.

The main underlying cause of these declines is intentional poisoning (Bridgeford 2001; Ogada 2014a, 2014b, Ogada et al. 2015a, 2015b, 2015b, 2015c; Buechley & Şekercioğlu 2016; Virani 2016), but indirect and unintentional sources of poisoning, like the indiscriminate use of pesticides, rodentices and veterinary medicines are also pointed out as important threats for the population survival (Thiollay 2006a; Ogada 2014a; Richards & Ogada 2015). The intensive use of vultures for traditional medicine and sorcery is common and have been reported in several West African countries, with evidences of relevant impact in the populations (Thiollay 2006b; Ogada & Buij 2011; Ogada 2012; Williams et al. 2014; Atuo et al. 2015; Buij et al. 2015). Hunting for food is less commonly reported but it allegedly resulted in some local extinctions in Ivory Coast and Nigeria (Rondeau & Thiollay 2004; Ogada & Buij 2011; Gbogbo et al. 2016). Other causes reported in some countries are the evolution of sanitary conditions, with the introduction of closed-system slaughter-houses, and the evolution of waste management of urban centres, which affect the amount of food available (Gbogbo & Awotwe-pratt 2008; Campbell 2009; Odino et al. 2014b; Gbogbo et al. 2016). All these reports of declines suggest that there may be a continental-scale problem, similar in extent - though more protracted - than the Asian situation, and as yet poorly documented (Ogada et al. 2015a).

While still with important gaps, the existing information and research is definitely increasing present knowledge on vulture population status, as there are already several cases of up-listing in the IUCN Red List of Threatened Species suggested by these scientists (Koenig 2006; IUCN 2016). Nevertheless, for many areas and countries, virtually nothing is known on vulture population status, trends and threats, hampering the development of adequate conservation strategies (Anderson 2007; Ogada et al. 2015a). This is the case for Guinea-Bissau, a small West African country which is home to 5 vulture species, most of them listed by the IUCN as globally endangered, namely: *Necrosyrtes monachus* (hooded – Critically Endangered), *Gyps africanus* (white-backed – Critically Endangered), *Gyps rueppelli* (Rüppell's – Critically Endangered), *Gypohierax angolensis* (palm-nut – Least Concern) and *Trigonoceps occipitalis* (white-headed - Critically Endangered) (Dodman et al. 2004; Borrow & Demey 2014; IUCN 2016). At least 3 (hooded, white-backed and palm-nut vultures) are still apparently abundant. The status and trends of vulture populations in the country is still unknown, but given the overall trend in West Africa and underlying causes for the astonishing declines reported, there is an urgent need to establish baseline information concerning population's abundances and identify possible threats. It is also important to raise awareness for vulture conservation by promoting their profile as providers of ecosystem services, notably in sub-Saharan West Africa, where the pressure on wildlife and their supporting habitats is high due to some of the highest human densities and growth rates on the continent (UNECA 2012).

In this study, we aim to assess the status of vulture populations in Guinea-Bissau, delivering the first baseline data on the abundance and distribution of all vulture species throughout the country, including the Bijagós archipelago, and give the first insights on conservation issues that may be affecting vultures in the study area. It is divided in 3 chapters, each with focus on the following components: in the first chapter, we provide a broad overview of the distribution, the relative abundance and an insight on threats of all vulture species in Guinea-Bissau, and describe their relation with other avian scavengers; in the second chapter, we focus on the most abundant species of vulture, the hooded vulture, assessing its total abundance on the country using alternative methods developed during this study; in the third chapter, we present a small study on the seasonal abundance of palm-nut vultures in the João Vieira/Poilão Marine National Park, in the Bijagós archipelago, Guinea-Bissau.

Chapter 1: Distribution and abundance of vultures and other avian scavengers in Guinea-Bissau, with insights over their conservation status

Abstract: *The "African vulture crisis" is currently in full force, with vultures considered the most threatened avian functional guild in the world. The main causes for these trends are becoming clearer, as more reports on declines in several African countries are coming to light. Unintentional and intentional poisoning were recognized as the most serious threats. Nonetheless, for several areas and countries, virtually nothing is known on vulture population status, trends and threats, as is the case for Guinea-Bissau, in West Africa. In this study we deliver the first baseline data on vulture populations and other avian scavengers in all of Guinea-Bissau's territory, study the factors influencing the patterns of the distribution of their abundance, analyze the distribution over the habitats, and overview some insights on possible threats affecting vulture conservation in the country. We conducted 1,733 km of road surveys and 184 point-counts between mid-February and end-April of 2016. Hooded vultures were the most common and widespread species (82.7% of all sightings), and encounter rates were among the highest recorded for the species (326 birds/100 km). White-backed vultures were fairly abundant in the northwest (7.2 birds/100 km for all study area), while Rüppell's and white-headed vultures were overall very rare. Pied crows and yellow-billed kites were common (22.3 and 18.7 birds/100 km) but the marabou stork was only sighted once. Hooded vultures, yellow-billed kites and pied crow's abundance distributions were significantly related to human population density, whereas griffons showed no significant relation to any predictor. Main potential threats reported during informal interviews were unintentional poisoning and prosecution for body parts for sorcery and traditional medicine. This study demonstrates the importance of vulture populations in Guinea-Bissau, especially hooded and white-backed vultures. We suggest the implementation of a monitoring program using the methods refined in this study and awareness actions in identified areas.*

Keyword: Guinea-Bissau, vultures, West Africa, abundance, avian scavengers

Introduction

Vultures are the only vertebrates that are obligate scavengers, being almost exclusively dependant of carrion to feed (Houston 1974b; Ruxton & Houston 2004; Buechley & Şekercioğlu 2016). Because they developed so many specific adaptations, like keen eye-sight, large wings for soaring, acid digestive tract, long and bald neck and heads, and feet adapted to walking on the ground, this group of birds have become a crucial element in the functionality of some terrestrial ecosystems (Ruxton & Houston 2004; Sekercioğlu et al. 2004; Ogada et al. 2012a; Chung et al. 2015; O'Neal Campbell 2016). Other birds have also developed scavenging as an opportunistic foraging strategy (Pomeroy 1975; Sekercioğlu et al. 2004; O'Neal Campbell 2016). Therefore, a competitive relationship can develop between vultures and non-obligate scavengers like storks, corvids, large gulls, eagles, kites and other predatory raptors (Buechley & Şekercioğlu 2016; O'Neal Campbell 2016).

Such specialized birds as vultures are very prone to extinction (Buechley & Şekercioğlu 2016). And indeed vulture populations are facing massive declines in almost all ecosystems and in all the world, with 16 of the 23 species of Old and New World vultures endangered (Buechley & Şekercioğlu 2016; IUCN 2016; O'Neal Campbell 2016). There are several causes of declines, which may vary among the continents, but unintentional and intentional poisoning is definitely the most serious threat (Prakash et al. 2003; Pain et al. 2008; Ogada et al. 2012a, 2015a; Ogada 2014a; Richards & Ogada 2015; Buechley & Şekercioğlu 2016; O'Neal Campbell 2016). Having such an important role in ecosystems, the consequences of their disappearance have already been felt in Asia (see Markandya et al. 2008) and are also beginning to be reported all over the African continent (Ogada et al. 2015a).

The “African vulture crisis”, which is currently in full force, is being finally discussed and researched at a continental scale, with parties coming together to develop a common strategy to save vultures (Botha et al. 2012; Ogada et al. 2015a). After the first Pan-African Vulture Summit in 2012, many researchers have been publishing reports on declines in several African countries and threats have been clarified for a considerable range (Virani et al. 2011; Kendall & Virani 2012; Ogada et al. 2012a, 2015a, 2015b; Odino et al. 2014b; Ogada 2014a; Whytock et al. 2014; Buij et al. 2015). Nonetheless, for several areas and countries, virtually nothing is known on vulture population status, trends and threats (Anderson 2007; Ogada & Buij 2011; Ogada et al. 2015a), hampering the development of adequate conservation strategies.

Guinea-Bissau is included in the West African region, one of the areas with the highest vulture population decline rates reported for the continent (Rondeau & Thiollay 2004; Thiollay 2006b; Ogada et al. 2015a; Buechley & Şekercioğlu 2016). However, nothing has ever been published concerning vultures in the country, neither there has been any systematic work focusing on these birds. Given the overall trend in West Africa and underlying causes for the astonishing declines reported, there is an urgent need to establish baseline information concerning population’s distribution and abundances. It is also important to identify possible threats for vultures in the country and ways for addressing them.

Guinea-Bissau is home to 5 vulture species: hooded vulture *Necrosyrtes monachus*, white-backed vulture *Gyps africanus*, Rüppell’s vulture *Gyps rueppelli*, white-headed vulture *Trigonoceps occipitalis*, and palm-nut vulture *Gypohierax angolensis* (Dodman et al. 2004; Borrow & Demey 2014). The first four species are currently listed in the IUCN Red List as Critically Endangered, while the palm-nut vulture is considered of Least Concern. At least three (hooded, white-backed and palm-nut vultures) are still common and, perhaps, abundant in many parts of the country. The main terrestrial non-obligate avian scavengers include pied-crows *Corvus albus*, yellow-billed kites *Milvus migrans parasitus*, and to a small extent also Marabou storks *Leptoptilos crumenifer* (Dodman et al. 2004; Borrow & Demey 2014).

In our study we aim to deliver the first baseline data on vulture populations and other avian scavengers by studying their distribution and abundance in virtually all of Guinea-Bissau’s territory. We also study the factors influencing the patterns of their abundance distribution throughout the country and analyse the distribution over the habitats. Finally, we overview some insights on possible threats and conflict sources with humans that can affect vulture conservation in the country, based on informal talks conducted with several key stakeholders during field work.

Methods

Study Area

Guinea-Bissau is a small (36,125 km²) West African country. It has a tropical humid climate with a bi-seasonal variation resulting in rainy (from May to October) and a dry (from November to April) seasons. The country is situated in a transition zone between Congo-Guinean and Sudanian environments (Ministério de Desenvolvimento Rural e Agricultura n.d.; Dodman et al. 2004). It is essentially flat, with maximum altitude values around 300 metres and has an interesting diversity of natural habitats, of which the most important in the interior are humid and dry savannas and different types of forests (palm, sub-humid, dry, gallery forests, among others) (Ministério de Desenvolvimento Rural e Agricultura n.d.). Along the coast and in the Bijagós archipelago are the palm and mangrove forests, salt marshes and extensive mudflats and sandbanks (Dodman et al. 2004). Human-modified habitats include crop areas (mainly rice fields), cashew plantations and some urban areas. Livestock farming is one of the most important subsistence activities (United Nations Statistic

Division 2016), with total grazing areas estimated to be around 35% of the country's surface area (Direcção Geral da Pecuária 2010). Guinea-Bissau has currently 8 Protected Areas covering around 9,520 km^2, of which 5 are in mainland and 3 are part of the Biosphere Reserve of the archipelago of Bolama/Bijagós (Instituto da Biodiversidade e das Áreas Protegidas 2014). The main faunal biodiversity is concentrated inside protected areas. The large wild vertebrates such as elephants and ungulates are currently rare over an important part of the country, with a total biomass likely to be small compared to livestock's. Nonetheless, this may not be the case in some forested areas in less humanized environments. In these places we may still find some wild fauna such as leopards and hyenas (Instituto da Biodiversidade e das Áreas Protegidas 2014).

Field methods

This study was conducted in Guinea-Bissau (mainland and Bijagós archipelago) during the dry season, between mid-February and end of April of 2016. We sampled all five vulture species recorded for the country but also recorded all sightings of yellow-billed kites, pied crows and marabou storks. To assess the distribution and relative abundance of the target species in the country we used two different approaches: roadside transects and point-counts.

Using the country's road network, we conducted roadside transects by car, a well-established method to study vultures and other large birds of prey (Thiollay 2001, 2006b; Prakash et al. 2003). Transects were carried out between 9:30h and 17:30h, during the period of the day in which vultures were most visible while riding thermal currents. Forty transects totalling 1,733 km were conducted in the country's mainland (Fig. 1.1). About 94% of the transect length was sampled by a team of 4 members, whereas 6% was conducted by 3 members, at least one of which was a well-trained ornithologist. All birds of the study species seen perched or flying on either side of roads were identified and counted while driving in a low nearly-constant speed (<50 km/h) and their position on the transect was recorded using a GPS. Stops were made only when necessary to identify birds, during which we did not record any new individuals observed. For every sighting, the observers registered the species, the time, the size of the group and the habitat over which it was spotted.

Point-counts, when placed in open areas, have the advantage of being much less sensitive than transects to differences in visibility among sampling units. Therefore, and to provide an alternative method for estimating the abundance and density of the target species in the country, we

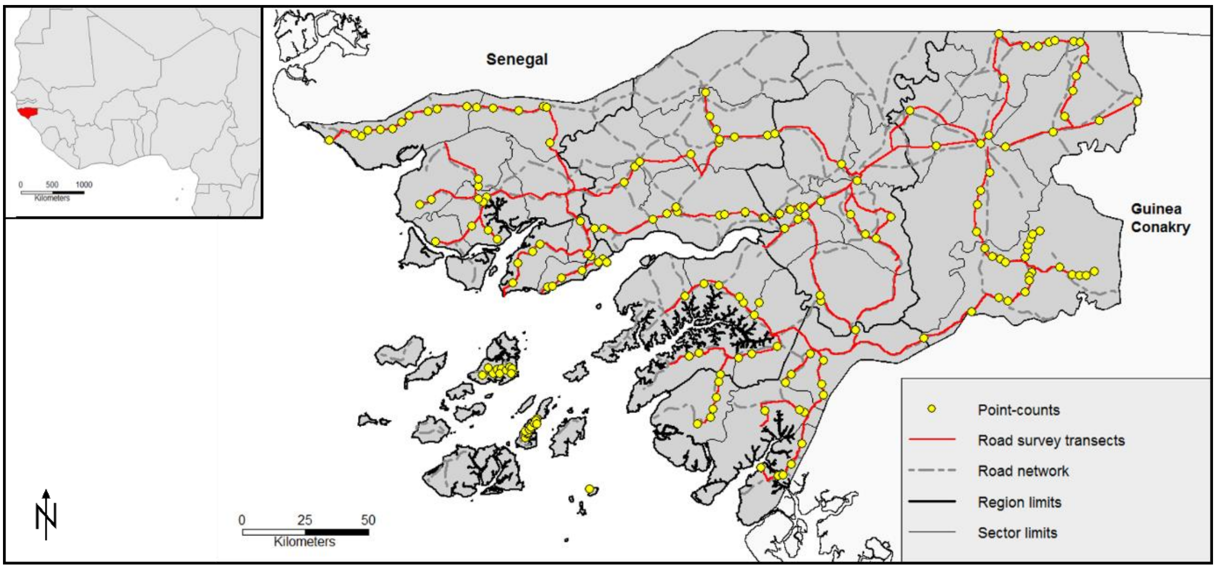

Figure 1.1. Map of Guinea-Bissau, with transects and point-counts represented.

performed unlimited radius point-counts (Blondel et al. 1981; Hutto et al. 1986; Cyr et al. 1995; Bird & Bildstein 2007), in areas with at least 65% of the sky view unblocked by vegetation or buildings. We also preferred this method on islands where there are few or no roads. We conducted 184 GPS-recorded point-counts across all the country's mainland and also in the Bijagós archipelago, carried out between 9:30h and 17:30h. Point-counts were at least 4 km apart, or less if good sense dictates otherwise, based on visibility constrains to avoid any overlap (Hutto et al. 1986) (Fig. 1.1). One or two observers preformed a 2 or 4-minute count, respectively, scouting the area with binoculars (each observer covering a 180° section, in case of two observers). Every time a more difficult identification had to be done, we left it to the end of the counts, when possible, and quickly used a telescope and/or a photo camera to confirm the species.

Data analysis

Encounter rates

Encounter rates were calculated as the number of birds of a target species or group of species detected per kilometre of transect, providing an abundance index (Prakash et al. 2003; Thiollay 2006b; Pomeroy et al. 2014; Ogada et al. 2016). The selected unit of analysis was the Sector, an administrative division within the country (there are 37 Sectors in total). Thus, we assigned all transect data to the Sector where it was carried out. We calculated the encounter rates for all but five Sectors of Guinea-Bissau which were not surveyed for logistical reasons. We calculated the mean encounter rates (±SD) for each of the target species/group of species (n = 32 Sectors) at national level.

Punctual abundance indexes (PAI)

Using the point-counts data, we calculate the punctual abundance index (PAI), which represents the mean number of birds that are detected per 2 minutes in every point-count of each analysis unit (Blondel et al. 1981; Uezu et al. 2005). We used the Region as the analysis unit, the largest administrative division within the country, and obtained an abundance index for all the 8 Regions. Sectors were not used for this analysis due to insufficient number of points in several of these.

Mapping the distribution and abundance

Encounter rates for each Sector were represented in a map of the country. We choose to compile all griffon detections in one group because several times we spotted juvenile griffons that we were not able to distinguish between white-backed and Rüppell's vultures. A similar procedure was used for PAI.

Predictors of distribution and abundance

We used multiple linear regressions to investigate the relationship between the encounter rates in each Sector for the study species, and the following potential explanatory variables: average annual Normalized Difference Vegetation Index (NDVI), mean annual temperature, annual temperature range, average annual precipitation, cattle density (heads per km^2), absolute human population (people per Sector), and human population density (people per km^2). The NDVI is an index (from -1 to 1) from remote sensing measurements that can show differences between water, barred areas (rock, sand or snow), grass and shrub lands, and tropical rainforests, here used to differentiate open areas from more dense habitats. Climatic variables were obtained from WorldClim (http://www.worldclim.org/) (Hijmans et al. 2005). Cattle density was obtained from Livestock Geo-Wiki (http://www.livestock.geo-wiki.org/) (Robinson et al. 2014). Human population data derived from counts during national population census (Instituto Nacional de Estatística 2009). Predictable variables are mapped for each sector in Section III of the Supplementary materials. Multiple linear regressions were run for species with enough number of sightings (hooded and griffon vultures, yellow-billed kites and pied crows), and variable selection followed a stepwise selection, based on AIC scores. When the model with lowest AIC included non-significant variables, we continued the stepwise procedure until only significant variables were left.

Table 1.1. Habitat classes created for the analysis of the distribution over habitats.

Habitat class	Description
Bolanhas	Rice fields in wet and saline environments
Cultivations	Plateau rice fields and gardens
Forests	All kind of natural forests, including palm tree forests
Human Settlements	All type of settlements with permanent or periodic presence of people
Lalas	Vast low ground areas flooded periodically, with grassy vegetation
Mixed	Areas with both natural and anthropogenic environments
Orchards	Mainly cashew trees, with also some mango trees
Savannahs	Sudan-Guinean savannahs, including wooded savannahs
Wetlands	Permanent or almost permanent humid habitats, including mangrove and rivers (both salty and freshwater rivers)
NI	Non identified habitat (when habitat was not visible from the road)

Distribution over habitats

The analysis of the distribution over habitats was performed from data collected only with the roadside transect method, since point-count sites were mainly in open habitats. We calculated the proportion of birds of each species that were perched or flying over a certain type of habitat in the moment of detection. In this analysis, we excluded rare species that were not spotted in sufficient numbers and also palm-nut vultures, as our methods were inadequate for this species (palm-nut vultures are mainly found in palm forests, wetlands and in the islands). Habitats were grouped in 9 classes, plus 1 class for cases when it was not possible to determine habitat (Table 1.1).

