The Distribution and Status of Lions and other Large Carnivores in Luengue-Luiana and Mavinga National Parks, Angola

A DISTRIBUIÇÃO E STATUS DE LEÕES E OUTROS CARNÍVOROS DE LARGE PORTE NO PARQUES NACIONAIS DE LUENGUE-LUIANA E MAVINGA, ANGOLA

PANTHERA

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THE DISTRIBUTION AND STATUS OF LIONS AND OTHER LARGE CARNIVORES IN LUENGUE-LUIANA AND MAVINGA NATIONAL PARKS, ANGOLA

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Executive summary

SURVEY DESIGN AND RESULTS

We assessed the status and distribution of lions, other large carnivores and key herbivores, in both Luengue-Luiana and Mavinga National Parks. The survey was conducted as part of a Cooperation Agreement signed between Panthera and INBAC of the Angolan Ministry of Environment on July 25th, 2015. Throughout both national parks, wildlife populations were decimated during the three decades' long Angolan Civil War. Although wildlife populations are recovering, there is intense bushmeat hunting by local villagers, and intense elephant poaching particularly along the Cuando (Kwando) River, south of the Luiana River.

Our approach was to use spoor surveys to cover the entirety of both protected areas, and camera traps in four areas of promising wildlife abundance along the Cuando (Kwando), Luiana and Luengue rivers. Our sampling periods spanned the cold and hot dry season months from June to October of 2015 and 2016. All human habitation was noted and an attempt was made throughout to assess the livelihood patterns of the respective communities. Additionally, all signs of activities typically regarded as illegal in a national park were noted where opportunistically observed. To assess tourism potential, we conducted exploratory mission and while conducting spoor surveys noted all areas that might be aesthetically pleasing to tourists.

During the spoor survey we recorded 2646 detections across 5 large carnivore and 8 large herbivore species. Leopard, sable and roan were detected in the highest number of survey areas and had the widest distribution across both parks. Conversely lion, kudu and zebra were detected in very few of the sampling units. For lions, the number of tracks recorded was too low to produce reliable estimates of population density, yet we estimated that there might only be 10-30 lions in the parks, largely from camera trap evidence and reports of sightings. Although lions are vulnerable to various forms of illegal hunting, we concluded that it is primarily the very low biomass of preferred prey species that is so severely limiting lions within both parks.

Population densities were calculated for the other four large carnivore species. Across both parks spotted hyaenas were the most abundant large carnivore, estimated to occur at an average density of about 0.92 individuals/100 km^2 (total population: 776 ±345 individuals). The estimate for African wild dogs was very encouraging (0.7 wild dogs/100 km^2; 599 ±260 individuals) as was that for cheetahs (0.2 cheetahs/100 km^2; 151 ±101 individuals). Leopards were widely distributed throughout both parks (0.6 leopards/100 km^2; 518 ±190 individuals). All five large carnivore species strongly avoided or where absent/diminished in areas around human settlements.

Combined, these factors resulted in the large carnivore guild having a higher probability of occupancy in the southern half of Luengue-Luiana National Park than the northern half of the park, and even less presence in Mavinga National Park. This pattern was repeated for most of the large herbivores, with the exception of roan and sable antelope, which were more widely distributed.

The camera trap survey covered an area of 27,500 km^2, largely along the Cuando, Luiana and Luengue rivers and adjacent woodlands. A total of 288,479 photographs were recorded, of which 37,032 were independent captures (not repeat captures of the same animals or blanks). A total of 51 different species were recorded. The only species for which we also used camera traps to estimate density was the leopard, of which we identified 120 different individuals captured on 188

occasions. Of these, 24 were classed as adult females, 55 as adult males and 41 as adults of unknown sex. Spatially-explicit capture-recapture analysis estimated the population density to be 1.5 (SD ±0.14) leopards per 100 km^2. For small carnivores (<20 kg) a good diversity of the typical savanna species was recorded; 20 species in total.

Signs of human activity were captured more frequently than was any wildlife species. Vehicles were recorded 1805 times, domestic animals 600 times, and humans on foot 1119 times. However, many of these captures would have been repeated at numerous cameras as most cameras where placed along the better access roads and tracks in the sampling areas.

Throughout both parks human settlements (n = 535) were particularly concentrated along the Luiana River system, and along the Cubango and Cuito rivers in the west. In the North-West, human settlements were predominantly located between Longa and Cuito Cuanavale rivers. There were also scattered settlements along the West bank of the Cuando River and people were found living on islands within its wide valley of marshlands

Of the activities which would typically be regarded as illegal in most national parks, we recorded bushmeat hunting (n = 83), diamond mining (n = 7), fishing (n = 1), and one incidence of devil's claw harvesting (a consignment of several hundred kilograms). Furthermore, we recorded 10 localities where presumably permitted private logging companies were extracting *Baikiaea plurijuga*, *Burkea africana*, and *Pterocarpus angolensis* within the area.

Bushmeat hunting was recorded in three contexts; 1) people seen hunting in the bush or evidence that they had been such a shell casings and gin traps (n = 20), 2) small bushmeat hunting/processing camps with meat drying racks (n = 46), and 3) evidence of bushmeat in villages or small settlements (n = 17). In total, 82 specimens of 19 different mammals and one reptile species where observed as poached bushmeat.

The extraction of bushmeat for both personal use and commercial purposes is clearly the biggest threat facing both parks, and is clearly particularly intense in Mavinga. There is a culture of hunting meat that was found to be pervasive, widespread and largely accepted (not regarded as illegal by most people).

According to our subjective assessments there are large areas of Luengue-Luiana which presently have tourism potential, either in the form of four-wheel drive routes with remote campsites, or stationary, such as in the one lodge already being built at Sasha on the Cuando River. There is also potential for campsites and small lodges along the Cubango and Cuito rivers, with sport fishing on the Cuito River being a current tourism drawcard. Throughout Mavinga National Park, we noted many sites of tourism potential that were either scored as pleasant or outstanding.

RECOMMENDATIONS

The interventions required to recover lions and other mammal populations across both parks vary, with most emphasis at least initially to be placed on Luengue-Luiana, due to its importance 1) for all large carnivore species, 2) as a dispersal range for African elephant, and 3) for all the large ungulates we monitored. Although Mavinga National Park is heavily settled by people, we feel its potential should not be lost, and ways to develop a wildlife based economy using similar principles as the conservancy system in Namibia could be applied.

Luengue-Luiana National Park

To secure the site, restore ecosystem functionality and unlock potential for human communities we propose three zones of engagement, in which we will focus on site security in a way that will integrate conventional law enforcement with community game guards acting as agents of change to realize a community owned and operated wildlife tourism product that delivers benefits to the community as active conservation and business partners.

1) Define high priority conservation buffers along the main rivers

The riverine habitats are critically important both for biodiversity conservation and tourism development. We recommend that corridors of no human development are defined along each of these rivers and, where necessary, smaller settlements of people should be encouraged through financial incentives to vacate defined corridors. These high priority zones offer the best potential for the development of tourism infrastructure in the form of lodges, with an established road network being used to link each. In certain high interest zones around each lodge we propose the development of more comprehensive four-wheel-drive tracks to be used both for tourism and the deployment of law enforcement patrols.

2) Securing an intensive protection zone 15 km west of the Kwando River

The area just west of the Kwando River, north of Namibia to the Luiana River is one of the most intensively poached areas for African elephants in Africa. Here we recommend:

- Establishing an anti-poaching unit that is fully functionally equipped and trained to deal with tackling the organised crime syndicates poaching elephants.
- Encouraging and supporting cross border patrols and intelligence sharing.
- Integrating the efforts of community game guards and statutory wildlife police offices (WPO's) in designated areas to increase site security through both patrol effort and community compliance whereby community game guards act as active and empowered agents of change with communities.
- Strongly encouraging the completion and improvement of tourism infrastructure at Sasha and establish at least one small lodge possibly near Boafe.
- Linking the 4x4 tourism route with the important habitat zone (see below).
- Support the community run road maintenance team to maintain existing roads and establish additional patrol and game drive tracks.

3) Securing important habitat zones within Luengue-Luiana National Park

The entire area covered by Luengue-Luiana National Park away from the high priority river zones defined above is important. We recommend that the area east of the road from Mucusso to Licua is prioritised as an important habitat zone. To address the uncontrolled hunting of ungulates and the rampant elephant poaching within the important habitat zone of Luengue-Luiana National Park, a number of Intensive Protection Zones (IPZs) could be defined. Within each, an Anti-Poaching Unit (APU) would be established and functionally equipped.

Each APU would cover an area of between 2000 and 10000 km^2, in which an anti-poaching command centre/patrol base camp is established and in which at least three teams of game scouts are deployed. Each APU would be self-sufficient in terms of transportation, equipment, manpower, communication and deployment strategies, and would employ the SMART law enforcement monitoring tool. It is recommended that INBAC partner with organisations for

technical support to establish a robust management system for both parks. Notably this support would focus on:

- From key villages in the area, especially those identified as hotspots of bushmeat hunting, identify and employ community game guards who will be trained to patrol and remove snares/gin traps, record information and act as agents of change within their respective communities.
- Deploy, empower and capacitate the community game guards to gather intelligence on any syndicate based wildlife crime in the area.
- Incentivize the voluntary submission of guns, gin traps and other paraphernalia used to hunt wildlife.
- Support the community to develop a 4x4 tourism route with community owned and run campsites and wildlife and cultural ambassadors as guides for income generation (there are sufficient wildlife, historic and cultural resources in this area to achieve this in the immediate future).
- Support the community to establish a community run road maintenance and establishment team.