Results

Roadside transects and encounter rates

We counted 4,509 vultures and 550 other avian scavengers (yellow-billed kites, pied crows and marabou storks combined) in the 1,733 km carried out all over the country (Table 1.2). While we saw all 5 species of vultures recorded for the country, only hooded and griffon vultures, yellow-billed kites and pied crows were seen in sufficient numbers to calculate encounter rates for each Sector (Section I of the Supplementary Materials). Hooded vultures were, by far, the most common species detected (82.7% of all sightings).

Point-counts and Punctual abundance indexes (PAI)

We counted 1,698 vultures and 426 other avian scavengers (yellow-billed kites and pied crows combined) in the 184 point-counts conducted, both in the islands (n = 22 points) and in mainland (n = 162 points) (Table 1.2). With this method we detected 4 of the 5 species of vultures recorded for the country and 2 of the 3 other avian scavengers. Only hooded and white-backed vultures, yellow-billed kites and pied crows were seen in sufficient number to calculate the PAI for each Region (Section I of the Supplementary Materials). Hooded vultures, as it was in the transect method, constituted the majority of sightings (73.4% of all detections combined). Palm-nut vultures were seen in good numbers, mainly in the islands, where there is a larger representation of its preferred habitat.

Mapping the distribution and abundance

Hooded vultures were present in all Sectors sampled being noticeably more abundant in Bissau (Fig. 1.2, see also Section I of the Supplementary Materials). The Sector with the lowest abundance was Boé (2 birds seen in 103.7 km of transect). Griffons were detected in 13 Sectors, with highest abundances in São Domingos, Quinhamel and Canchungo (Fig. 1.3). In the South there were almost no griffons (only 4 birds detected south of the Geba river). Abundance distribution of white-backed vultures' mimics almost entirely that represented by griffon's detections, since only 2% of the griffon

Table 1.2. Relative measures of abundance (±SD) of all detected vultures and other avian scavengers at the national level, as measured during transect (n= 32 sectors) and point-count (n= 9 regions) surveys. NA – Not applicable, for species that were not seen in sufficient number to calculate encounter rates or, in the case of the palm-nut vultures, that are not well sampled by the method

Species	Transect surveys		Point-count surveys	
	Number of birds counted	Mean encounter rates (birds/100 km ±SD)	Number of birds counted	Mean punctual abundance index (birds/point-count ± SD)
Hooded vultures *Necrosyrtes monachus*	4313	326.44 (±503.32)	1559	13.68 (±20.46)
Griffons *G. africanus + G. rueppelli+ Gyps sp.*	160	8.65 (±14.99)	65	0.30 (±0.55)
White-backed vultures *Gyps africanus*	128	7.24 (±13.78)	63	0.296 (±0.53)
Rüppell's vultures *Gyps rueppelli*	3	NA	0	NA
Palm-nut vultures *Gypohierax angolensis*	24	NA	73	NA
White-headed vultures *Trigonoceps occipitalis*	3	NA	1	NA
Yellow-billed Kites *Milvus migrans parasitus*	275	18.65 (±22.46)	219	1.37 (±1.87)
Pied Crows *Corvus albus*	274	22.31 (±56.24)	207	3.96 (±10.25)
Marabou storks *Leptoptilos crumenifer*	1	NA	0	NA

detections with confirmed identifications were Rüppell's vultures (see maps in Section II of the Supplementary Materials). Yellow-billed kites were detected in all but six Sectors, with a clear difference in abundance from North to South (only 7 birds seen south of the Geba river) (Fig 1.4). Finally, pied crows were present in 20 Sectors, the species being much more abundant in Bissau than elsewhere (Fig. 1.5).

Data collected with the point-count method confirms, at a larger scale (Region), the patterns obtained above with the mapping of the encounter rates for hooded vultures, being the species present in all the country (Fig. 1.6). In the Bijagós archipelago we found the second lowest PAI of the country (around 2 birds per point-count). We detected griffons in 7 of the 9 Regions, in line with data obtained from encounter rates (Fig. 1.7, see also Section I of the Supplementary Materials). Yellow-billed kites were present in every Region, with the highest abundance in Bafatá and the lowest in Gabú (Fig. 1.8). The PAI calculated for pied crows confirms the presence of the species in all but 2 Regions, namely Oio and Quinara (Fig. 1.9).

During transect surveys we detected only 3 Rüppell's vultures, 3 white-headed vultures and 1 marabou stork, while during point-counts only 1 white-headed vulture was spotted (Fig. 1.10). The vultures were seen only in the Northwest, in congregations of vultures over carcasses of dead farm animals (pig and cow) in rural human settlements. The marabou stork was only spotted flying over patches of well-conserved sub-humid forest, inside the Cufada Lagoons Natural Park, in the Sector of Fulacunda.

Predictors of distribution and abundance

Hooded vulture distribution of abundances was significantly related to human population density ($F = 6.5$ on 1 and 29 DF, Adjusted $R^2 = 0.155$, $p = 0.016$), whereas average annual NDVI, mean annual temperature, annual temperature range, average annual precipitation, cattle and absolute human population were excluded from the model. The same was observed with pied crows ($F = 18.7$ on 1 and 29 DF, Adjusted $R^2 = 0.37$, $p = 0.00017$). Yellow-billed kite distribution of abundances could be explained both by the human density and the average annual precipitation ($F = 39.9$ on 2 and

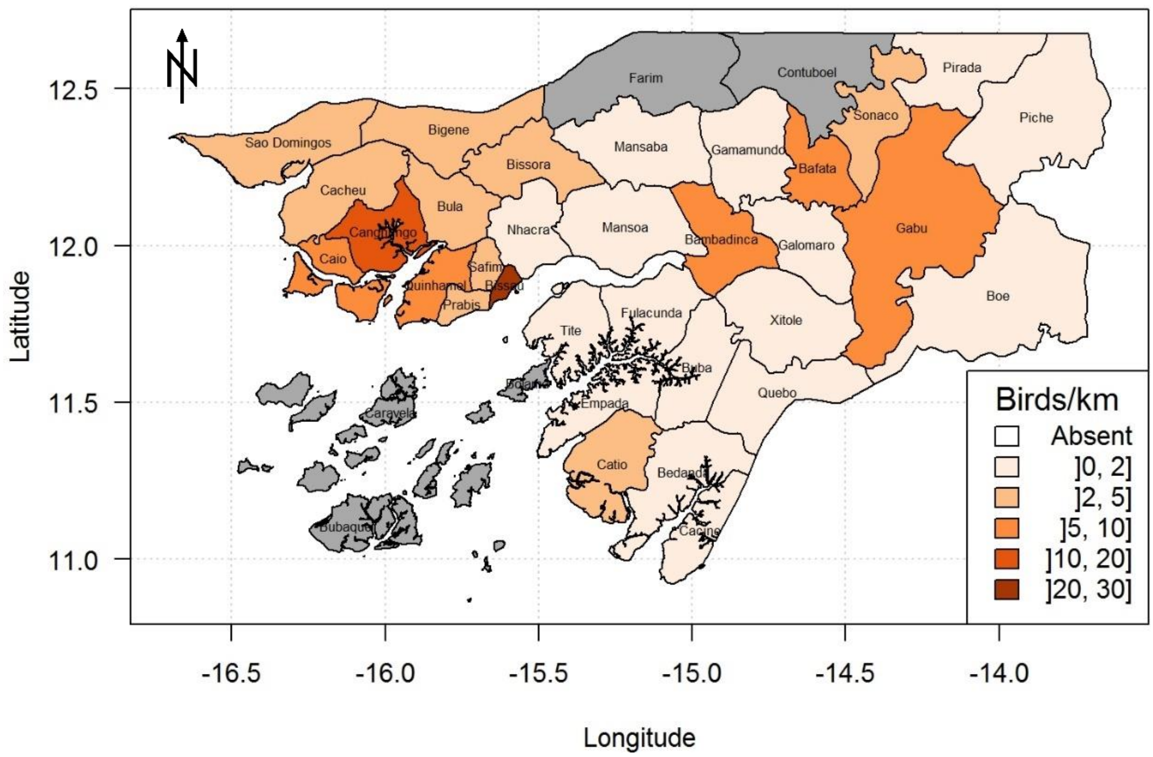

Figure 1.2. Abundance of hooded vultures *Necrosyrtes monachus* in sampled Sectors of Guinea-Bissau obtained from road survey transects. Grey areas represent Sectors that were not sampled.

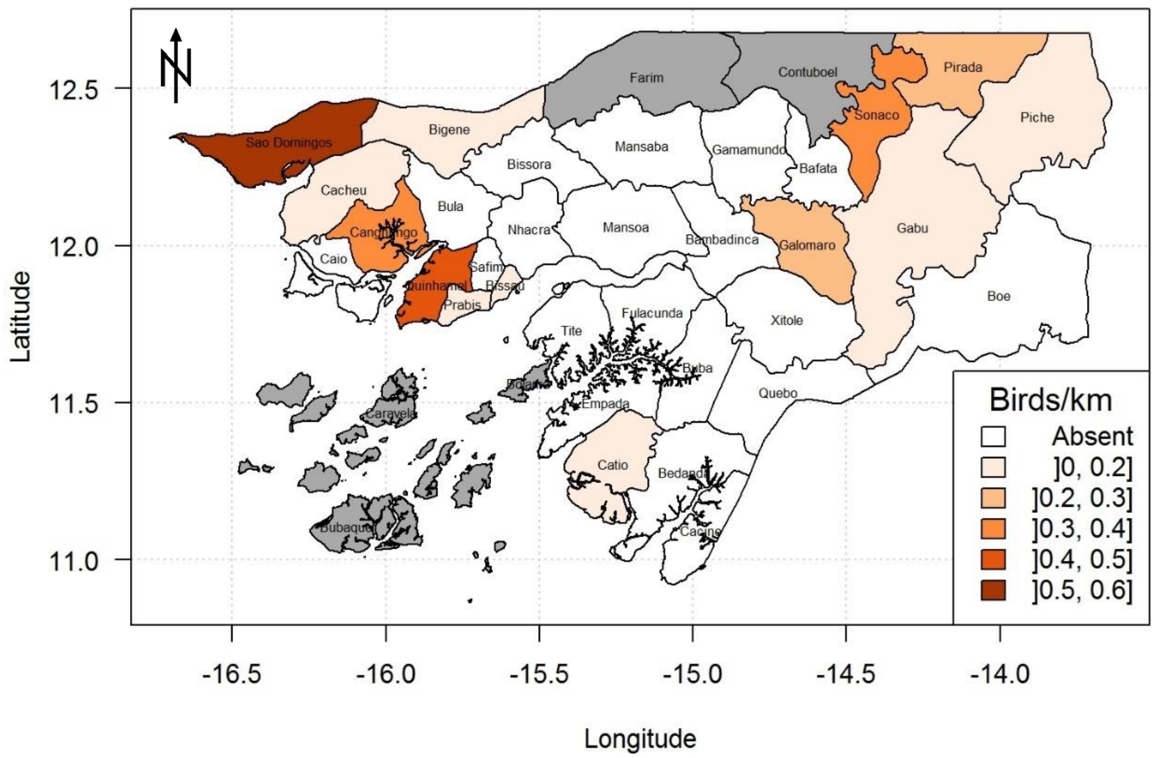

Figure 1.3. Abundance of Griffon *Gyps sp.* vultures in sampled Sectors of Guinea-Bissau obtained from road survey transects. Grey areas represent Sectors that were not sampled.

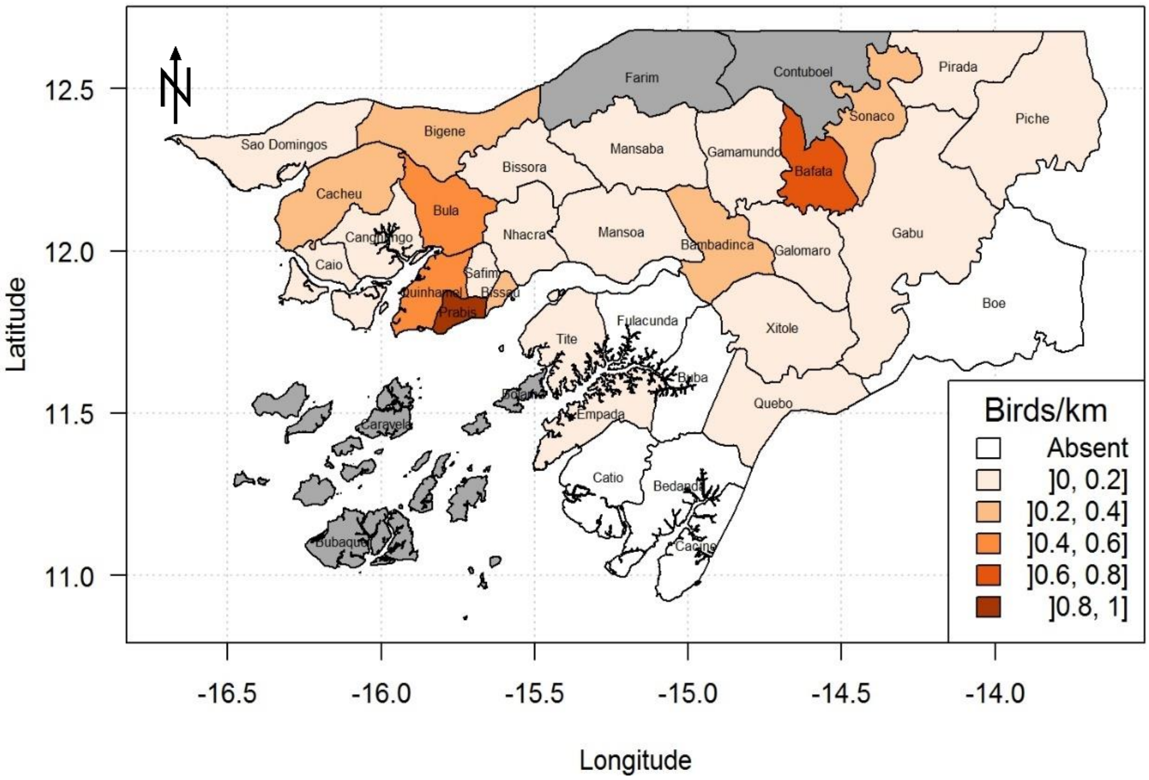

Figure 1.4. Abundance of yellow-billed kites *Milvus migrans parasitus* in sampled Sectors of Guinea-Bissau obtained from road survey transects. Grey areas represent Sectors that were not sampled.

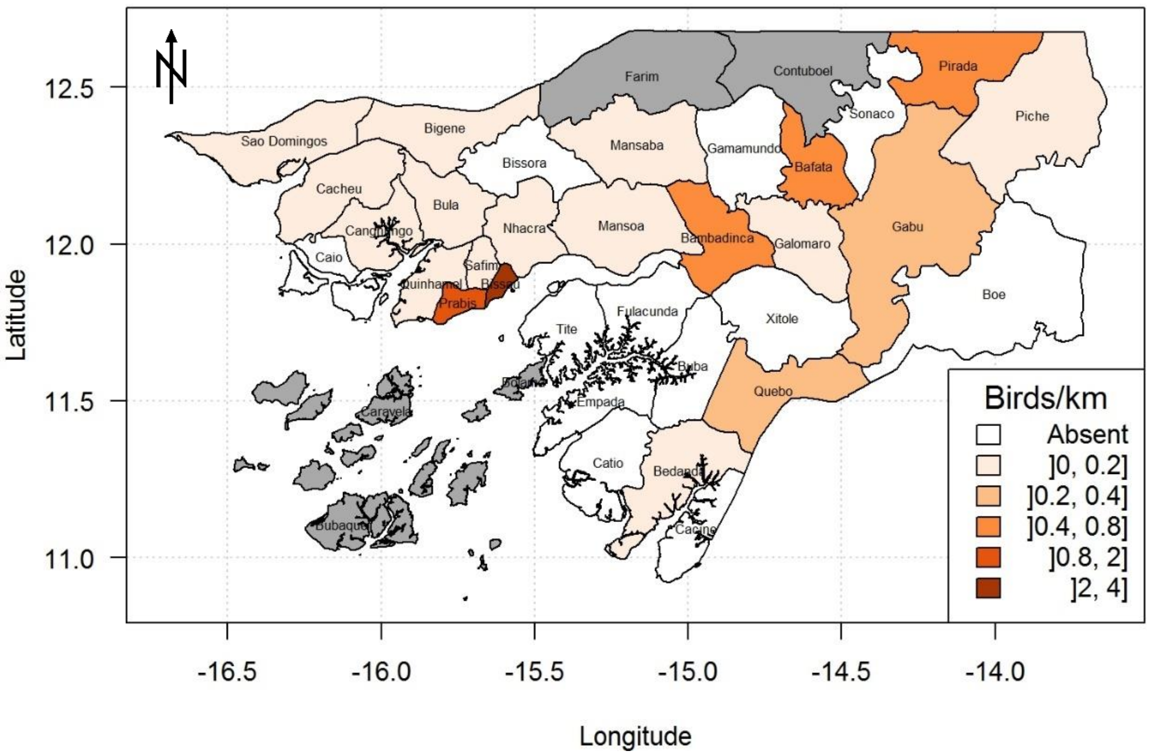

Figure 1.5. Abundance of pied crows *Corvus albus* in sampled Sectors of Guinea-Bissau obtained from road survey transects. Grey areas represent Sectors that were not sampled.