4) Secure the less important habitat zone

The western half of Luengue-Luiana National Parks is also of vital importance especially for elephant, but would be classified as a less important habitat zone. This area has the scenically attractive confluence of the Cuito and Cubango rivers within it; an area that has been earmarked for tourism development and that is extensively utilised by elephants in the dry season. Improved anti-poaching support is needed throughout the area, and this is also perhaps the area within Luengue-Luiana National Park that might be best suited to the establishment of community conservancies. Community conservancies could ensure direct benefit-sharing with communities settled along the Kavango and Cuito rivers, and controlled access to resources, such as devil's claw. Therefore, we suggest:

- Assessing the feasibility of developing community conservancies, secure government support and implement trial conservancies at Mucusso, Licua, and Dirico (this long-term investment in human development and wildlife protection and use has possibly the greatest potential for both empowering human communities through a wildlife and natural resource based economy, for tourism development and the full recovery of wildlife populations).
- Identify and implement corridors for wildlife to access key drinking and foraging areas along the Cuito and Cubango rivers (through an incentive scheme create easy access to key water resources such that wildlife can prosper and human-wildlife conflict can be minimised before these areas become too heavily settled by people).

Mavinga National Park

Large carnivore and other wildlife populations are so depleted throughout Mavinga National Park generally, and it is so heavily settled with human communities, such that at this stage there are limited conservation recommendations that we can make. However, we do see the potential for the model of conservation and human development that has been so successful in Namibia, and that we recommend for the western parts of Luengue-Luiana National Park; the implementation of communal conservancies. Discussions with the key NGOs in Namibia, IRDNC and ACADIR indicate a strong willingness to participate in such a development, but this can only occur if the Angolan government creates the necessary enabling environment.

Within each conservancy, a conservancy committee would need to be established and the conservancy given the guidance and support to decide for itself what of a range of wildlife and resource use opportunities it wanted to develop. These could include:

- Photographic tourism development
- Regulated use of wild plants
- Highly regulated use of timber
- Trophy hunting is currently illegal in Angola and wildlife populations are generally below sustainable offtake thresholds.

Sumário executiva

DESENVOLVIMENTO DA PESQUISA E RESULTADOS

Avaliou-se o estado e distribuição de leões, de outros grandes carnívoros e de herbívoros-chave nos Parques Nacionais de Luengue-Luiana e Mavinga. A pesquisa foi realizada como parte de um acordo de cooperação assinado com o Instituto Nacional da Biodiversidade e Áreas de Conservação (INBAC) do Ministério do Ambiente (MINAMB) em 25 de julho de 2015. Em ambos os Parques Nacionais, populações de vida selvagem foram dizimadas durante a longa guerra civil angolana. Embora tais populações estejam se recuperando, há uma intensa caça de subsistência pelos aldeões locais e intensa caça furtiva de elefantes, particularmente ao longo do rio Cuando (Kwando), sul do rio Luiana.

Foi realizado um levantamento de rastros para cobrir a totalidade de ambas as áreas protegidas e foram utilizadas armadilhas fotográficas (ou câmeras traps) para registros da promissora abundância de fauna ao longo dos rios Cuando (Kwando), Luiana e Luengue. Os períodos de amostragem abrangeram os meses da estação seca e chuvosa, de junho a outubro de 2015 e 2016. Todas as habitações humanas foram registradas e foi feita uma tentativa de avaliar os padrões de subsistência das respectivas comunidades. Além disso, todos os sinais de actividades tipicamente consideradas ilegais em um Parque Nacional foram registradas quando oportunisticamente observadas. Para avaliar o potencial turístico, realizamos uma missão exploratória e durante a realização dos levantamentos de rastros foram registradas todas as áreas que podem ser esteticamente agradáveis aos turistas.

Durante o levantamento de rastros, registrou-se 2646 detecções de cinco grandes espécies de carnívoros e oito de grandes herbívoros. Leopardo, palanca-negra e palanca-vermelha foram detectados em maior número nas áreas de pesquisa e tiveram a maior distribuição entre os dois parques. Inversamente, leão, kudu e zebra foram detectados em poucas unidades de amostragem. Para os leões, o número de pegadas registradas era muito baixo para produzir estimativas confiáveis da densidade populacional. No entanto, a partir principalmente de evidências de câmera trap e relatos de avistamentos, estimamos que pode haver apenas 10-30 leões nos referidos parques. Embora os leões estejam vulneráveis a várias formas de caça ilegal, concluímos que é principalmente a baixa biomassa das espécies presas preferenciais que limita severamente a ocorrência de leões dentro de ambos os parques.

As densidades populacionais foram calculadas para as outras quatro espécies de grandes carnívoros. Para ambos os parques, a hiena-malhada foi a espécie mais abundante, com densidade média estimada em cerca de 0,92 indivíduos / 100 km^2. A estimativa para cães-selvagens-africanos (mabecos) foi bastante encorajadora (0,7 indivíduos / 100 km^2; 599 ±260 indivíduos), assim como para a chita (0,2 indivíduos / 100 km^2; 151 ±101 indivíduos). Leopardos estavam amplamente distribuídos ao longo de ambos os parques (0,6 indivíduos / 100 km^2; 518 ±190 indivíduos). Ao redor de assentamentos humanos, todas as cinco grandes espécies de carnívoros são ausentes, evitam fortemente ou ainda têm baixa densidade nessas áreas.