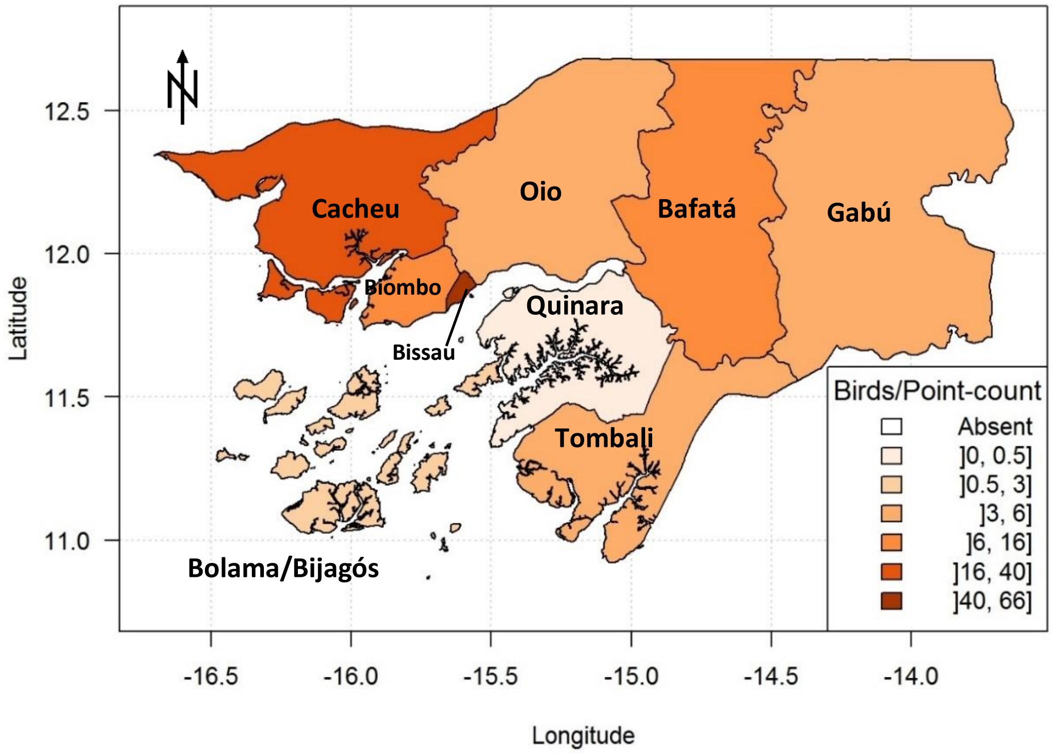

Figure 1.6. Abundance of hooded vultures *Necrosyrtes monachus* in all Regions of Guinea-Bissau calculated from point-count surveys.

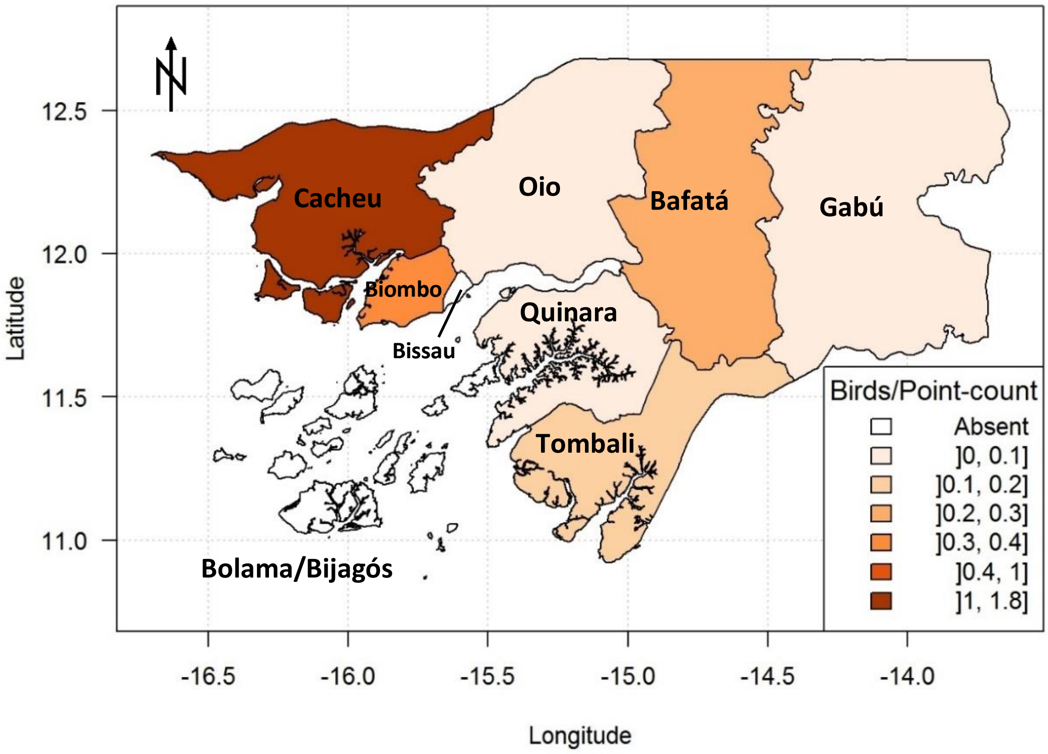

Figure 1.7. Abundance of griffon vultures *Gyps sp.* in all Regions of Guinea-Bissau calculated from point-count surveys.

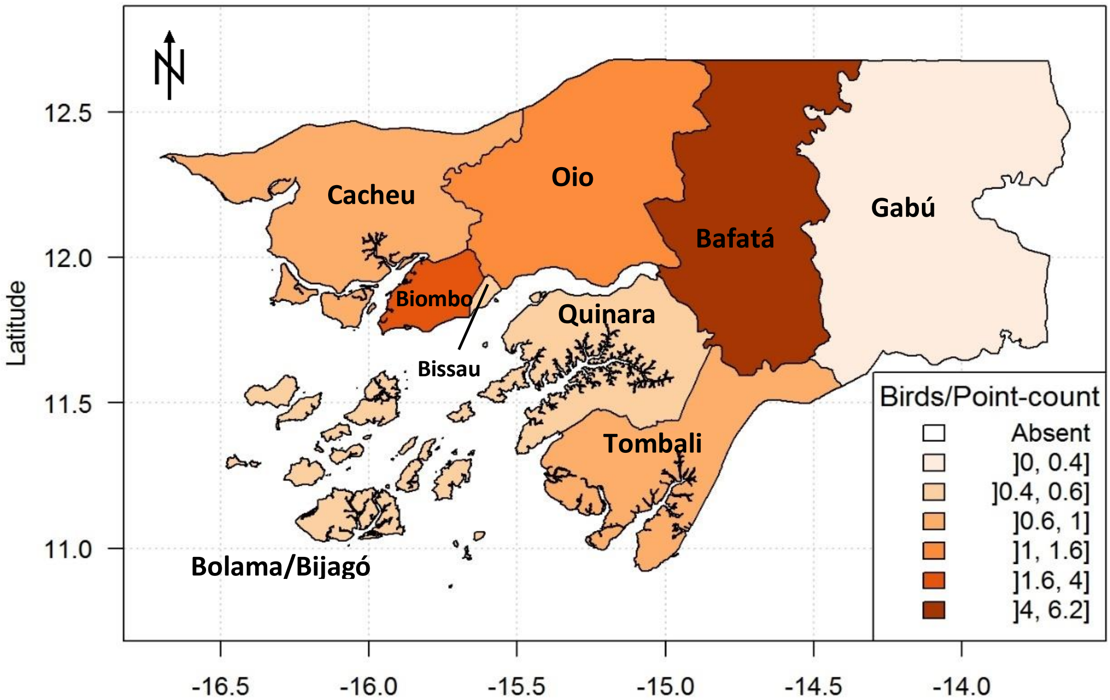

Figure 1.8. Abundance of yellow-billed kites *Milvus migrans parasitus* in all Regions of Guinea-Bissau calculated from point-count surveys.

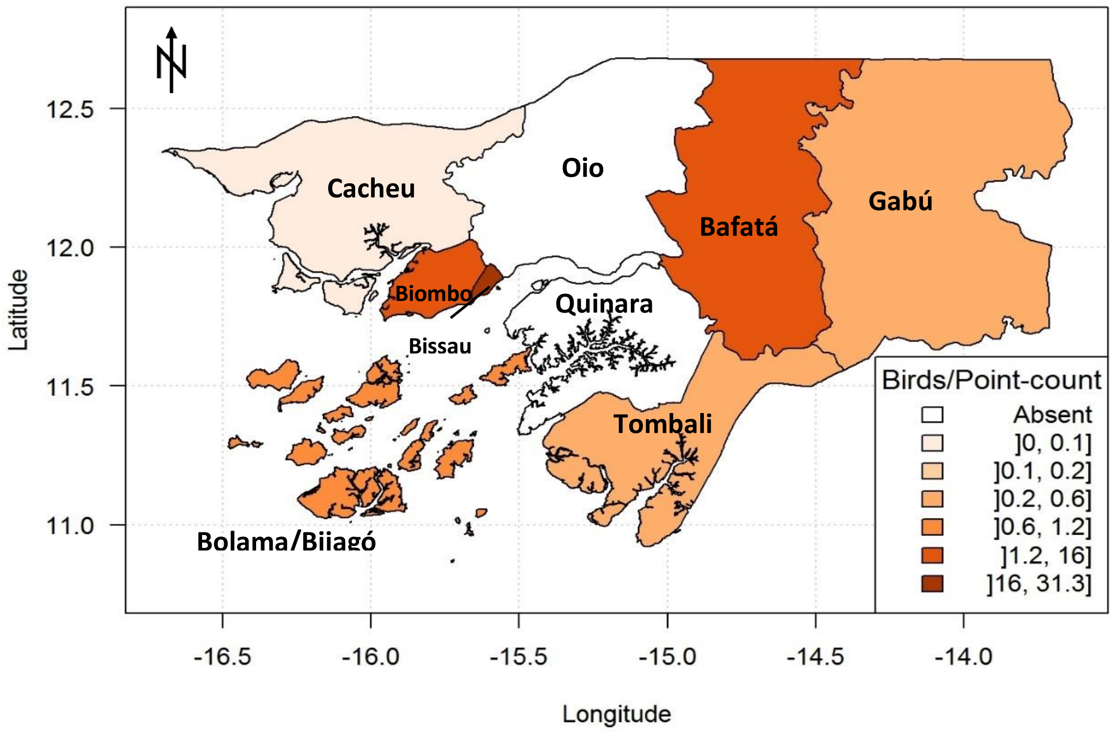

Figure 1.9. Abundance of pied crows *Corvus albus* in all Regions of Guinea-Bissau calculated from point-count surveys.

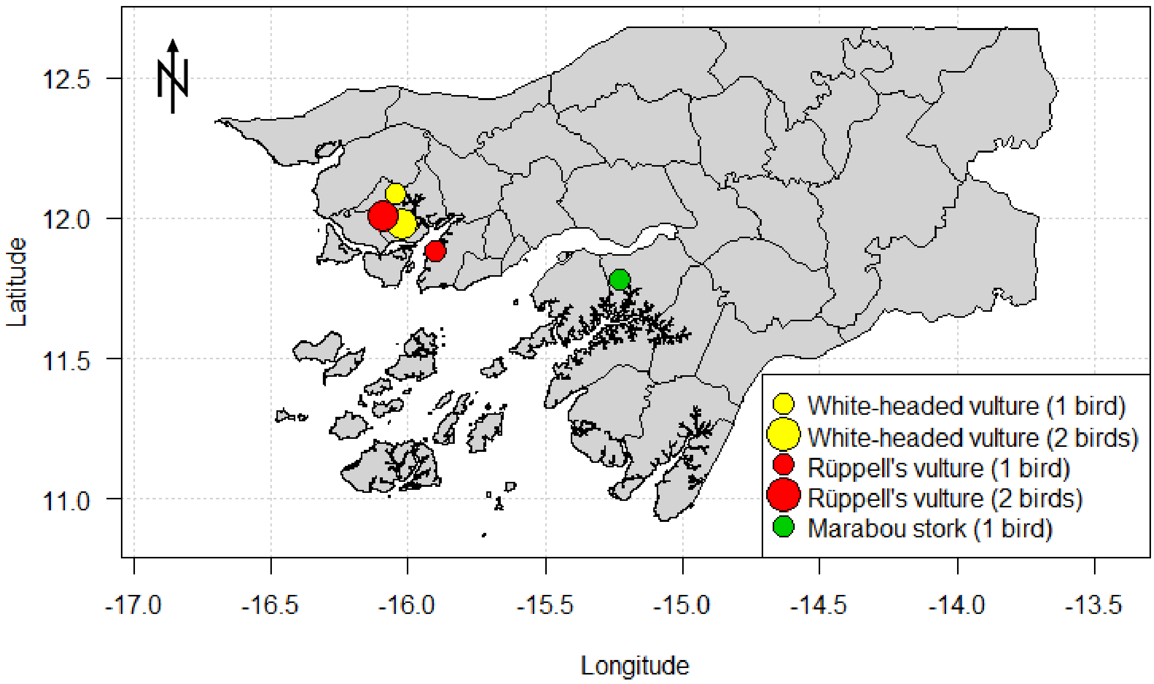

Figure 1.10. Map of the sightings of rare study species with both road surveys and point-counts during this study.

28 DF, Adjusted $R^2 = 0.72$, $p < 0.0001$). Griffons showed no significant relation with any of the selected explanatory variables.

Distribution over habitats

In general, most of the species analysed here were detected frequently in human settlement areas (Fig. 1.11). The majority (63%) of the 4,360 hooded vultures seen were landed on or flying over human settlements of different sizes. The 159 griffons detected were slightly more associated with savannahs (31%) than with human settlements (30%). 36% of the 275 yellow-billed kites seen were using human settlements, while a significant percentage (12%) was using lalas. Finally, pied crows are the species with the strongest association with human settlements, with 77% of the 297 birds detected using this habitat (see also Section III of the Supplementary Materials).

Discussion

Vulture abundance and distribution in Guinea-Bissau: the first baseline-data

In this study we present the first systematically collected data ever reported on the status of vulture populations in Guinea-Bissau.

Hooded vultures were by far the commonest of all vultures in the country. Our results suggest that its abundance in Guinea-Bissau represents one of the highest in all of the species range, only surpassed by recent reports for the Gambia (Table 1.3). However, in that same country, a survey conducted 10 years before counted 290 birds/100 km in and around Banjul (Barlow & Fulford 2013). Such large variation might be explained by the fact that the surveys conducted in 2013 and 2015 were carried out only in densely populated areas, which may introduce an important bias in the results. Hence, we analyse these numbers with caution.

The multiple linear regression results clearly demonstrate the importance of human population density in the distribution patterns of hooded vultures. Apart from cities, hooded vultures are

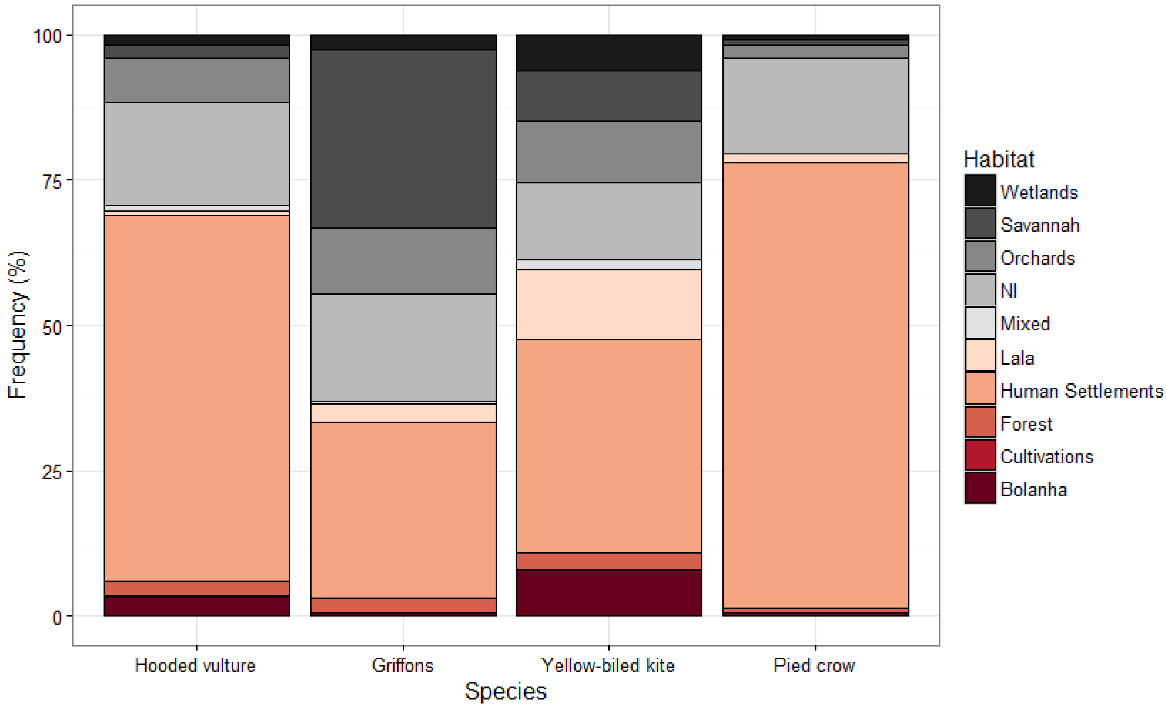

Figure 1.11. Distribution over habitats of detected study species during transect surveys in Guinea-Bissau mainland. NI – Non identified habitat, for detections that were impossible to assign to a habitat class. Refer to Table 1.1 for details on habitat classes.

Table 1.3. Comparing encounter rates (birds/100 km) between our study and other published data from elsewhere in Africa.

Species	Guinea-Bissau[1] (2016)	Guinea-Conakry[2] (2006)	Western Gambia (2015)[3]	West Africa[4] (2003 - 2004)	Cameroon[5] (2000)	Chad and Niger[6] (2010-2012)	Uganda[7] (2008-2013)	East Africa[8] (Northern Kenya/ Masai Mara) (2016/2003-2005)
hooded vultures *Necrosyrtes monachus*	326.4	33.9	1750.0	62.6	33.9	0.7	0.5	3.1/2.3
Griffons *Gyps spp.*	8.7	7.7	-	21.4	40.3	4.8	11.6	10.1/46.1
Effort (km of transect)	1,733	3,635	195	8,353	1,359	14,905	8,232	2,356/3,400

[1] Our study;
[2] Rondeau et al. 2008;
[3] Jallow et al. 2016;
[4] Sum of mean encounter rates in unprotected and protected areas in Burkina Faso, Mali and Niger (Thiollay 2006b);
[5] Sum of mean encounter rates in unprotected and protected areas (Thiollay 2001);
[6] Wacher et al. 2013;
[7] Estimates calculated from GLMM fitted values and mean encounter rates summed from unprotected and protected areas (Pomeroy et al. 2014);
[8] Virani et al. 2011; Ogada et al. 2016.

more numerous in the areas with the highest congregations of people, as it happens in the Northwest of the country, where people gather near the coast. More inland, hooded vulture abundance is also high in the Sectors of Bambadinca, Bafatá and Gabú, which holds important human populations in major urban centres like the cities of Gabú and Bafatá, the largest after Bissau. In these cities, a great deal of rubbish and refuses are available for these scavengers.

Our results show that griffons are still present in many parts of the country, and are even abundant in some Sectors, in which we counted between 24 - 57 birds/100 km. Comparing with encounter rates of griffons elsewhere, our results resemble those on neighbouring Guinea-Conakry and are also almost at the same level than those reported for many parts of East Africa, where griffons encounter favourable habitats with large populations of wild ungulates (Table 1.3).

The Northwest is clearly the area that is more important to these griffons, although it remains unclear which are the main drivers of this distribution, as regression analysis did not find cattle density to be significant. As expected, griffons are absent from all the forested areas of the South and do not occur in the Bijagós islands, which is mainly comprised by mangrove and palm forests.

Of all griffon detections recorded during this study, 80% were white-backed vultures *Gyps africanus*, while only 2% where Rüppell's *Gyps rueppelli*. The remaining 18% were griffons that we were not able to distinguish between the two species, mainly immature birds. Rüppell's vultures are rare in Guinea-Bissau and probably all unidentified griffons were white-backed vultures. Rüppell's vultures may be rare in Guinea-Bissau due to habitat constraints, especially for nesting, as they prefer cliffs (none available in Guinea-Bissau), and tree nesting is considered atypical (O'Neal Campbell 2016). Therefore, the occurrence of this species may have always been at least uncommon and birds that visit Guinea-Bissau may breed in Guinea-Conakry, where the species is considered common (Rondeau et al. 2008).

White-headed vultures *Trigonoceps occipitalis* appears to be currently very rare in the country, probably the rarest of all vultures. It occurs in low densities, as it happens in many parts of its range in West Africa (O'Neal Campbell 2016). White-headed vultures are different from other vultures in that they are mainly solitary foragers and most of the cases they occur in small groups of 2-4 birds (Murn & Holloway 2014; Murn et al. 2016). For that reason, it is harder to detect during surveys. Nonetheless, it is unclear if the present rarity results from a decline of the species, or whether white-headed vultures were also rare in the past.

Palm-nut vultures *Gypohierax angolensis* are probably the second most abundant species of vulture in the country, as shown by point-count results. The largest fraction of the population occurs in the Bijagós archipelago where the species is abundant (pers. obs.).

Vultures and facultative avian scavengers

Vultures are often dominant over facultative avian scavengers in natural habitats, but in human environments, namely in urban areas, this relationship may become inverse (Campbell 2009; Gbogbo et al. 2016; O'Neal Campbell 2016). In African urban centres and in rural human settlements, hooded vultures, kites and pied crows are known to compete over refuse in open-system slaughterhouses and in dumpsites (Pomeroy 1975; Boshoff & Boshoff 2007; Campbell 2009; O'Neal Campbell 2016).

In our study, we found that in the largest cities, namely Bissau and Gabú, yellow-billed kites were overall scarce to absent, while in more rural areas they were significantly associated to human settlements, as shown by the regression results. Nonetheless, yellow-billed kites in Guinea-Bissau appears to be less abundant than reported elsewhere (Pomeroy 1975; Thiollay 2007b; O'Neal Campbell 2016) and there were no clear evidences of a strong competition relationship between this species and vultures. Pied crows, on the other hand, were found mainly in large human settlements during our study, with the highest abundance in Bissau. The regression results showed that these corvids are highly related to human densities. Pied crows have already been reported to feed on the same food types than hooded vultures elsewhere (Annorbah & Holbech 2012), and the possibility that the crows have been outcompeting this vulture was reported in Accra (Gbogbo et al. 2016). Given the high adaptability and reproductive rate of this species in the presence of resources (Buechley & Şekercioğlu 2016) it is not unlikely that in the near future, similar outcompeting events may occur if the number of hooded vultures decreases. Therefore, it is important to monitor the evolution of this relation between obligate and facultative avian scavengers. Due to the scarcity of marabou storks (only 1 bird observed), this species is not a relevant competitor of vultures in Guinea-Bissau, as found in Ghana (Campbell 2009; Annorbah & Holbech 2012; Gbogbo et al. 2016).

Distribution over habitats: the importance of human-altered environments to avian scavengers in Guinea-Bissau

Our results confirm the importance of urban environments to hooded vultures and pied crows. As much as 75% of all hooded vultures and 80% of pied crows detected during road transects were associated with human-altered environments (human settlements, cultivations, bolanhas, orchards and mixed). Griffon vultures were usually found in open habitats, mostly savannahs and lalas (totalling 34% of all spotted individuals). On several occasions, we found these birds in flocks over carcasses of livestock. The presence of several small human settlements embedded in these natural environments contribute with food sources to griffons, which may be one of the reasons why 30% of these birds were spotted in such places. Human-altered environments in rural areas were also important for yellow-billed kites, reinforcing the evidences already presented in the regression analysis in this study. However, kites showed to be distributed over a large variety of habitats, being the study species more frequently spotted in wetlands, lalas and bolanhas. This may be explained in part by the extremely varied diet of this species (Scheider et al. 2004; Bijlsma et al. 2005 in The Peregrine Fund 2012; Kumar et al. 2014; BirdLife International 2016c).

Our overall results suggests that in Guinea-Bissau, human-vulture commensalism is a reality, as reported elsewhere in West Africa and the Yemen (Herremans & Herremans-Tonnoeyr 2000; Gbogbo & Awotwe-pratt 2008; Campbell 2009; Buij et al. 2013b; Gangoso et al. 2013; Morelli et al. 2015; Buechley & Şekercioğlu 2016). It is very likely that vultures in the country are currently very dependent on people due to the scarcity of wild fauna, hence their distribution and habitat use reported in this study. This is consistent with reports in the Cameroon, where the interaction between human populations and natural habitats were important predictors of Afrotropical raptor richness (Buij et al. 2013a) and hooded vulture abundance and distribution were found positively correlated to higher anthropogenic land-use degrees (Buij et al. 2013b).

Insights on increasing conservation issues

Distribution maps on griffons showed in this study suggest that these vultures are very scarce or absent in the extreme East, especially in the Sectors of Piche, Gabú, Boé and Bafatá. These areas have large extents of suitable habitat for these species, including some protected areas with very low human densities. Moreover, some of these Sectors are the ones with the highest abundance of cattle in the country (Direcção Geral da Pecuária 2010; DGA & DGP 2013). All these facts suggest that these Sectors should have more griffons than they actually hold currently. Hooded vultures (and other raptors) are also very scarce in the extreme East, namely in Piche and Pirada and are almost absent in Boé Sector. From several informal interviews with stakeholders (village leaders, livestock herders, veterinaries, butchers and others) during field trips, we captured information of great concern to vulture conservation. According to these reports, in some parts of the country, particularly in the East near areas with the presence of hyenas and leopards, there were events of poisoning campaigns organised by livestock herders and veterinaries as retaliation or prevention of attacks of these carnivores. In two of these reports, around 60 vultures were allegedly killed unintentionally (unidentified species). This may explain the unusually low number of vultures observed in those otherwise highly suitable areas and the inability to predict griffon distribution with the factors selected in this study. Vultures have very low reproduction rates (birds mature late and normally lay only one egg), which makes the populations very sensible to mortality.

The centre of the country also demonstrates to have less vultures than other parts. Griffons are totally absent of the majority of Sectors of the Region of Oio and hooded vultures are less abundant there than elsewhere in the country. These sectors are dominated in part by the ethnic groups of *Mandingas* and *Balantas*, which have important cultural and religious influences from Mali and Guinea-Conakry. We collected several reports of the increasing use of vultures in traditional medicine and sorcery, which is causing the persecution of vultures for body parts in the country, as it happens elsewhere (Williams et al. 2014; Buij et al. 2015; Ogada et al. 2015a). This was described as practices that were originally introduced by foreigners, namely from Mali, Guinea-Conakry and Sierra Leone. These practices do not appear to have a very significant expression yet, but are probably growing with unclear levels of impact, based on the frequency of these reports during the interviews. Therefore, it may be important to develop more research into the human activities of risk to vulture conservation. On the other hand, unlike reported in other countries (Whytock & Morgan 2010; Whytock et al. 2014; Buij et al. 2015), there were no reports of hunting for food, since vultures were generally regarded as “not eatable”.

Vultures provide important ecosystem services in urban areas (Markandya et al. 2008; Ogada et al. 2012b; Buechley & Şekercioğlu 2016). These services are of great importance in a country like Guinea-Bissau, where healthcare services are very lacking, waste management capacity very rudimentary, and there is a lot of organic waste left on the streets. The prevalence and magnitude of threats for vultures in the country is largely unknown and there is urgent need to assess them. We also highlight the undeniable need for the implementation of a monitoring program, using the methodologies refined during this study, which would allow to detect important fluctuations in trends of vulture populations in the future. Finally, as we identify certain Sectors where there are suitable habitats but very few vultures and reports of poisoning events, awareness actions directed to these areas and to key stakeholders which can constitute a threat to vulture survival is of great importance and urgency.

Chapter 2: Estimating the population of hooded vultures *Necrosyrtes monachus* in Guinea-Bissau

Abstract: *The hooded vulture is an African endemic scavenger whose global conservation status jumped from Least Concern to Critically Endangered in only 6 years, as an echo of dramatic population declines registered continent-wide. It provides important ecosystem services in urban areas in most sub-Saharan countries. Hence, its disappearance has a range of socio-economic, cultural and biodiversity impacts affecting the entire biological system. Few studies have been dedicated to quantify the global population of hooded vultures and Guinea-Bissau is one of the several West African countries that have no data on its populations size. Therefore, arises the need for the development of other more adapted methodologies, which would allow population estimates and long-time monitoring to measure trends in the future. In this work we studied the daily activity patterns of these scavengers in the capital, Bissau, to collect information to refine methodologies for vulture monitoring in the country, and estimate the population size nationwide using alternative methodologies. We conducted daily observations in the centre of Bissau between mid-February and end-April of 2016, using a point-count method. We found that hooded vultures are mostly active between 9:20h and 17:10h. Using two complementary approaches (strip transects using bicycle in the two largest cities, and complete counts by car during low activity periods of vultures), we sampled 21 human settlements of different sizes. We estimated 7,117 and 991 hooded vultures in Bissau and Gabú, respectively. In the other 19 human settlements we counted 1,123 hooded vultures during low activity periods. Using a linear regression between the number of hooded vultures and the number of people in settlements, we predicted the size of the national population to be between 67,872 and 88,287 birds. Our results suggest that Guinea-Bissau could be home to around 35 - 45% of the global population of the species.*

Keywords: hooded vultures, Guinea-Bissau, population estimate, strip transects, activity pattern

Introduction

The hooded vulture *Necrosyrtes monachus* is an African endemic scavenger widely distributed across the continent (Ferguson-Lees and Christie 2001 in O'Neal Campbell 2016). It was once described as a common species, in some places the commonest vulture (Brown 1971, in Ogada & Buij 2011), found in a variety of habitats like deserts, coastal lands, grasslands, wooded savannas and forest edges (Anderson 1999 in Ogada & Buij 2011). However, unlike other vultures, it is known to be increasingly more connected to human environments than natural habitats in most (but not all) sub-Saharan countries (Buij et al. 2013b; O'Neal Campbell 2016).

Currently, this species is part of one of today's most endangered group of birds worldwide (Long 2015). Its IUCN Red List conservation status jumped from Least Concern to Critically Endangered in only 6 years, between 2009 and 2015, as an echo of the dramatic population declines registered continent-wide (Ogada & Buij 2011; BirdLife International 2015; Ogada et al. 2015a). In the particular case of the West African region, there have been well substantiated reports of serious declines in all raptors, including hooded vultures, throughout the Sahelian and savanna areas (Rondeau & Thiollay 2004; Thiollay 2006a, 2006b, 2007b).

Despite these indications, in parts of Ghana and the Gambia populations appeared to remain stable, or even increasing (Gbogbo & Awotwe-pratt 2008; Campbell 2009; Ogada & Buij 2011; Barlow 2012). However, more recently, even in

Ghana, populations also started suddenly to collapse, with a reported 91% decline between 2011 and 2016 in Accra (Gbogbo et al. 2016). On the other hand, a recent paper reported evidences that the Gambia holds the highest current regional density of hooded vultures, with 12.0 and 17.5 birds per km of transect counted in 2013 and 2015, respectively (Jallow et al. 2016).

Several causes for the declines observed in vulture populations have been pointed out by researchers and conservationists throughout the world (Ogada et al. 2012a). In Africa unintentional poisoning from poisoned baits targeting mammal predators, intentional poisoning from illegal game hunters, intensive use for traditional medicine and sorcery, and hunting for food are the ones with the greatest impact over vultures (Bridgeford 2001; Thiollay 2006a, 2006b, 2006c; Ogada & Buij 2011; Botha et al. 2012; Roxburgh & McDougall 2012; Ogada et al. 2012a, 2015b; Williams et al. 2014; Ogada 2014a, 2014b; Atuo et al. 2015; Buij et al. 2015; Richards & Ogada 2015; Virani 2016).

Vulture's importance on ecological processes in terrestrial ecosystems is complex , but here we highlight two aspects: first, as nature's most successful scavenger, they contribute greatly in the nutrient cycling dynamics by increasing the decomposition rate of carcasses and positively affecting transmission of nutrients to the soil (Parmenter & Macmahon 2009; Ogada et al. 2012b). This has a chain-effect that is important in maintaining biodiversity (Barton et al. 2013). Second, hooded vultures also provide important ecosystem services in urban areas, like the disposal of organic waste, the control (through competition) of facultative mammalian scavengers and disease transmission between them, among many others (Ogada & Buij 2011; Gangoso et al. 2013). Thus, as key-stone species, vulture declines have a range of socio-economic, cultural and biodiversity impacts, mainly on human health, costs to industry, disposal costs to local communities, cultural and religious values and other biodiversity impacts (Markandya et al. 2008; Ogada & Buij 2011; Ogada et al. 2012b).

Roadside counts have been the most widely employed method for census of vultures in West African habitats (Thiollay 2001; Ogada & Keesing 2010; Virani et al. 2011; Ogada et al. 2013, 2016; Pomeroy et al. 2014; Whytock et al. 2014). However, this method not only gives us only a relative measure of abundance, but also it is not the best to sample species with a clustered distribution related to the roads itself, as is the case of the hooded vultures, resulting in biased estimates (Pomeroy et al. 2014). Few studies have been dedicated to quantify the global population of hooded vultures in African countries. Of these, we highlight Pomeroy (1975), Chemonges (1991), Amuno (2001) and Ssemanda (2005), who estimated the population of hooded vultures of Kampala, in Uganda, identifying the roosting and feeding congregations of the species and conducting simultaneous total counts (Pomeroy 1975; Ssemmanda 2005). A similar approach was used later in Accra, Ghana (Gbogbo & Awotwe-pratt 2008; Roberts 2013; Gbogbo et al. 2016). Using a different approach, Pomeroy et al. (2014) estimated the population of several vulture species in Uganda in relation with land use using Distance Sampling techniques, but they were unable to meet the assumptions of the method for hooded vultures, and their estimates were associated with extremely wide confidence limits (Pomeroy et al. 2014). Finally, in the Gambia, Jallow et al. (2016) estimated the density of hooded vultures in the Western region of the country using a strip transect method (Jallow et al. 2016).

Guinea-Bissau is one of the several countries in West Africa that have insufficient data to measure trends of hooded vulture populations (Ogada & Buij 2011). Moreover, to date there has been no census in any part of the country to try to assess the size of populations of this scavenger or any other vulture. Nonetheless, hooded vultures are not only common in the majority of the country, but are apparently abundant in many places. Being that hooded vultures are currently considered Critically Endangered globally, and several threats have already been identified in other neighbour countries, it is urgent to gather knowledge about population sizes and trends to be able to advocate for its protection and conservation. However, hooded vultures in Guinea-Bissau appear to roost mainly scattered in small-medium groups, and also are quite dispersed all over the urban areas during periods of activity to feed on small dumpsites. This makes the employment of the methods used in Uganda and Ghana very unpractical and highlights the need for the development of other more adapted methodologies, which would allow better population estimates and long-time monitoring to measure trends in the future.

This chapter focus on hooded vultures in Guinea-Bissau, with two main objectives: (1) study the daily activity patterns of these scavengers in the capital, Bissau, to describe the periods in which hooded vultures are more active, and collect information to refine methodologies for vulture monitoring in the country, particularly in densely populated human settlements; and (2) estimate the population size nationwide.

Methods

Study Area

The study was conducted from February to early May 2016. Guinea-Bissau has a humid tropical climate with a bi-seasonal variation resulting in a rainy (from May to October) and a dry (from November to April) season (Ministério de Desenvolvimento Rural e Agricultura n.d.). Human population in 2016 is estimated to be around 1.55 million, with about 42.6% of the population living in urban areas (Instituto Nacional de Estatística 2013). As one of the poorest countries in the world and home to more than 30 ethnic groups, subsistence activities often depend largely on exploiting natural resources and economic activities are rather underdeveloped to this point. We sampled 19 human settlements distributed all over the country, plus two major cities (Fig. 2.1).

Field methods

Daily activity pattern of hooded vultures in an urban centre

Using a point-count method (Thiel 1977; Dunbar 1976 in Dawson et al. 1984) we conducted daily observations in the centre of Bissau for 3 full days and 2 partial days, during the dry season (April and May of 2016). The site selected met the requirements of easy access, good visibility and no bias due to the presence of congregation factors (no roost or feeding sites). We then counted systematically the number of vultures flying between 7:00 and 19:20, in 10 minute intervals, and over a 360 degrees' angle.

Nationwide population estimate

We sampled 21 human settlements of different sizes, given the strong connection of this species to people. We used two different and complementary sampling methods, according to the type of human settlement:

i. in cities we conducted transect counts using a bicycle, in the early morning and late afternoon, between 7:00 and 8:20 and between 17:30 and 19:20. Transects were previously identified using Google Earth images ("Google Earth" 2016). Sampling design was based on literature recommendations for line and strip transects (Eberhardt 1978; Conner & Dickson 1980; Carrascal et al. 2008). Surveys were conducted by one observer, which counted every hooded vulture seen during transects, recording only perched birds. Perpendicular distances of each bird to the transect line were measured with precision using a laser rangefinder. Distances were measured using as reference buildings or trees over which the birds were perched. Birds that were spotted right before taking off or birds that were flying and landed in sight were registered as well. Notes were taken mostly using a voice recorder, allowing the observer to give full attention to his surroundings. This method was used to sample the two biggest human settlements of the country, Bissau and Gabú (82.9 and 8.7 km^2 of total area, respectively). In the city of Bissau, we conducted 14 transects along 71.4 km of roads and streets, ranging from 1 to 12 km long (mean = 5.1; SD = ± 3.2). In the city of Gabú we conducted 3 transects along 16.9 km of roads and streets. Transects were of 2.2 – 9.3 km long (mean = 5.6; SD = ± 3.6).

ii. in villages and towns, we conducted complete counts by car in the early morning and late afternoon, when hooded vultures were largely inactive. This method provided us with a minimum number of the population of vultures in each sampled site. During these counts, we slowly crossed the main roads and pathways through all the settlement and counted all the hooded vultures seen perched or flying. Three to four observers were used, placed in both sides of the car. Using this method, we sampled 5 villages, 13 small towns and 1 larger town (Fig. 2.1).

The city of Gabú was sampled using both methods, providing an opportunity to compare them.

Data analysis

Density estimates with strip transects in towns

Data collected during bicycle transects in the city of Bissau and Gabú was used to estimate the density of hooded vultures (birds per km^2) for each one of these cities and extrapolate to obtain the population size in them. We used the perpendicular distances recorded for each sighting to apply the strip transect methodology, in which we assume to spot every bird inside a given distance band. The sampled area is calculated multiplying the strip width by the total length of the transects and then, extrapolate the number of birds for all the area of each of the two cities (Eberhardt 1978; Conner & Dickson 1980; García-del-Rey 2005; Carrascal et al. 2008). To select which strip width to use for the estimation we used data from Bissau to construct a graph with all the density estimates for strip widths of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 meters (half of this value on each side of the transect). The most stable area of the graph was selected and the strip width which produced the higher density estimate was chosen to extrapolate for the entire city. The same strip width was then used to also estimate the hooded vulture population in Gabú, based on the transect counts conducted there.