Estes factores combinados resultam na maior probabilidade de ocorrência da grande guilda dos carnívoros na porção sul do Parque Nacional de Luengue-Luiana do que na parte norte. Tais factores também implicam na menor presença destes animais no Parque Nacional de Mavinga. Este padrão se repetiu para a maioria dos grandes herbívoros, com exceção da palanca-negra e palanca-vermelha, que foram mais amplamente distribuídas.

A pesquisa com armadilhas fotográficas cobriu uma área de 27,500 km^2 principalmente ao longo dos rios Cuando, Luiana e Luengue e bosques adjacentes. Ao todo, foram contabilizadas 288.479 fotografias, sendo 37.032 capturas independentes. Um total de 51 espécies foram fotografadas. A única espécie cuja densidade foi estimada a partir do presente método foi o leopardo, dos quais foram 120 indivíduos registrados em 188 ocasiões. Destes, 24 foram classificados como fêmeas adultas, 55 como machos adultos e 41 adultos de sexo indeterminado. A análise espacialmente explícita de captura-recaptura estimou a densidade populacional em 1,5 (DP ±0,14) indivíduos por 100 km^2. Para pequenos carnívoros (<20 kg) foi registrada uma boa diversidade de espécies típicas de savana, com 20 espécies no total.

Sinais de atividade humana foram registrados com maior frequência do que qualquer espécie de animal silvestre. Veículos foram registrados 1805 vezes, animais domésticos 600 vezes, e seres humanos circulando a pé 1119 vezes. No entanto, muitos desses registros já eram esperados em várias câmeras, uma vez que nas áreas de amostragem a maioria das armadilhas fotográficas foram instaladas ao longo das melhores trilhas e estradas de acesso.

Em ambos os parques, os assentamentos humanos (n = 535) são particularmente concentrados ao longo do sistema do rio Luiana e ao longo dos rios Cubango e Cuito, a oeste. No noroeste, os assentamentos humanos são predominantemente localizados entre os rios Longa e Cuito Cuanavale. Havia igualmente estabelecimentos distribuídos ao longo da margem ocidental do rio Cuando e situados em ilhas dentro de um amplo vale de pântanos (áreas alagadas).

O registro de actividades que tipicamente seriam consideradas ilegais na maioria dos parques nacionais incluía: caça de subsistência (n = 83), exploração de diamantes (n = 7), pesca (n = 1) e uma incidência de colheita de garra-do-diabo (um lote de várias centenas de quilogramas). Além disso, registraram-se 10 localidades onde empresas madeireiras privadas, presumivelmente autorizadas, extraem *Baikiaea plurijuga*, *Burkea africana* e *Pterocarpus angolensis* dentro da área.

A caça de subsistência foi registrada em três contextos: avistamento de caçadores ou encontro de evidências como munição e armadilhas (N = 20); 2) pequenos acampamentos de caça / processamento dos animais abatidos com prateleiras de secagem para as carnes de caça (n = 46); e 3) evidência de carne de caça em aldeias ou pequenos assentamentos (n = 17). No total, 82 espécimes de 19 mamíferos diferentes e uma espécie de réptil foram observados como carne de caça.

A caça para fins pessoais ou comerciais é claramente a maior ameaça que ambos os parques enfrentam e é particularmente intensa em Mavinga. Existe uma cultura de caça aparentemente difundida e amplamente aceita (não considerada ilegal pela maioria das pessoas).

De acordo com nossas avaliações subjectivas existem grandes áreas de Luengue-Luiana que atualmente têm potencial turístico, como por exemplo um turismo de quatro rodas com acampamentos remotos. Já existe uma pousada sendo construída em Sasha, no Rio Cuando. Há também potencial para acampamentos e pequenas pousadas ao longo dos rios Cubango e Cuito, sendo a pesca esportiva neste último um cartão turístico atual. Ao longo do Parque Nacional de Mavinga, observaram-se muitos locais com potencial turístico, os quais foram marcados como agradável ou excepcional.

RECOMENDAÇÕES

As intervenções necessárias para a recuperação de leões e outras populações de mamíferos em ambos os parques variam de modo significativo, pelo menos inicialmente, no Luengue-Luiana, o qual é de grande relevância para todas as espécies de grandes carnívoros, é uma importante área de dispersão para o elefante-africano e é fundamental para todos os grandes ungulados monitorados. Embora o Parque Nacional de Mavinga seja fortemente povoado por pessoas, sentimos que o seu potencial deve ser aproveitado. Formas de desenvolver uma economia baseada na vida selvagem usando princípios semelhantes ao sistema de conservancies na Namíbia poderiam ser aplicadas nesse local.

Parque Nacional de Luengue-Luiana

Dentro do Parque Nacional de Luengue-Luiana propomos priorizar o esforço de conservação dentro de zonas específicas, cada qual exigindo diferentes abordagens. Alinhadas às recomendações no plano de manejo do Parque de Luengue-Luiana (2016) apoiamos e propomos o seguinte:

1) Definir "buffers" de alta prioridade para a conservação ao longo dos principais rios

Os habitats ribeirinhos são fundamentais tanto para a conservação da biodiversidade como para o desenvolvimento do turismo. Recomendamos que sejam definidos corredores ecológicos ao longo de cada um desses rios e, onde necessário, pequenos assentamentos devem ser desocupados após os devidos incentivos financeiros (indenizações) nos corredores definidos. Estas zonas prioritárias oferecem o melhor potencial para o desenvolvimento da infraestrutura turística sob a forma de pousadas, sendo estabelecida uma rede rodoviária para ligar cada uma delas. Em certas zonas de grande interesse ao redor de cada pousada, propomos o desenvolvimento de estradas mais abrangentes a serem utilizadas tanto para o turismo como para a implantação de patrulhas policiais.

2) Protecção de importantes zonas de habitats no Parque Nacional Luengue-Luiana

Além das zonas ribeirinhas acima mencionadas, toda a área do Parque Nacional Luengue-Luiana é importante. Recomendamos que a área a leste da estrada de ligação entre Mucusso e Licua seja priorizada como uma importante zona de habitat selvagem. Para tentar solucionar a problemática da caça ilegal de ungulados e de elefantes nessa importante zona de habitat do Parque Nacional de Luengue-Luiana, várias zonas de protecção intensiva (IPZ) podem ser definidas. Em cada IPZ, uma unidade anti-caça (APU) seria estabelecida e funcionalmente equipada.

Cada APU cobriria uma área entre 2000 e 10000 km^2, onde um acampamento base/central de comando anti-caça furtiva / patrulha seria estabelecido com pelo menos três equipes para patrulhar a região. Cada APU seria autossuficiente em termos de transporte, equipamento, mão-de-obra, comunicação e estratégias de implantação, e empregaria a ferramenta SMART (inteligente?) de fiscalização da aplicação da lei. Recomenda-se que o INBAC se associe a organizações para apoio técnico a fim de estabelecer um sólido sistema de gestão para ambos os parques. Esse apoio se concentraria principalmente em:

- Patrulhas anti-caça
- Criação de aceiros para impedir a propagação de incêndios

- Aperfeiçoamento do projecto de estratégia de controle de incêndios apresentado neste plano de gestão
- Estabelecimento no parque de uma abordagem viável e sustentável de Gestão de Recursos Naturais baseados na Comunidade (CBNRM)
- Estabelecimento de uma indústria certificada de produtos indígenas (por exemplo, garra do diabo)

3) Zona de habitat menos importante

A parte ocidental do Parque Nacional Luengue-Luiana é também de vital importância especialmente para elefantes, mas seria classificada como uma zona de habitat menos importante. Esta área tem o atractivo cênico da confluência dos rios Cuito e Cubango, uma região indicada para desenvolvimento do turismo e que é extensivamente utilizada por elefantes na estação seca. É necessário um melhor apoio anti-caça ao longo da área, e talvez esta também seja a área dentro do Parque Nacional Luengue-Luiana mais adequada para o estabelecimento de comunidades de conservação. Estas poderiam garantir a partilha direta de benefícios com as comunidades ao longo dos rios Kavango e Cuito e o acesso controlado a determinados recursos, como garra-do-diabo.

Parque Nacional de Mavinga

De modo geral, populações de grandes carnívoros e outros animais selvagens são escassos em todo o Parque Nacional de Mavinga. Por ser tão fortemente povoado, nesta fase existem limitadas recomendações de conservação a serem feitas. No entanto, vemos o potencial para o modelo de conservação e desenvolvimento humano que tem sido tão bem-sucedido na Namíbia, o qual recomendamos para áreas do Parque de Luengue-Luiana: a implementação de conservancies comunitárias. As discussões com as principais ONGs da Namíbia, IRDNC e ACARDIR indicam um forte interesse de participar desse desenvolvimento, mas isso só pode ocorrer se o governo angolano criar o ambiente propício.

Dentro de cada conservancy um comitê precisaria ser estabelecido e a devida orientação e apoio deveria ser dado para que ele decida por si mesmo quais oportunidades em relação a vida selvagem e uso de recursos se desejaria desenvolver. Estes poderiam, por exemplo, incluir:

- Desenvolvimento do turismo fotográfico
- Uso regulado de plantas silvestres
- Uso altamente regulado da madeira
- A caça ao troféu é actualmente ilegal em Angola e as populações de animais selvagens estão geralmente abaixo dos limiares de consumo sustentável

Introduction

The lion is the largest terrestrial carnivore in Africa and an iconic species representing the essence of wildness. Yet lion populations are declining fast, with illegal killing, habitat loss and fragmentation, and bushmeat poaching of their prey having led to a >40% decrease in lion numbers over the past 20 years, prompting their new classification on the IUCN Red List of Threatened Species (globally 'Vulnerable' and 'Critically Endangered' in West Africa) (Bauer et al., 2015). To date, lions have vanished from more than 90% of their historic range. Current estimates place the wild lion population at about only 20,000 individuals Africa-wide (Bauer *et al*. 2015).