Correction factor for hooded vultures flying during low activity periods

We used the activity pattern counts to calculate a correction factor for birds that are flying during low activity periods (early morning and late afternoon). This correction factor is to be applied to the hooded vulture population estimate in the cities of Bissau and Gabú, since in the strip transect method we only account for perched birds. We calculated the mean of all daily activity point counts between 7:20 and 8:20 (mean = 0.7 birds; SD = ± 2.9; n = 33) and between 17:30 and 19:20 (mean = 14.6 birds; SD = ± 16.5; n = 50), which corresponds to the mean of the number of birds flying during those periods. Then, we also

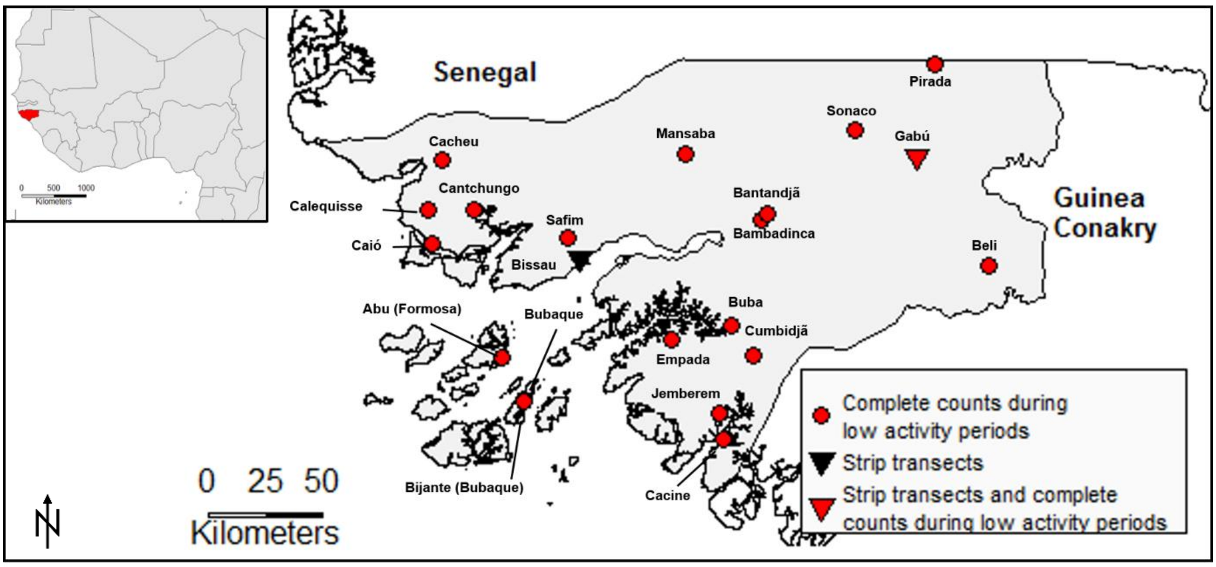

Figure 2.1. Map of the study area, comprised by all of Guinea-Bissau territory. The distribution of 21 human settlements sampled for this study is shown.

calculated the mean of the birds flying during the most active period of the day, between 10:00 and 15:30 (mean = 71.6 birds; SD = ± 30.5; n = 102). The proportion of birds flying during the periods of the transects is given relatively to the mean of the number of birds flying during the most active period (proportion of early morning period = 1%; proportion of late afternoon period = 20.3%, mean = 10.65%). This results in a correction factor of 1.12, calculated from the following formula: Numb. vultures = Numb. vultures perched/(1-Mean proportion of vultures flying during low activity periods).

Complete counts in human settlements during low activity periods

The counts of hooded vultures conducted during the early morning and late afternoon in 19 human settlements were used to compute a linear regression using the log(number of hooded vultures +1), against the number of people in settlements. We then compiled the human population size data from the National Census of 2009 concerning all settlements in Guinea-Bissau and used the regression to predict the size of the population of hooded vultures in each settlement, and finally sum up all the values to estimate the national population. In this process we excluded the cities of Bissau and Gabú, which showed to be outliers in terms of human population size (see results). In order to obtain a confidence interval for the national estimate, we randomly selected an estimate of number of vultures for each settlement, obtained from a normal distribution with mean located at the value predicted by the regression for that settlement size and a standard deviation equal to the corresponding prediction bands. We then summed up all the individual estimates to a new national estimate. This procedure was repeated 1000 times and we calculated the confidence intervals of our original estimate as the 0.025 and 0.975 quantiles of the distribution of the 1000 replicates. To this estimated total number of hooded vultures in the country, we then added the estimations for the cities of Bissau and Gabú, calculated with the method of strip transects.

Results

Daily activity pattern in an urban centre

Counts conducted in a central point in Bissau showed that hooded vultures are mostly active between ca 9:20h and ca 17:10h (Fig. 2.2). The mean number of birds counted in the air during this period was 66.8 ± 33.2 (SD), in 158 counts.

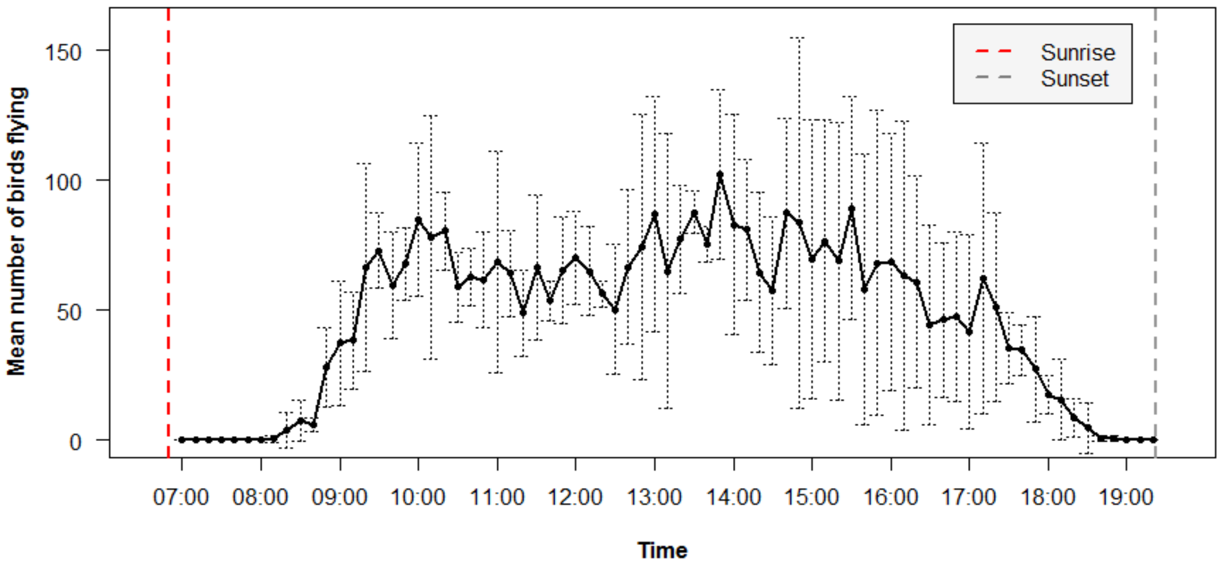

Figure 2.2. Daily activity pattern of hooded vultures in a central point of the city of Bissau. The line represents the mean (±SD) of birds flying, counted every 10 minutes for 3 full days (between 07:00 and 19:20), plus 2 half days counts (between 07:30 and 09:30 and between 16:30 and 18:30 local time). Sunrise and sunset exact timings obtain from the mean of the sampling period, data retrieved from http://www.timeanddate.com.

Between 7:00h and 8:20h the mean number of birds flying was less than one (mean = 0.6; SD = ± 2.7; n = 39 counts) just has it happened between 18:40h and 19:20h (mean = 0.3; SD = ± 0.7; n = 15 counts). Transition periods, during which hooded vultures go from inactive to active and vice-versa, occurred between 8:20h and 9:20h, and between 17:10 and 18:40.

Nationwide population estimate

Density estimates with strip transects in towns

In the city of Bissau, we counted 1,071 birds, of which 828 were perched. In Gabú we counted 340 birds, 200 of them perched. Using the data collected during bicycle transects in the city of Bissau (only for perched birds), we estimate the density of hooded vultures for each band width, as shown in Table 2.1. Graphic representation of the distribution of these density estimates along increasing bandwidths led us to choose the 60-meter band as the best estimate (Estimate 6) (Fig. 2.3). Thus, the density of hooded vultures in the city of Bissau, for the chosen band width is approximately 77 birds per km^2, equivalent to a total of 6,354 perched birds, and approximately 7,117 vultures, after applying the correction factor (1.12). Using the same band width for the calculations in city of Gabú, and based on the surveys conducted there, we estimate a density of approximately 102 birds per km^2, which results in a total abundance estimate of 991 hooded vultures for that city (885 individuals*correction factor). This compares with a minimum of 548 individuals recorded during an early morning survey covering a significant portion of the entire city, including the city's biggest slaughterhouse.

Complete counts in human settlements during low activity periods

We counted a total of 1,123 hooded vultures in 19 human settlements during low activity periods, with values ranging from 0 to 201. At only one settlement we counted 0 vultures. There are 4,424 human settlements in the country (mainland and Bijagós archipelago included) (Instituto Nacional de Estatística 2009), and the number of hooded vultures in each one of them could be predicted

Table 2.1. Results of the estimates of density and abundance of hooded vultures in the city of Bissau, using different total band widths (left plus right side of the transects) to produce several estimated densities. Estimate 6, highlighted in grey, represents the best Estimate, with a reasonable sampling area while remaining realistic as to the assumptions of the method (100% detectability up to 30 meters of each side of the transect line).

City	Estimate	Band width (m)	Sampled area (% of city area)	n (birds)	Estimated N	Estimated Density (birds/km^2)
Bissau	Estimate 1	10	0.86	16	1860	22.4
	Estimate 2	20	1.72	52	3022	36.4
	Estimate 3	30	2.58	129	4998	60.3
	Estimate 4	40	3.44	211	6131	73.9
	Estimate 5	50	4.30	252	5858	70.6
	Estimate 6	60	5.16	328	6354	76.6
	Estimate 7	70	6.02	329	5463	65.9
	Estimate 8	80	6.88	346	5027	60.6
	Estimate 9	90	7.74	351	4533	54.7
	Estimate 10	100	8.60	373	4335	52.3

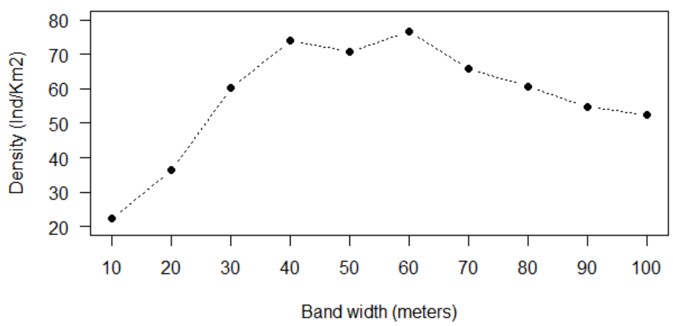

Figure 2.3. Representation of estimated densities of hooded vultures in Bissau, based on several different strip widths and sampling areas. Density values for band widths of 40, 50 and 60 meters (3.4%, 4.3% and 5.2% of the area of the city sampled, respectively) remains relatively stable.

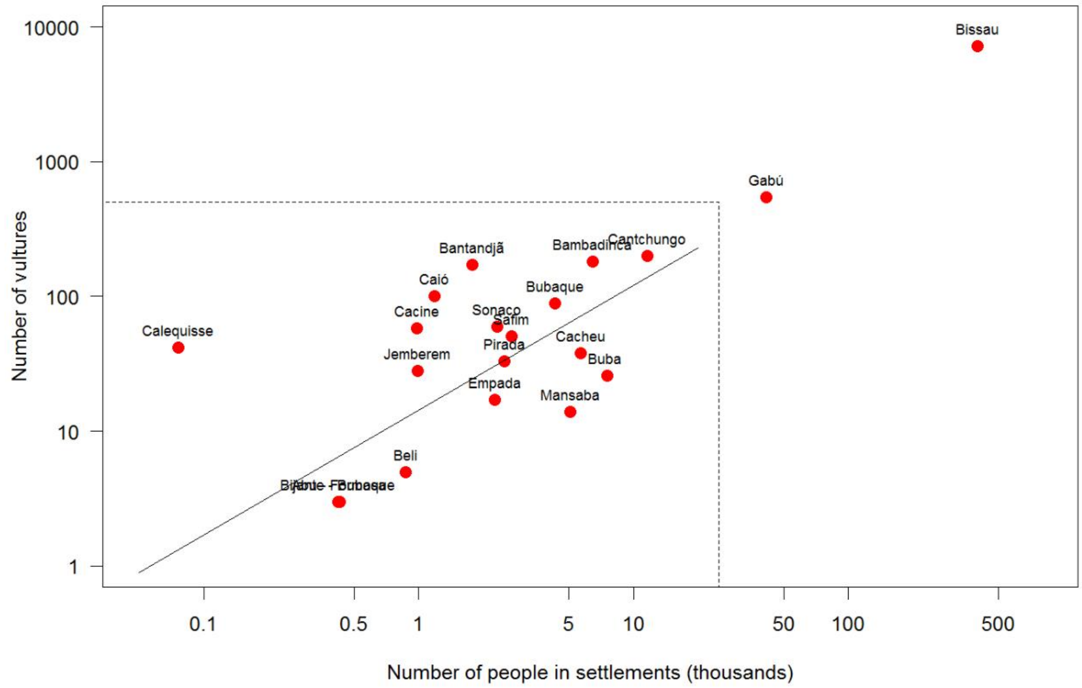

Figure 2.4. Number of hooded vultures in relation to the size of the settlements in Guinea-Bissau (note the log scales in both axes). Sampled human settlements are represented as red points. Data used to compute the regression are represented inside the dotted rectangle. The cities of Bissau and Gabú were not included in the regression, but are plotted to show that they follow the same trend represented by the regression line.

from the number of people by the following formula: *log(Numb. hooded vultures + 1) = 2.7119542 + 0.0002286*Population size, Adjusted* $R^2 = 0.189$, $p = 0.036$ (Fig. 2.4). Using this equation, we estimate that the number of hooded vultures in Guinea-Bissau, excluding Bissau and Gabú is 67,885 birds (quantile 2.5% = 59,764, quantile 97.5% = 80,179).

Adding the results from Bissau and Gabú to the above estimate we obtain a total of 75,993 hooded vultures in all of Guinea-Bissau territory (confidence interval = 67,872 - 88,287 birds).

Discussion

Daily activity pattern in an urban centre

Results from the daily activity pattern study indicate that to count hooded vultures using road survey methods (Thiollay 2006b, 2006c; Ogada & Keesing 2010; Virani et al. 2011; Pomeroy et al. 2014; Jallow et al. 2016) in Guinea-Bissau it is important to start the survey not earlier than 10:00h and end it not after 17:00h. If the focus is to try to deliver absolute estimates of population sizes from strip transects counting perched vultures, then surveys must be conducted between 7:00h and 8:20h and between 18:40h and 19:20h, when few birds fly.

Estimating the population size of hooded vultures: an alternative

Population size estimates of hooded vultures based on systematic work are rare. Only in Uganda, Tanzania, Mozambique, Ghana and in the Gambia there have been attempts (some very incomplete) to estimate the number of individuals (Ssemmanda 2005; Ogada & Buij 2011; Pomeroy et al. 2014; Gbogbo et al. 2016; Jallow et al. 2016). In the case of our study area, replicating these methods (i.e., counting roosts) would have not been adequate for several reasons: (1) hooded vultures there tend to roost scattered in many small groups all over the settlements, (2) birds in roost are difficult to spot in the canopy, and (3) hooded vultures in the country have been observed entering roosts when there is almost no light.

In our study we used two complementary methods to survey vultures to obtain a nationwide estimate. The strip transect method was used in urban centres that were too large to sample by one-time total counts. We used a bicycle for this method because it presented several advantages, namely high detection capacity, allowed to cover large areas, freedom of movements with no traffic constraints, and low cost transportation. Strip transects are a popular method to estimate densities of birds that are easy to spot (Eberhardt 1978; Conner & Dickson 1980) and it has been used in certain species of passerines and raptors (Eberhardt 1978; Andersen et al. 1985; Carrascal et al. 2008; Jallow et al. 2016). It has the advantages of covering a considerable area per unit of transect, allows the estimation of the number of birds, it is highly repeatable, and replicated transects of the same area can be compared through time (Conner & Dickson 1980). The bandwidth of 60 meters wide (30 meters on each side of the road) chosen from the transects conducted in Bissau, is a reasonable choice since hooded vultures are fairly easy to spot in urban environments while it also provides a good coverage area. Narrower strip transects over represent street areas with few perches between buildings (hence the lower densities in narrower strips) and broader strips likely result in lower densities because of visibility problems beyond the first row of buildings and trees on each side of a street. There are very few tall buildings in Guinea-Bissau, which also allows good visibility up to fairly long distances and therefore it is quite unlikely to miss vultures within a 30m range on each side, but nevertheless a strip count potentially always slightly underestimates densities. For these reasons, and because other methods employed elsewhere are inadequate, we believe that strip transects using bicycle is an effective and low cost alternative to estimate the population of hooded vultures in larger urban centres.

For smaller human settlements, we used complete counts during low activity periods, to obtain a minimum count of the number of roosting hooded vultures. Here roosting trees are smaller and have few leaves in the dry season, and areas to cover while vultures are still perched are much smaller. Since there are no known roosts outside human settlements in Guinea-Bissau, by sampling several settlements with varied sizes and characteristics (i.e., with and without markets, along the coast or inland, with and without fish ports), we modelled and predicted the expected number of vultures for all the country. In Guinea-Bissau, like elsewhere in West Africa (Rondeau & Thiollay 2004; Thiollay 2006b, 2007b; Ogada & Buij 2011), hooded vultures are mostly found in human settlements and very few can typically be seen living on natural habitats. With the combination of these two methods to estimate vultures in human settlements, we believe that we deliver a valid estimation of the number of hooded vultures in the country and we suggest that this approach could be tested in other countries.

In Gabú, we conducted both strip transects and complete counts during low activity periods, which produced different results (991 and 548 birds, respectively). The broad similarity in the results obtained by two completely different and independent methods gives a certain confidence in the approaches used in this study, although the results suggest that complete counts in human settlements as big as Gabú will probably underestimate the population size more markedly than the strip transect approach. More exercises to validate the methodologies would ideally be carried out, but there are few settlements in Guinea-Bissau where both approaches can be used effectively.

Guinea-Bissau: a stronghold for hooded vultures?