Wild lions require wild areas to survive, which are characterized by intact communities of large herbivores, intact habitats, and low human impact. Lions are thus ideal indicators of the overall health or state of ecosystems. By focusing on lions and other large carnivore species in our surveys and conservation initiatives, we at Panthera use a key umbrella species to assess the integrity of wild ecosystems and develop strategies for conserving not only lions, but the entire landscapes they require to survive.

In Angola, we aimed to assess the status and distribution of lions, other large carnivores and key mega-herbivores, in Luengue-Luiana and Mavinga National Parks, in Cuando-Cubango Province and comprising the entire Angolan contribution (84,400 km^2) to the Kavanago-Zambezi Transfrontier Conservation Area (KAZA TFCA). We also aimed to document all human activities that may have adverse effects on the occurrence of these species. The survey was conducted as part of a Cooperation Agreement signed between Panthera and INBAC of the Ministry of Environment on July 25th, 2015.

Plate 1. Senior Director Dr Paul Funston signs the Cooperation agreement with Director Heliodoro Abrames, Dirico, Angola, June 2015.

Plate 2. Senior Director Dr Paul Funston celebrates the signing of the Cooperation Agreement at Dirico on June 15, 2015, with Madame Maria de Fatima Jardim, Minister of the Environment; Mr Higino Carneiro, Governor Cuando-Cubango Province; and Mrs Paula Francisco, Secretary of State for the Ministry of Environment.

KAZA is the world's largest transfrontier conservation area (520,000 km^2) and Africa's largest conservation landscape. It is a stronghold for lions (Funston, 2014), leopards and cheetahs and also boasts Africa's largest populations of African buffalo and wild dog as well as half of Africa's elephant population. Angola made an important contribution to global conservation by designating vast tracks of land for inclusion into KAZA, promulgating two enormous national parks in 2011; Luengue-Luiana (42,400 km^2), north of the Namibian border with the Kavango River and Bwabwata National Park, and north thereof Mavinga National Park (42,000 km^2) (see Figure 1).

Until this report, little was known, however, about the population status of the key species in the Angolan parks comprising KAZA. For lions, conservation officials from Angola estimated in 2006 that there might be as many as 1905 throughout the Cuando-Cubango Province, without about 1000 lions within the KAZA section (IUCN, 2006; Riggio et al., 2013). As unlikely as these guesses were, the sheer size of the conservation area and the order of the estimate suggested that south-eastern Angola was the most important area in Africa still to be surveyed for lions. Our approach was to use spoor surveys (Funston et al., 2010) to cover the entirety of both protected areas, and to camera-trap four promising areas within Luengue-Luiana National Park, to obtain a) parks-wide population size estimates for large carnivores and b) assess overall species composition and assemblage also including smaller species (particularly carnivores) in the most promising wildlife areas.