Mundy *et al.* (1992) guess-estimated the global population of hooded vultures to be between 200,000 – 330,000 birds. From that estimate, Ogada *et al*. (2011) subtracted the decline rates from several countries and suggested that the population did not exceeded 197,000 birds by 2011 (Ogada & Buij 2011). These last numbers may be underestimated, since it seems to reflect more strongly the declines reported for several countries and overlook other areas, like the Gambia and Guinea-Bissau, where no information was available. Nevertheless, based on this last estimate, our results suggest that Guinea-Bissau could be home to around 35 - 45% of the global population of the species. This reinforces the indications of the importance of this region for the species recently reported by Jallow *et al.* (2016), that estimated between 7,000 – 10,500 hooded vultures in the Western coast of the Gambia (Jallow et al. 2016). In neighbouring Guinea-Conakry, several reports pointed hooded vultures as common in the Eastern part of the country and in large human settlements during the 1980s and the 1990s (Ogada & Buij 2011). More recent surveys (2008) reported that healthy vulture populations were still present in that country (Rondeau et al. 2008). In other countries around this area, namely Mali, Burkina-Faso, Sierra Leone and Ivory Coast, hooded vultures were also described as common until the early 2000s, but since then dramatic declines have been reported in all, where populations have now much smaller densities than the ones reported here for Guinea-Bissau and reported for the Gambia (Rondeau & Thiollay 2004; Thiollay 2006b, 2006c; Ogada & Buij 2011; Jallow et al. 2016).

Our estimate of the number of hooded vultures of between 67,872 and 88,287 birds is the only one yet delivered for the country, and one of the few for all the range of the species. We believe it to potentially be realistic since in the two and a half months we spent in the field for this study (including all the time spent on trips between sampling sites) we saw 7,055 hooded vultures, equivalent to about 9.3% of our estimate. We felt that there were hooded vultures in almost every settlement we went. Exceptions were national parks in the Southeast and more forested areas (with less density of people), where in fact there were few vultures overall.

Monitoring, conservation and environmental education: a recipe to save vultures

Hooded vulture populations collapsed by a roughly estimated 83% in the last 27-39 years in East and West Africa (Ogada et al. 2015a). However, declines were uneven in West Africa and may not have happened throughout the entire range (Rondeau & Thiollay 2004; Thiollay 2006b). These data were derived mainly from Sahelian and savannah areas and it has been suggested that it may not be the same in more forested regions, where populations appear to be more robust (Ogada & Buij 2011). That seems to be the case for Guinea-Bissau, where several of the decline causes reported for other West African countries appear, at a first glance, to have much lower prevalence, as it has been suggested also for the Gambia (Jallow et al. 2016). For instance, killing for food was reported as the cause for local extinctions of hooded vultures in Nigeria and Ivory Coast but in Guinea-Bissau almost no reports of these events has been collected during field work. Intentional poisoning also seems to have little expression, since there is no reserves full of game that attracts illegal hunters and ivory poachers, as it happens in Kenya, Namibia and Zambia (Bridgeford 2001; Roxburgh & McDougall 2012; Ogada 2014b; Ogada et al. 2015b). Also agro-pastoral industries are still quite underdeveloped in the country and there is little evidence of the use of chemicals and/or drugs (such as diclofenac) that could cause harm to vultures, unlike elsewhere (Van Wyk et al. 2001; Anderson et al. 2005; Taggart et al. 2007; Ogada 2014a).

On the other hand, hooded vultures are not free of threats in Guinea-Bissau. We collected several reports during our field trips, that consistently suggested that the use of hooded vultures for traditional medicine and body parts for sorcery was a growing market in the country, mainly because of influences from visitors from other countries of West Africa. Likewise, unintentional poisoning appears to be a reality in some parts of the country that may be causing the extirpation of vultures in those areas. Thus arises the necessity of gathering more knowledge on the prevalence of such threats in the country and conduct environmental education in key-areas where vulture survival may be at stake. The fact that vultures provide such an important service to humans may be used as a tool to convince people of the necessity for their conservation. The development and implementation of a monitoring program in the country is also essential to screen trends in populations and allow timely interventions when and where needed.

Chapter 3: Population estimate and observations on seasonal movements of the palm-nut vulture *Gypohierax angolensis* in the João Vieira and Poilão Marine National Park, Guinea-Bissau

Abstract: *The palm-nut vulture is a unique member of the Old World vultures, having an extremely opportunistic and varied diet, different foraging behaviour and closely related to palm forests and wetlands. It is widely distributed across the tropical Africa and in Guinea-Bissau it is common in the Bijagós archipelago. Palm-nut vultures have been observed in large numbers in the João Vieira and Poilão Marine National Park (JVPMNP), one of the 3 marine protected areas of that archipelago. In this study we assess the abundance of palm-nut vultures in the JVPMNP, to evaluate the importance of this protected area in a national and regional scale. We also investigate the seasonal variation in the number of immatures in the main islands and islets during the dry and rainy seasons, and discuss possible reasons of such variations. We conducted transect counts in 2015 along the beach to survey palm-nut vultures in the four islands of the park, averaging 265 (SD = ±9.8, n = 5) birds during the dry season and 305 (SD = ±38.9, n = 10) during the rainy season. The island with the highest numbers during both seasons was João Vieira. Encounter rates (number of birds per km) for all the JVPMNP totalled 8 birds/km in 36.2 km, with Poilão presenting the highest score (16.3 birds/km). Poilão also presented the largest variation in the number of immatures between dry and rainy seasons (from 5 to 23 birds). Meio also showed an important variation (11.4% increment). Poilão presented 5 times more palm-nut vultures during the rainy season. We discuss reasons for these fluctuations in populations. Based in our experience, we guess-estimate between 355 and 525 palm-nut vultures in all the JVPMNP. This study provided solid evidences for the national and regional importance of the population of palm-nut vultures in that protected area.*

Keywords: Palm-nut vulture, Bijagós archipelago, João Vieira and Poilão Marine National Park, abundance, seasonality.

Introduction

The palm-nut vulture *Gypohierax angolensis* is considered to represent the transition from vultures to fish eagles (Brown and Amadon 1968 in Arshad et al. 2009). It is phylogenetically closer to Egyptian (*Neophron percnopterus*) and bearded (*Gypaetus barbatus*) vultures, being included with these in the Gypaetinae subfamily (Mundy 1992; Lerner & Mindell 2005; O'Neal Campbell 2016). Palm-nut vulture populations are distributed over a wide range in tropical Africa, being present throughout West and Central Africa, where the species is common and abundant, and as far South as Northeast South Africa, where is rarer (Mundy 1992; BirdLife International 2016b; O'Neal Campbell 2016). It is one of the few Old World vultures that is not considered endangered and populations are believed to be stable in most of its distribution (BirdLife International 2016b; IUCN 2016).

This species is ecologically distinct from any other vulture in several aspects: first, it is mainly connected to dense forests and tree savannahs, usually near water and often with oil and raffia palms (Mundy 1992; O'Neal Campbell 2016). Second, they are very opportunistic and their diet includes a wide range of items, like fruits of the palm tree *Elaes guineensis*, fruits and grains of other plants, fish, small mammals, birds, reptiles, invertebrates and amphibians, and can also scavenge on carcasses (Brown 1982; Mundy 1992; Butchart 1995; Catry et al. 2010; O'Neal Campbell 2016). Palm-nut vultures build large nests in tall trees and breeding season in West Africa is reported to begin in October and end around May (Mundy 1992; Ferguson-Lees and Christie 2001 in O'Neal Campbell 2016).

In Guinea-Bissau, palm-nut vultures are known to be strongly associated to palm oil forests in humid coastal areas, as reported elsewhere (Ferguson-Lees and Christie 2001 in O'Neal Campbell 2016). In the Bijagós archipelago this species is well established in almost every island and is overall common and abundant. Nonetheless, there is almost no quantitative information on the status of this species in the country (but see Mendes et al. 1998). Palm-nut vultures have been observed in large numbers in the João Vieira and Poilão Marine National Park (JVPMNP), one of the 3 marine protected areas of the Bijagós archipelago, and an important biodiversity stronghold for many species (Ministério de Desenvolvimento Rural e Agricultura n.d.; Clemmons 2003; Instituto da Biodiversidade e das Áreas Protegidas 2008, 2014; Catry et al. 2010; Lopes 2015). Given the large availability of suitable habitat for palm-nut vultures in the Bijagós archipelago, and particularly in the JVPMNP, this study aims to obtain estimates of the population of this species, in order to confirm the importance of this area for these vultures, and gather baseline data for future monitoring. We also investigate the occurrence of seasonal variation in the number of adults and immatures in the main islands and islets during the dry and rainy seasons, and discuss possible reasons of such variations.

Methods

Study Area

The Bijagós archipelago is a group of 88 islands and islets situated off the coast of the Republic of Guinea-Bissau (Figure 3.1). The archipelago was constituted Reserve of the Biosphere by the UNESCO, reflecting its exceptional natural value

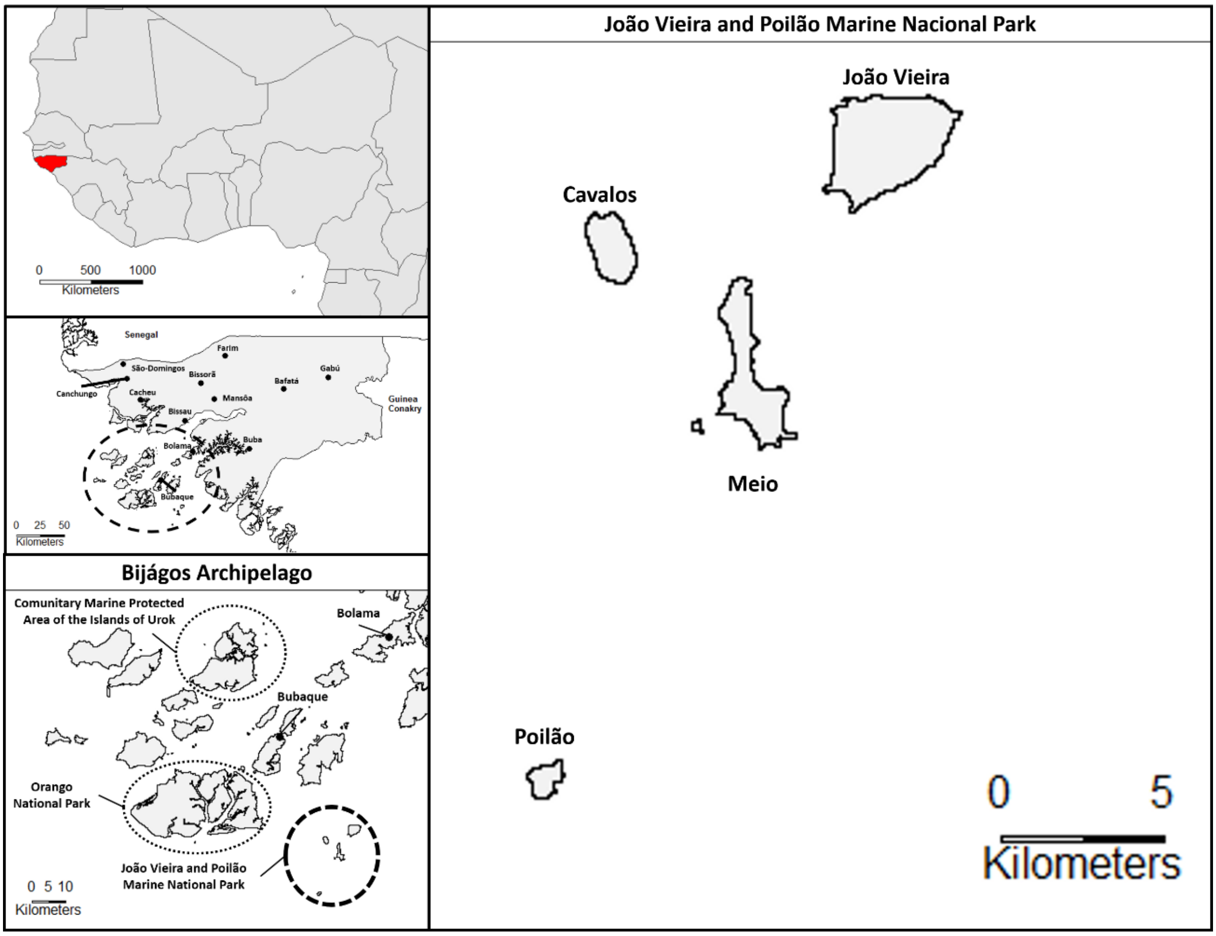

Figure 3.1. Map of the study area.

and importance for biodiversity (INEP 2006). It is also constituted by 3 Marine Protected Areas, one of which is the João Vieira and Poilão Marine National Park. The JVPMNP is located at the extreme Southeast of the Bijagós Archipelago. It is constituted by 4 main small islands and islets, namely Cavalos, João Vieira, Meio, and Poilão (Figure 3.1). The total surface of the protected area is around 495 km^2, of which 95% are comprised by intertidal and shallow marine-aquatic areas. The inland vegetation cover is dominated by dry forests, natural palm forests and patches of grassland savannah (Instituto da Biodiversidade e das Áreas Protegidas 2008). There are several relevant species for conservation in the protected area, of which we highlight the globally threatened green turtles, which have the third biggest breeding colony of the Atlantic Ocean in the islet of Poilão (Catry et al. 2010; Instituto da Biodiversidade e das Áreas Protegidas 2014). The four main islands of the JVPMNP are considered sacred by the communities of the island of Canhabaque, to whom they traditionally belong, and are not permanently inhabited. These villagers usually organize regular campaigns and travel from Canhabaque to these islands seasonally to fish, explore palm trees and to perform temporary and shifting upland rice plantations (Instituto da Biodiversidade e das Áreas Protegidas 2008, 2014).

Field Methods

To conduct the survey of the palm-nut vultures we used transect counts along the beach (from here on referred to as beach counts) in the four areas of JVPMNP (Figure 3.1). These counts were led by 1 or 2 observers, which walked through the beach rapidly to avoid double counting, and counted all birds seen perched or flying. Fully grown adults were differentiated from immature birds when possible, using the plumage pattern, with the aid of binoculars if necessary. Given that palm-nut vultures daily activity pattern is ruled, to an extent, by the tide, which is connected to food availability, we conducted the counts from receding half-tide to increasing half-tide, when birds are out to feed. On Poilão islet, in some periods of the year there is also variation in daily activity patterns depending on the type of food available. This islet holds very high concentrations of green turtles nesting during the rainy season, and palm-nut vultures feeding on green turtle hatchlings tend to be more active at early morning and very late afternoon, when there are more green turtle hatchlings crossing the beach and trying to reach the sea (Catry et al. 2010). In the case of this specific islet and period of the year, we conducted counts very early in the morning, during receding half-tides. We carried out several counts on all of the 4 main islands during the year of 2015, as follows: 3 counts on the island of Cavalos (2 during dry season and 1 during the rainy season), 3 on the island of João Vieira (1 during dry season and 2 during rainy season), 2 on the island of Meio (one during each season), and 6 on the islet of Poilão (one during dry season and 5 during rainy season).

Data analysis

Total abundance and encounter rates

To calculate a minimum number of palm-nut vultures in the JVPMNP, we used all the counts conducted during the year of 2015. We calculated the mean of the number of birds recorded in each island during the dry and rainy seasons separately. Then we summed up the means for each island for dry and rainy seasons. Incertitude is measured as Standard Deviations (SD), calculated from the global estimates of each island (n=4). We calculated encounter rates as an abundance index, dividing the total abundance of palm-nut vultures by the total number of kilometres of transects conducted in each island, for all the counts.

Spatial and seasonal variation in abundance

We compared the abundance of palm-nut vultures in each island between dry and rainy seasons to understand the spatial dynamic of the population in relation to seasonality, inside the protected area. To do so, we used the same database used for the total abundance estimate, with means of the counts for each island and in each season.

Results

Total abundance and encounter rates

Using data from counts conducted in 2015 in the JVPMNP, we obtained a minimum average number of palm-nut vultures of around 265±9.8 birds during the dry season and 305±38.9 birds during the rainy season (Section IV of the Supplementary Materials). The island with the highest results during both seasons was João Vieira. From our experience in the study area, we estimate that there may be between 355 and 525 birds in all the JVPMNP. This is an informed guess-estimate, based on observations on each island at the time of counts and the assumption (varying across islands) that roughly between 25 and 50% of the vultures were not visible on the beach at the time of surveys.

We calculated an encounter rate of approximately 8 birds per km (total distance walked 36.2 km) in all the protected area (Table 3.1). Poilão presented the highest value.

Table 3.1. Encounter rates, calculated from counts conducted in JVPMNP during 2015.

Island	Encounter rates (Birds per km)	Transect length (km)	Number of counts
Cavalos	6.3	6.48	3
João Vieira	10.5	12.76	3
Meio	4.9	13.79	2
Poilão	16.3	3.19	6
JVPMNP	8.1	36.22	14

Spatial and seasonal variation of the population

João Vieira and Poilão islands are the ones with the highest variation in the number of birds, between dry and rainy seasons. Meio and Poilão present the largest variation in the number of immatures (Figure 3.2, see also Section IV of the Supplementary Materials).

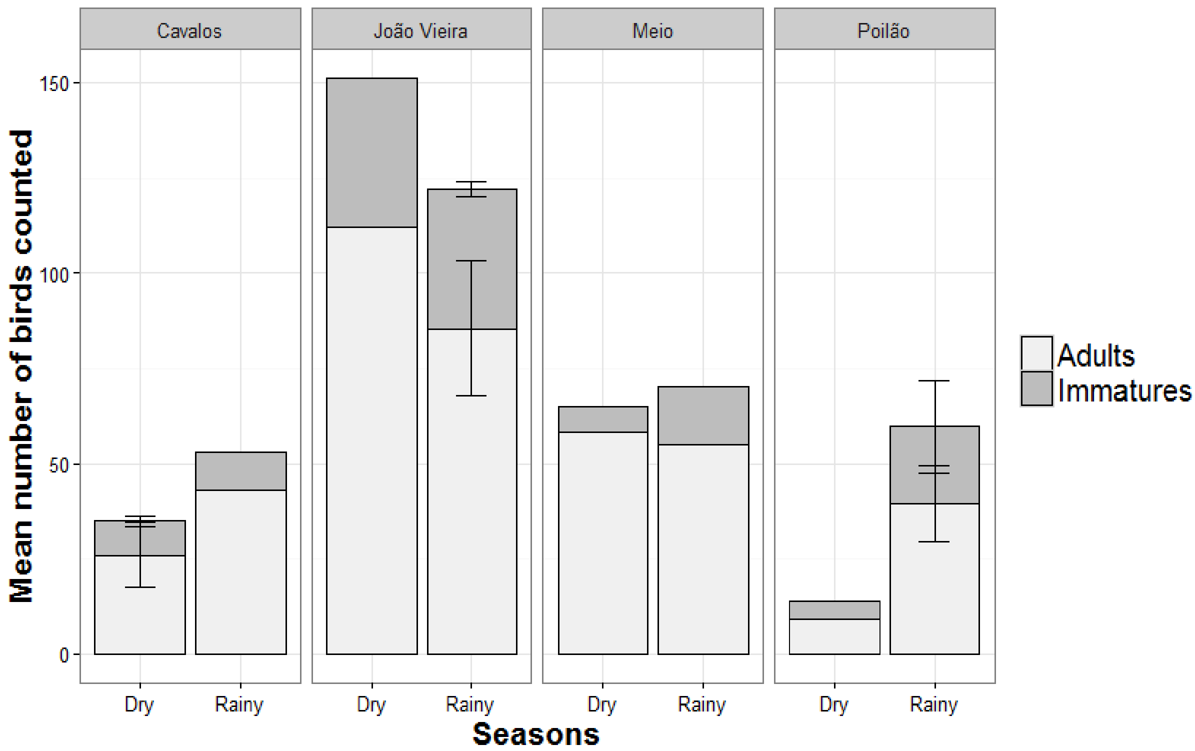

Figure 3.2. Seasonal variation in the abundance of palm-nut vultures in four islands of the JVPMNP, in the dry and rainy seasons of 2015.