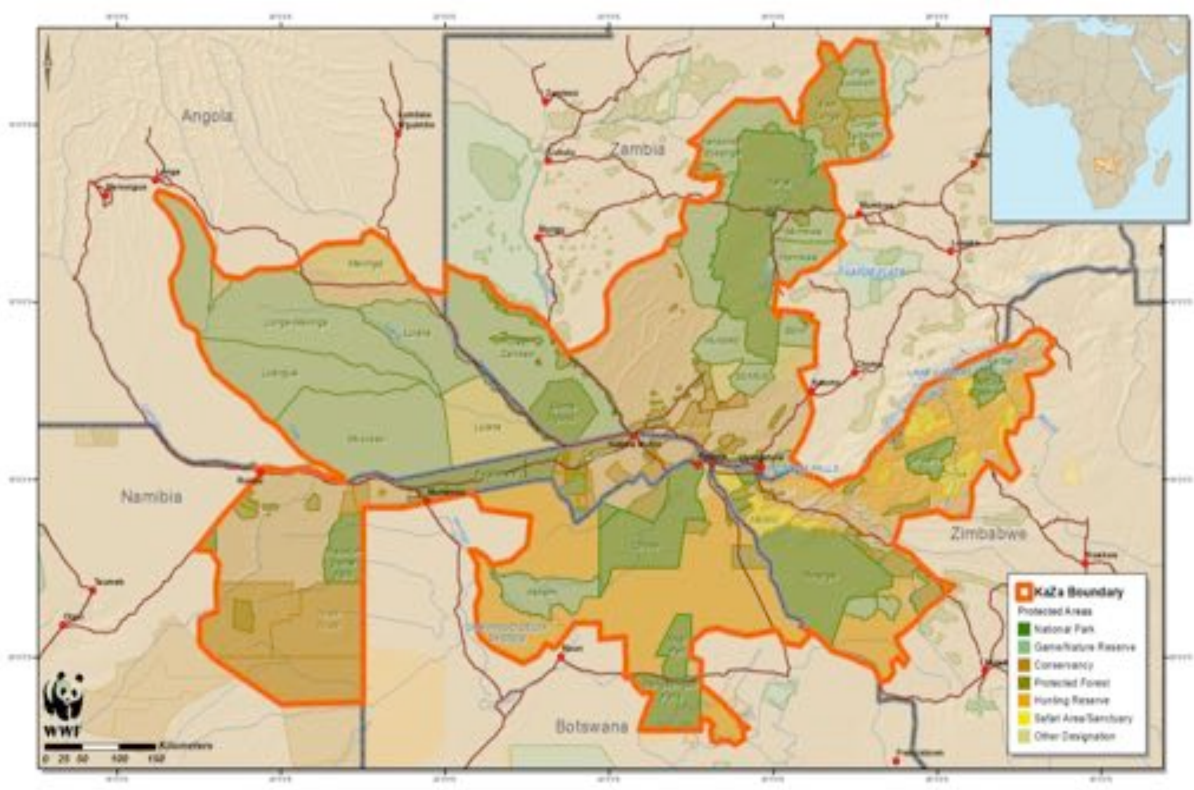

Figure 1. Map of the Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA) indicating the land included in the 2011 treaty by the five partner countries (adapted from WWF Namibia).

Survey objectives

Our specific survey objectives were to:

1. Determine the current distribution and abundance of lions, cheetahs, leopards, African wild dogs and spotted hyaenas across both Luengue-Luiana and Mavinga National Parks;
2. Determine the current distribution of the main large carnivore prey species across both parks;
3. Determine the dry season distribution of elephants across both parks;
4. Determine the species diversity and relative abundance in selected wildlife blocks using camera traps;
5. Collect spatial data on potential threats to large carnivores and other wildlife species (e.g. presence of livestock/herders, settlements, etc.) and biotic factors (presence of water, habitat types, etc.), to assess factors that potentially limit their distribution and densities across the Angolan KAZA areas;
6. Consider and provide information regarding interventions that will mitigate identified threats to large carnivore across the Luengue-Luiana and Mavinga National Parks, and the Cuando-Cubango Region.

Study area and wildlife populations

Luengue-Luiana (42,400 km^2) and Mavinga (42,000 km^2) national parks park fall within the Kavango Zambezi (KAZA) Transfrontier Conservation Area (TFCA), which embraces contiguous parts of southeast Angola, northern Botswana, northeast Namibia, southwest Zambia, and western Zimbabwe (Figure 1). The study area embraced the full extent of both parks, which lie between the Cuito River in the west, and the Cuando (Kwando) River in the east, which is also the boundary with Zambia. The southern boundary comprises the Cubango (Okavango) River in the west and the Bwabwata National Park, Namibia. These are perennial rivers with broad river valleys having extensive wetlands and floodplains (Figure 2).