Discussion

Total abundance estimates and encounter rates

Encounter rates obtained in this study from beach counts enable some preliminary comparatives with data from the study of Mendes et al. (1998) and also with other countries, although in this last case methods may differ and, for that reason, interpretation is limited. The only known study on palm-nut vultures in Guinea-Bissau was conducted in the Orango National Park (ONP), also in Bijagós archipelago. In that study, the authors counted palm-nut vultures using boat transects along the coast and in-between the islands and obtained encounter rates of 1.72 birds/km. By extrapolating for the all ONP, they estimated a total number of 475 birds (Mendes et al. 1998), which is similar to our guess-estimate. In Guinea-Conakry, road surveys counted 1.2 palm-nut vultures per 100 km in natural and crop areas, being classified has an uncommon species (Rondeau et al. 2008). In the Central African Republic, surveys conducted by vantage points, opportunistic sightings and transects by foot reported palm-nut vultures as a common species (25 sightings per day in a 5-week period) both inside and outside natural parks (Keys et al. 2012). In Uganda, road surveys reported 0.5 birds/100 km in natural areas (Pomeroy et al. 2014). Nevertheless, it is clear that palm-nut vultures are common and abundant in a wide area of the tropical Africa (BirdLife International 2016b). In Mundy et al. (1992) there are reports of information received from other observers, like Rob Jeffrey, that reported very high abundances of palm-nut vultures of 47 birds/km along Central Cubal River, in Western Angola, which are the highest ever reported to date. Mundy et al. (1992) also reports on Pakenham one count of 40 birds in 1 km radius on Pemba island and states that similar densities could be found in the Casamance, in the Southern border of the Senegal with Guinea-Bissau. However, the only true density figure was that provided by J. M. Thiollay of five breeding pairs per 10 km^2 in an abundant wild oil palm area in Ivory Coast, while road surveys by the same observer along his trip through part of West Africa averaged 10.2 birds/100 km, with the highest count being 13.4 birds/100 km in 3,208 km transect in Ivory Coast (Mundy 1992). These numbers show that the JVPMNP holds an important population of these vultures in the frame of these comparatives, which reinforces what is already suggested by our total abundance estimates.

Spatial and seasonal variation of the population

There is little variation in the maximum number of palm-nut vultures counted in each island between dry and rainy seasons, with the clear exception of Poilão, where there is a five-fold increase in numbers from one season to the other. Given that marine turtle hatchlings are an important food source for palm-nut vultures during the rainy season in the JVPMNP (Catry et al. 2010), it is evident that the increase in the numbers of palm-nut vultures in Poilão are directly related to the hatching period of marine turtle nestlings. This was already suggested by Catry et al. (2010). The increase in the mean number of birds counted between dry and rainy seasons from 265 to 305 birds for all the park can be due mostly to the input of birds from other islands of the Bijagós archipelago, given that the archipelago is not very large and migration inter-islands in search of food may occur in this species (O'Neal Campbell 2016). However, it is unclear the importance of this factor in the population dynamics of palm-nut vultures.

When analysing the proportion of immature birds in the maximum total counts between March (dry season) and September (rainy season) of 2015 (Fig. 3.2), we found that variations are not consistent between islands. Poilão presented the largest variation, with an increase on the number of immatures from dry to rainy season (from 5 to 23 birds). The island of Meio also showed an important percentage variation (11.4% increment). Cavalos and João Vieira, however, do not seem to present the same pattern. Therefore, no conclusions can be drawn from these results.

This study provided solid evidences for the importance of the population of palm-nut vultures resident in the JVPMNP. We believe this may be the one of the most important areas for these vultures in all Guinea-Bissau and perhaps one of the most important in a wide range of West Africa, as these vultures have plenty of resources there, face no predation and are not persecuted by humans for any reason. Nonetheless, habitat destruction from seasonal upland rice plantations and nest perturbation from people exploring palm trees are threats that occur with unknown impact. For this reason, we suggest that more studies should be conducted about palm-nut vultures in the JVPMNP, especially on breeding and feeding ecology, in order to better assess the drivers of this high abundance and potential threats. Other parts in the Bijagós archipelago are also quite under researched and we suggest that a wider approach could be employed to study this species demography in all the archipelago and the pattern of possible inter-island migrations.

Final Considerations

In the context of the "vulture crisis" in the African continent, it is very important to gather as much knowledge as possible in every country within the range of distribution of vulture species. This study provides the first information on vulture populations in Guinea-Bissau, which appears to be important in the framework of vulture conservation in West Africa. National population estimates are crucial to assess the current status of species, to identify important areas for the conservation, to support the development of conservation strategies and for future monitoring. It is noteworthy other positive impacts that may have been generated by this study, as part of a broader conservation project. This project was implemented with the cooperation of national biologists and nature wardens and with the involvement of the National Institute for Biodiversity and Protected Areas (IBAP), which provided opportunities to train national staff in a range of field techniques and establish important connections with this institution. This can be crucial to implement future monitoring and conservation actions in the country.

The abundance and distribution of the vulture species in the country is clearly affected by humans, which means that human activities will play a very important role in the survival of these populations in the future. Although in other countries of Africa vultures are becoming extinct from the impact of all the threats reported in all the continent, it appears that in Guinea-Bissau these threats still occur in a smaller scale and in restricted areas, so far. This provides an opportunity to intervene while is still possible to control the situation. Henceforth, we recommend using the data gathered by this study to tackle strategic areas with a well-conceived environmental education program directed to the relevant stakeholders. As important ecosystem providers in Guinea-Bissau, we suggest that vultures should be nominated as priority species in the country by the conservation organizations, both national and international.

The relevance of filling knowledge gaps as the one existing for Guinea-Bissau prior to this study, is demonstrated by the estimate of the population of hooded and palm-nut vultures delivered in the second and third chapters of this work, respectively. Gathering accurate population estimates is fundamental as part of conservation efforts (Murn & Botha 2016) and this study makes an important contribution for that matter, especially in what concerns hooded vultures. The methods we propose for the estimation of the population size of this species (i.e. strip transects and counts during periods of low activity of vultures) can also be important when it comes to the design of conservation plans, which often include numerical population objectives. For instance, to classify a site as an Important Bird Area (IBA), numerical estimates are one of the criteria used (BirdLife International 2016c).

Given the results obtained here, it is even more clear that vulture populations in Guinea-Bissau are relevant on a global scale and further research is needed in order increase the knowledge on their ecology, the pattern of movements (e.g. foraging, post-breeding dispersal) and the threats that they are currently facing. This study must be regarded as an important basis for future studies in the country, but not as a definitive assessment for vultures. The fact that vultures have a large territory which they can explore and know no boundaries, calls for the importance of conjoint actions between the countries of West Africa. Not only every country must assume their responsibility to protect vulture populations within their boundaries, but coordinated action is needed in order to establish coherent, solid and effective conservation measures to save vultures from extinction. In this line of thought, a continental approach is already in preparation since the African Vulture Summit of 2012, and a second Summit is going to take place in 2016 (Botha et al. 2012). In this meeting, a continental action plan for vultures is going to take form, which will be an important tool. Collaboration between research teams is also important to standardize methodologies for vulture monitoring and population estimates in each area.

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Supplementary materials

Section I: Abundance indexes per administrative division

Table 1. Abundance indexes for the study species in each administrative division (Regions and Sectors) of Guinea-Bissau. ND - No data, for Sectors that were not sampled. Encounter rates are calculated at the Sector level and measured in birds per km, while PAI (Punctual abundance index) are calculated at the Region level and measured as birds per point-count.

Region	Sector	Effort		hooded vultures		Griffons		Yellow-billed kites		Pied crows	
		Transect size (km)	Numb. Point counts	Enc. rates	PAI	Enc. rates	PAI	Enc. rates	PAI	Enc. rates	PAI
Bafatá	Bafatá	45.3	18	6.73	11.78	0	0.28	0.77	6.17	0.57	1.44
	Bambadinca	63.7		5.42		0		0.39		0.61	
	Contuboel	ND		ND		ND		ND		ND	
	Galomaro	96.1		1.56		0.24		0.09		0.05	
	Gã-Mamudo	37.4		0.40		0		0.03		0	
	Xitole	71.2		1.04		0		0.03		0	
Biombo	Prabis	21.1	11	2.89	10.09	0.09	0.36	0.99	1.91	0.81	1.45
	Quinhamel	44.2		6.73		0.45		0.41		0.14	
	Safim	29.0		3.55		0		0.14		0.10	
Bissau	Bissau	13.9	4	27.19	65.75	0.14	0	0.22	0.50	3.09	31.25
Bolama/ Bijagós	Bolama	ND	22	ND	2.14	ND	0	ND	0.55	ND	0.82
	Bubaque	ND		ND		ND		ND		ND	
	Caravela	ND		ND		ND		ND		ND	
Cacheu	Bigene	52.5	27	2.61	20.22	0.11	1.74	0.36	0.70	0.06	0.07
	Bula	54.1		2.38		0		0.41		0.15	
	Cacheu	47.3		4.65		0.02		0.30		0.02	
	Caió	12.0		6.00		0		0.17		0	
	Canchungo	65.7		10.56		0.37		0.20		0.06	
	São Domingos	67.2		2.19		0.52		0.16		0.13	
Gabú	Boé	139.7	45	0.01	3.82	0	0.09	0	0.11	0	0.31
	Gabú	93.4		5.56		0.03		0.18		0.32	
	Piche	99.0		1.02		0.09		0.13		0.06	
	Pirada	70.2		1.07		0.30		0.06		0.46	
	Sonaco	36.7		2.10		0.35		0.27		0	
Oio	Bissorã	19.7	24	2.59	5.21	0	0.04	0.15	1.25	0	0
	Farim	ND		ND		ND		ND		ND	
	Mansaba	66.0		0.74		0		0.14		0.06	
	Mansoa	61.3		0.38		0		0.20		0.03	
	Nhacra	53.1		1.21		0		0.06		0.11	
Quinara	Buba	49.3	12	0.10	0.42	0	0.08	0	0.50	0	0
	Empada	40.1		0.37		0		0.02		0	
	Fulacunda	31.7		0.32		0		0		0	
	Tite	14.4		0.42		0		0.07		0	
Tombali	Bedanda	40.3	21	0.30	3.71	0	0.14	0	0.62	0.05	0.29
	Cacine	37.4		1.04		0		0		0	
	Catió	25.9		2.74		0.04		0		0	
	Quebo	112.3		0.60		0		0.03		0.25	

Section II: Abundance maps for the white-backed vulture *Gyps africanus*

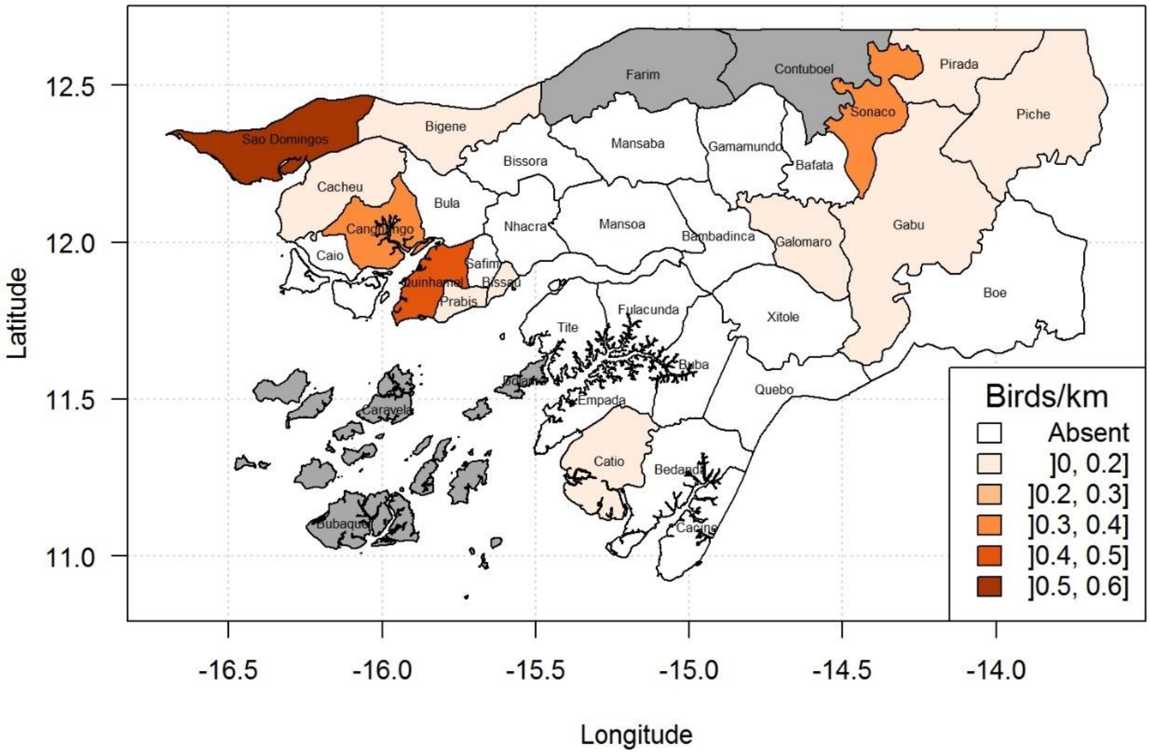

Figure 1. Abundance of white-backed vulture Gyps africanus in sampled Sectors of Guinea-Bissau obtained from road survey transects. Grey areas represent Sectors that were not sampled.

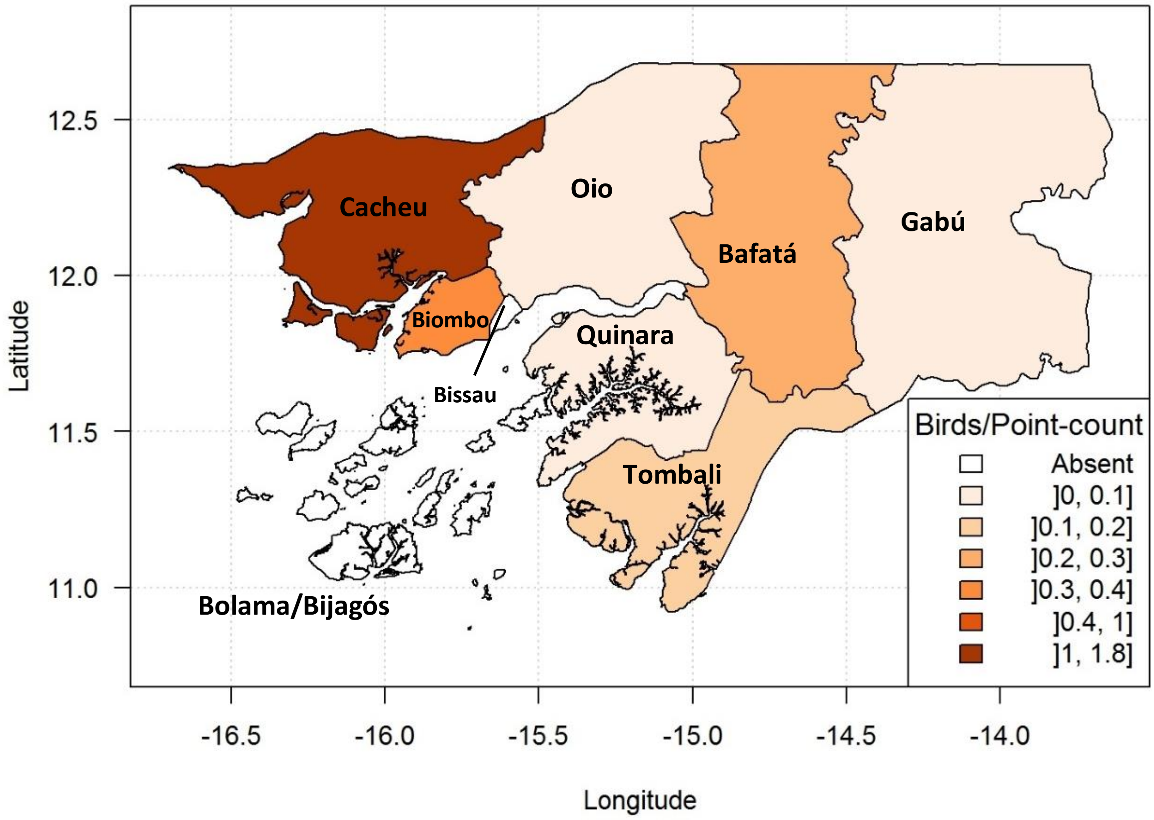

Figure 2. Abundance of white-backed vultures Gyps africanus in all Regions of Guinea-Bissau calculated from point-count surveys.

Section III: Maps of predictor variables

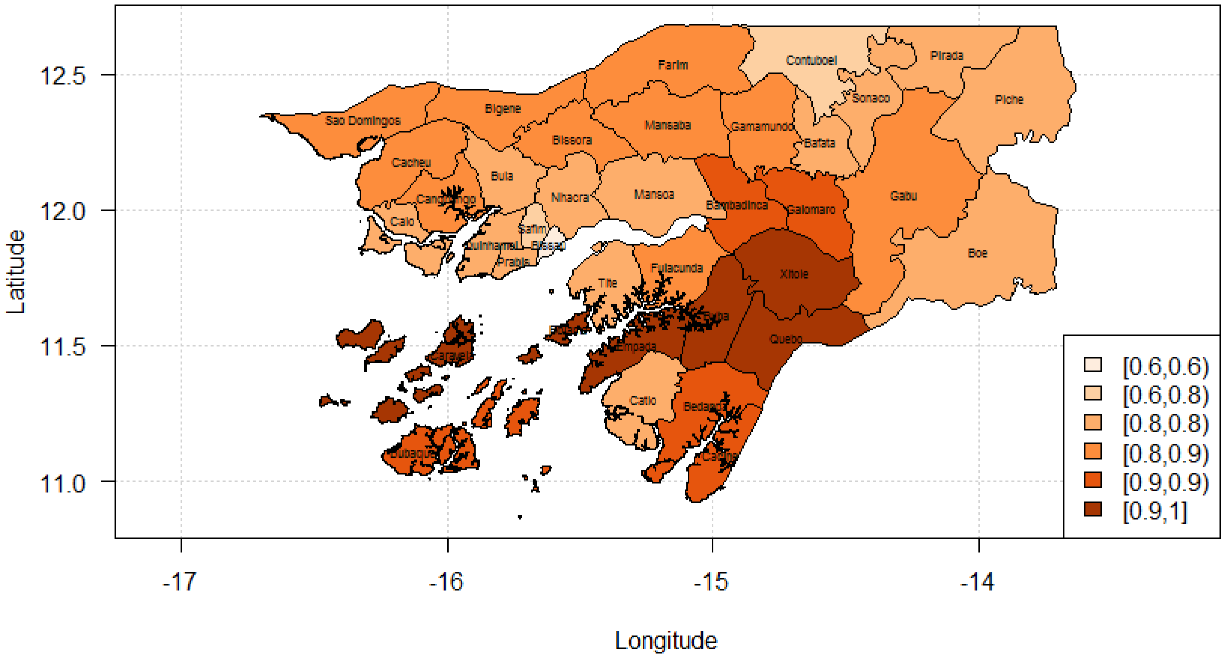

Figure 3. Map of the distribution of mean annual NDVI in each Sector of Guinea-Bissau

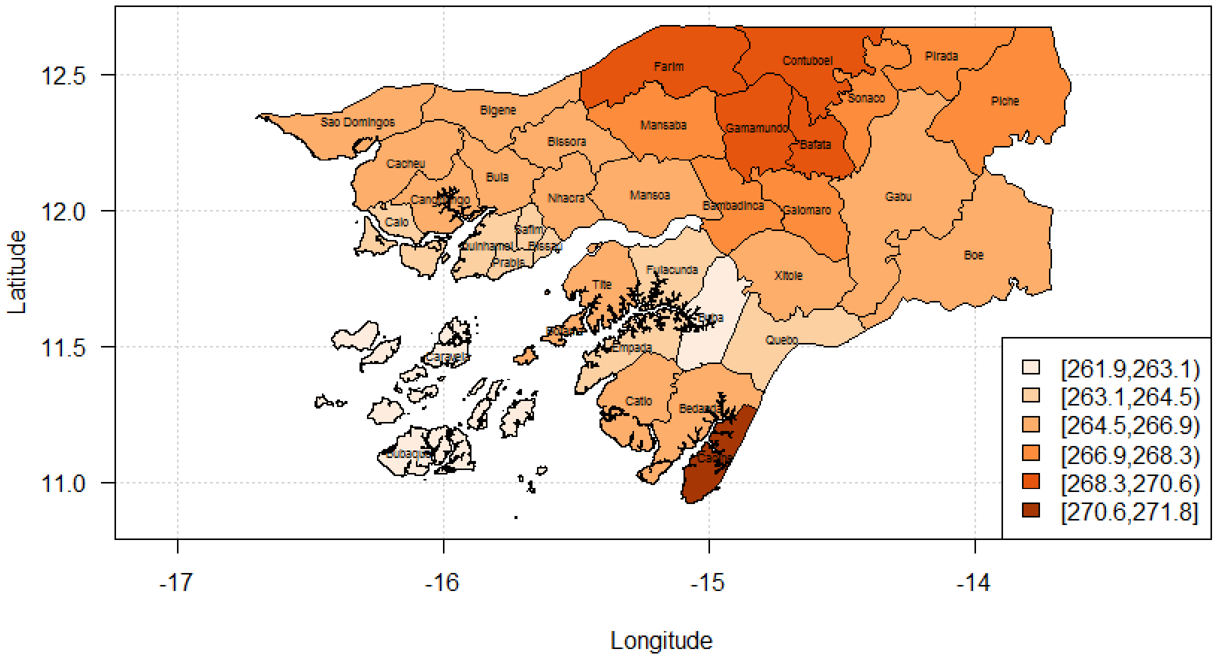

Figure 4. Map of the distribution of mean annual temperature in each Sector of Guinea-Bissau

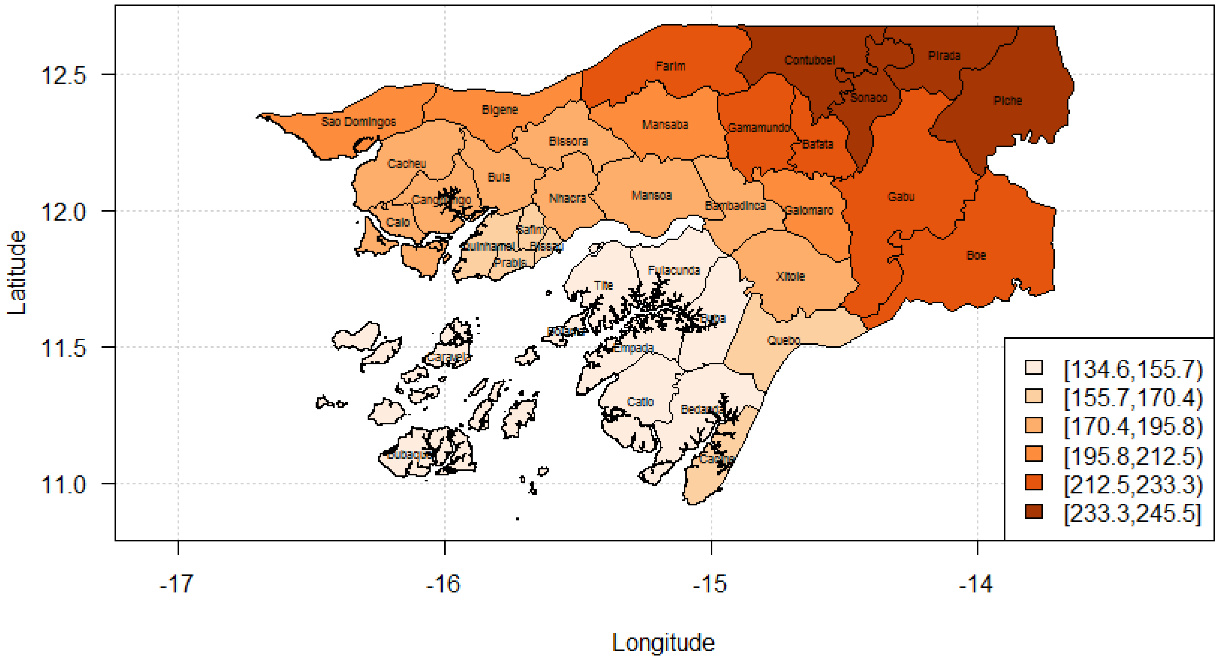

Figure 5. Map of the distribution of the annual temperature range in each Sector of Guinea-Bissau

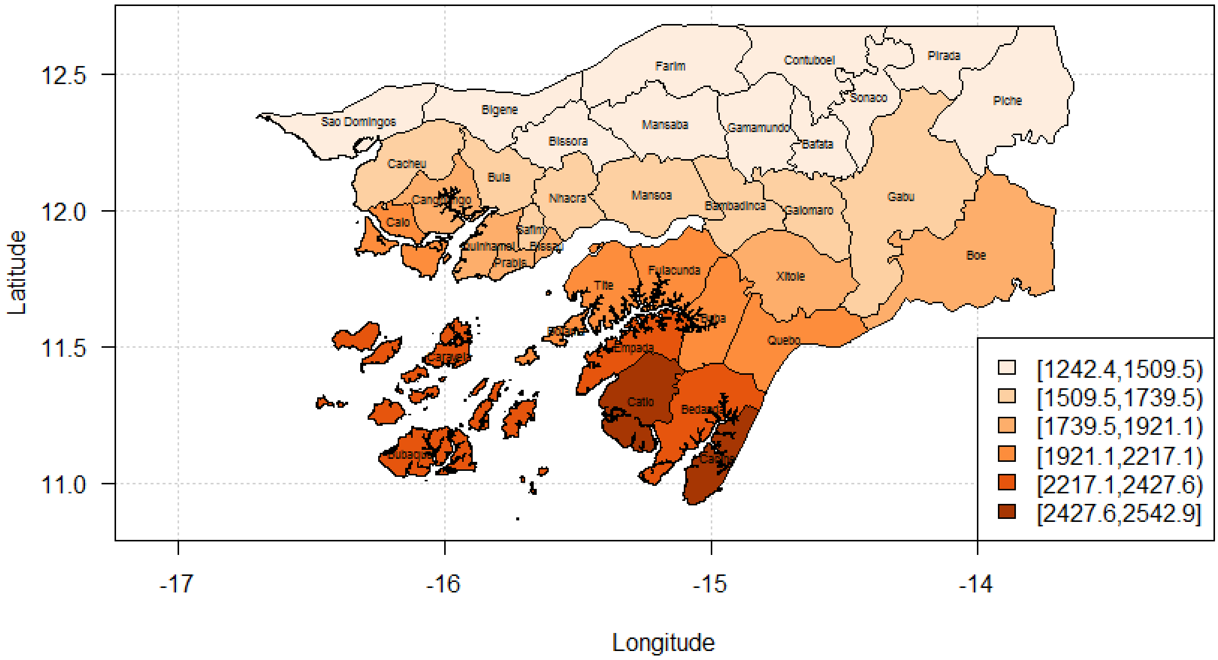

Figure 6. Map of the distribution of average annual precipitation in each Sector of Guinea-Bissau

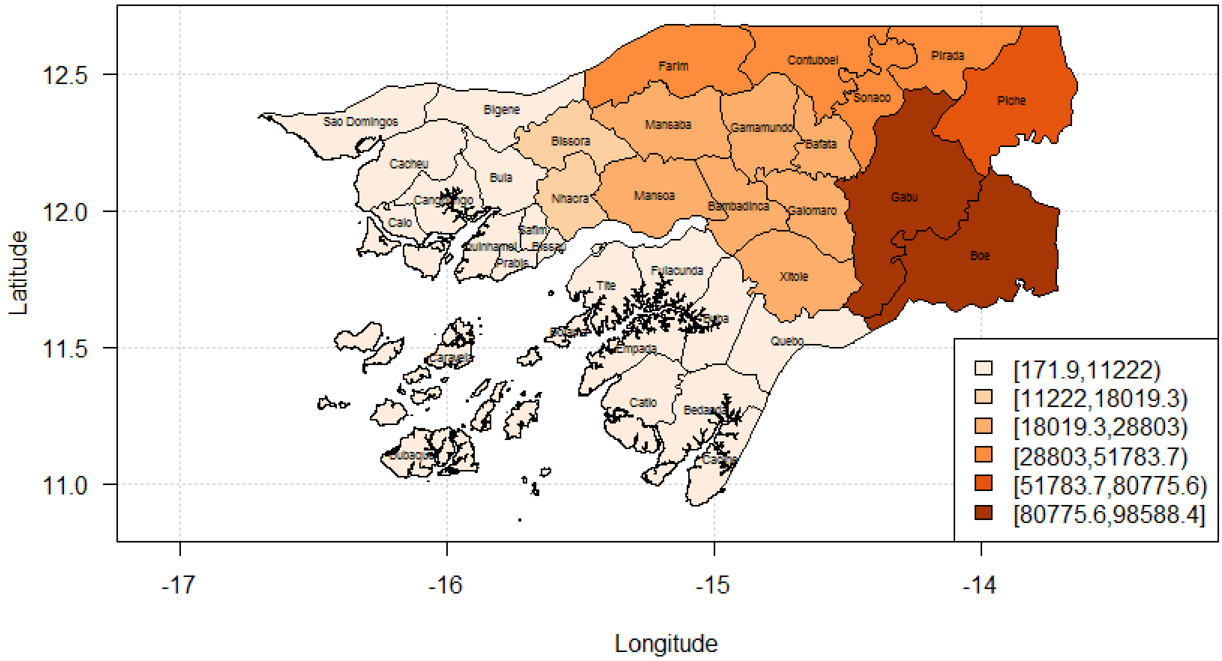

Figure 7. Map of the distribution of the cattle density (heads per km^2) in each Sector of Guinea-Bissau

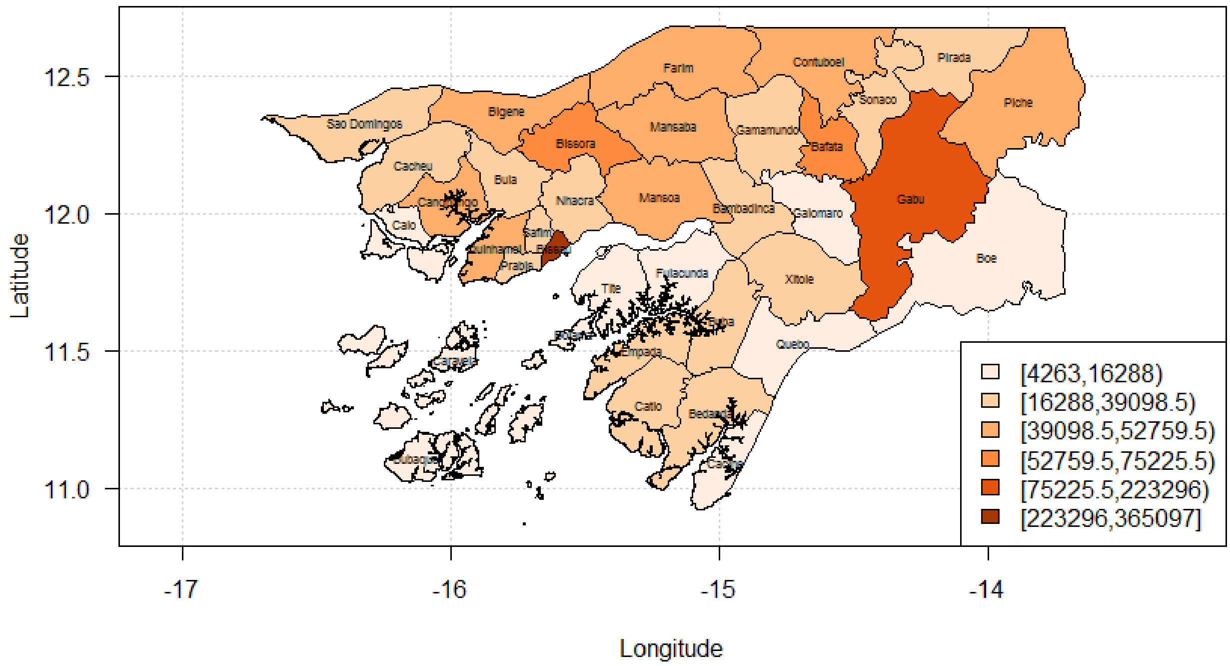

Figure 8. Map of the distribution of the absolute human population (people per Sector) in each Sector of Guinea-Bissau

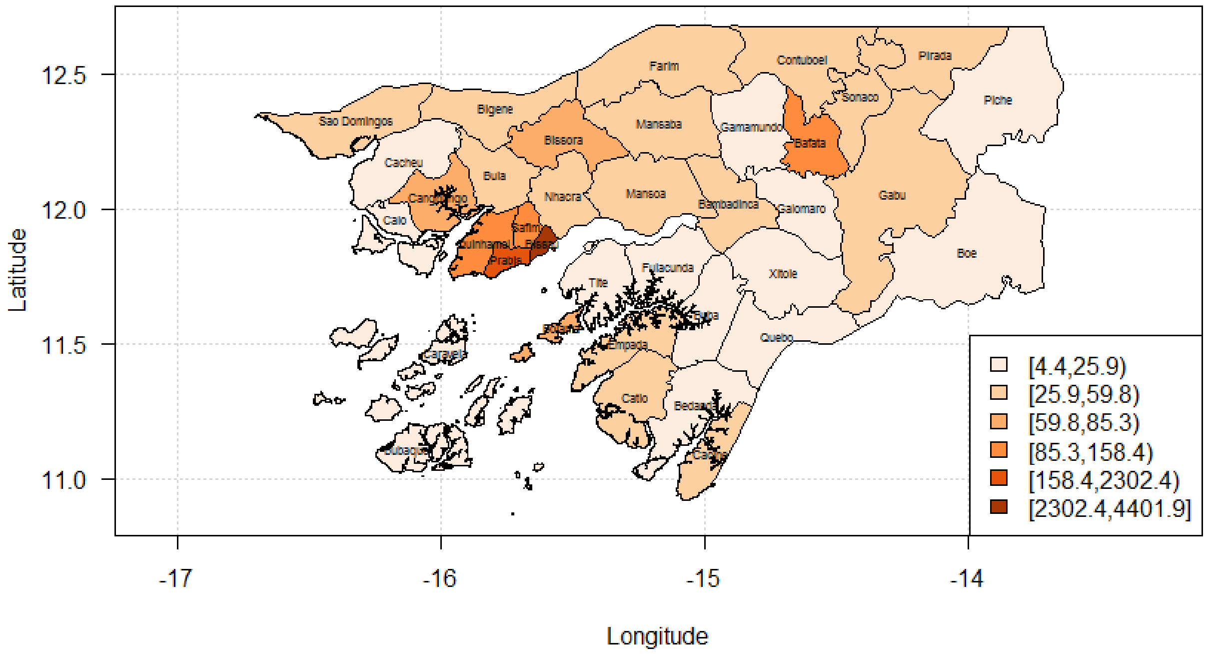

Figure 9. Map of the distribution of human population density (people per km^2) in each Sector of Guinea-Bissau

Section IV: Distribution over habitats

Table 2: Frequencies (in %) of the number of birds of each species associated with each of the habitat classes recorded during transect surveys. NI – Non identified habitat. NA – Not applicable. The N row is the number of birds counted per species in each method.

Habitats	**Hooded vultures** *Necrosyrtes monachus*	**Griffons** *Gyps spp.*	**Yellow-billed kites** *Milvus migrans parasitus*	**Pied crows** *Corvus albus*
Bolanhas	3.4	0.6	8.0	0.7
Cultivations	0.1	0	0	0
Forests	2.6	2.5	2.9	0.7
Human Settlements	62.9	30.2	36.7	76.8
Lalas	0.8	3.1	12.0	1.4
Mixed	1.0	0.6	1.8	0
Orchards	7.6	11.3	10.6	2.4
Savannah	2.4	30.8	8.7	1.0
Wetlands	1.7	2.5	6.2	0.7
NI	17.6	18.2	13.1	16.5
n	4360	159	275	297

Section IV: Abundance of palm-nut vultures

Table 3. Mean number of individuals observed (±SD) in counts of palm-nut vultures carried out in the JVPMNP during dry and rainy seasons.

Island	Season	Effort (Number of counts)	Mean number of adults (±SD)	Mean number of Immatures (±SD)	Total (±SD)
Cavalos	Dry	2	26±8.5	9±1.4	35±9.9
Cavalos	Rainy	1	43	10	53
João Vieira	Dry	1	112	39	151
João Vieira	Rainy	2	85.5±17.7	36.5±2.1	125±24
Meio	Dry	1	58	7	65
Meio	Rainy	1	55	15	70
Poilão	Dry	1	9	5	14
Poilão	Rainy	6	34.3±9.9	17.7±12.1	57.3±14.9