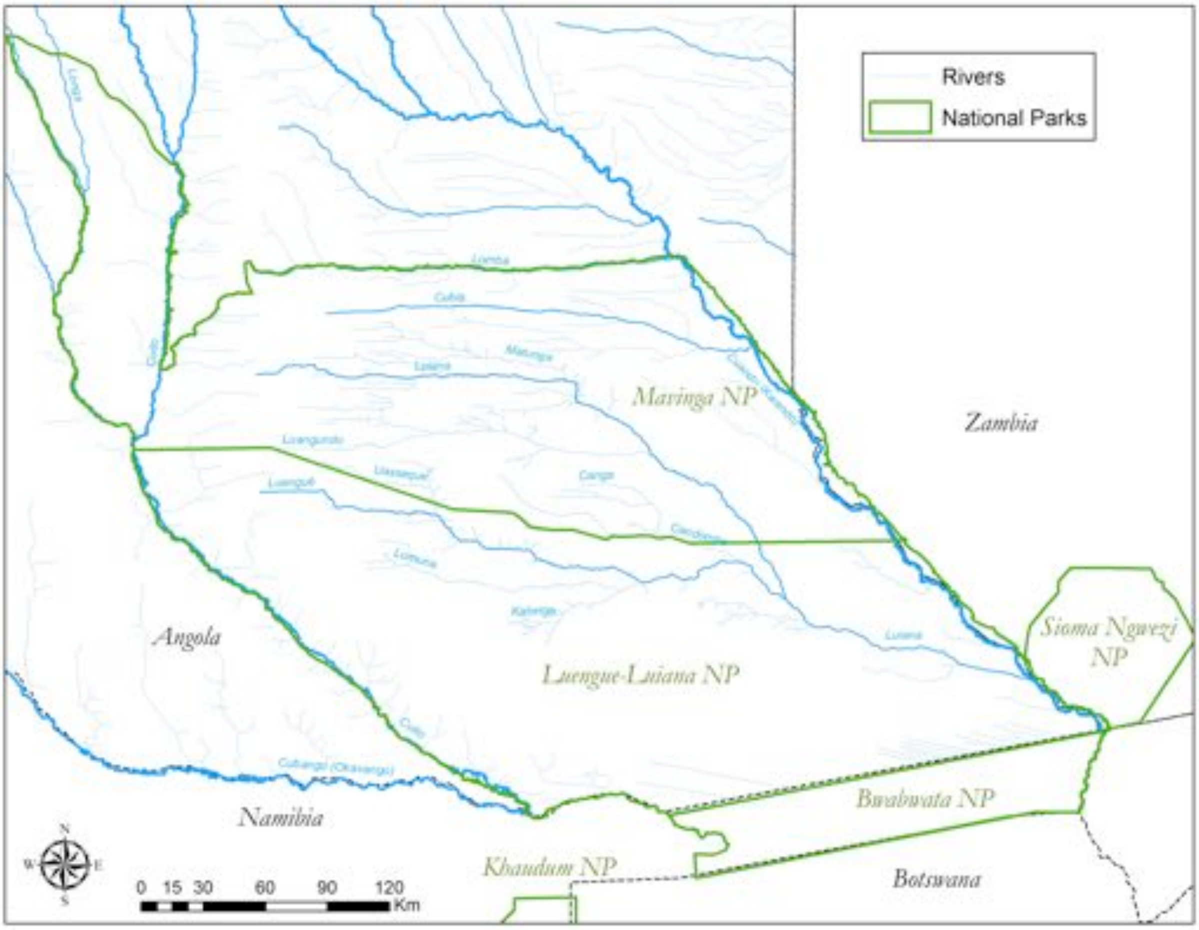

Figure 2. The main rivers occurring within Luengue-Luiana and Mavinga National Parks, Angola.

The topography is generally flat throughout both parks, with fossil dunes valleys and sandy ridges in the south. These are fossilized belts of Tertiary Kalahari sand dunes that underline long, narrow, parallel depressions known locally as '*omurambas*'. Habitats in the parks include mixed woodlands, shrublands, and grasslands as well as riparian forests in river floodplains. Most rivers that have their drainage within the parks flood seasonally, with large pools and lakes existing even in very dry years. These include the Lumuna, Luengue and Luiana Rivers, with seasonal regimes, with the Luiana having drainage systems stretching up into Mavinga National Park (Figure 2).

Small villages and agricultural settlements are common throughout both parks, especially along the main river systems. Most households practice subsistence agriculture in a slash and burn practice with a very demanding impact on land availability and vegetation cover. SAREP (2016) classified these areas as cultivated land. Due to the concentration of settlements these are most prominent in the northern areas of Mavinga National Park between and around the towns of Longa and Cuito Cuanavale. Cultivated land can be observed around almost every human settlement within Luengue-Luiana and Mavinga National Parks. These settlements are either connected by roads that have been demined since the cessation of the civil war, or a network of smaller tracks used predominantly by oxcarts. Private logging companies extract various teaks trees species such as *Baikiaea plurijuga*, *Burkea africana*, and *Pterocarpus angolensis*, within Luengue-Luiana National Park, and account to another major extractive use, yet this is currently considered permitted and legal.

SAREP (2016) identified the following five habitats in the two parks: dense woodland, open woodland, bushland (largely open grassland), aquatic vegetation, and cultivated land (Figure 3). Generally, both parks are covered by open woodland, which is characterised by relatively widely spaced tress such as *Burkea, Baikiaea, Pterocarpus*, and *Erythrophleum* in the southern areas, whereas *Erythrophleum, Burkea, Julbernadia* and *Guibortia* are more dominant towards the northern areas. The shaded canopy and soil types result in grass cover typically being sparse (SAREP, 2016). Dense woodland occurs on some areas around Likuwa and in the north-west along the upper reaches of the Cuito River. All rivers in the parks, and some dune valleys that flow into rivers, are characterised by flanking aquatic vegetation. This is most prevalent along the Cuando River which has extensive wet- and marshlands up to 10-15 km in width. Relatively scare patches of open grassland typically have hard substrate and accumulate water in wetter times, often resulting in intense fires. Some of these grasslands remain seasonally flooded and thus support few trees (Figure 3).

The region has a tropical savanna climate with a hot dry season from August to October, a hot wet season from November to April and a cool dry season from May to July. In the coldest months, June and July, frost occasionally occurs along the valleys and depressions. The hottest months are October and November, coinciding with the beginning of the rainy season, which stretches until March-April. Average annual rainfall varies along a south to north gradient from about 600 to 1000 mm of rainfall.

Our sampling periods spanned the cold and hot dry season months from June to October of 2015 and 2016. Due to the dry conditions at the time, the grass had largely died back by then, with deciduous trees and shrubs losing their leaves throughout.

Throughout both national parks wildlife populations were decimated during Angola's three decades' long Angolan Civil War. Although wildlife populations are recovering, there is intense bushmeat hunting by local villagers, and intense elephant poaching particularly along the Cuando River, south of the Luiana River (Chase & Schlossberg, 2016). Two elephant surveys have been conducted in Luengue-Luiana National Park, the first in 2004/5 (Chase & Griffin, 2011) and the second in 2015 (Chase & Schlossberg, 2016). In 2015, it was estimated that there were about 3,409 (95% CI: 1,783 to 5,034) elephants in the Luengue-Luiana National Park, with highest densities along the Cuando River and in the Likuwa areas (Chase & Schlossberg, 2016). However, observers estimated a total of 452 fresh carcasses in the survey, with a carcass ratio of 13%, which indicates a very high level of mortality in roughly the past year, and is evidence that the population is declining rapidly.

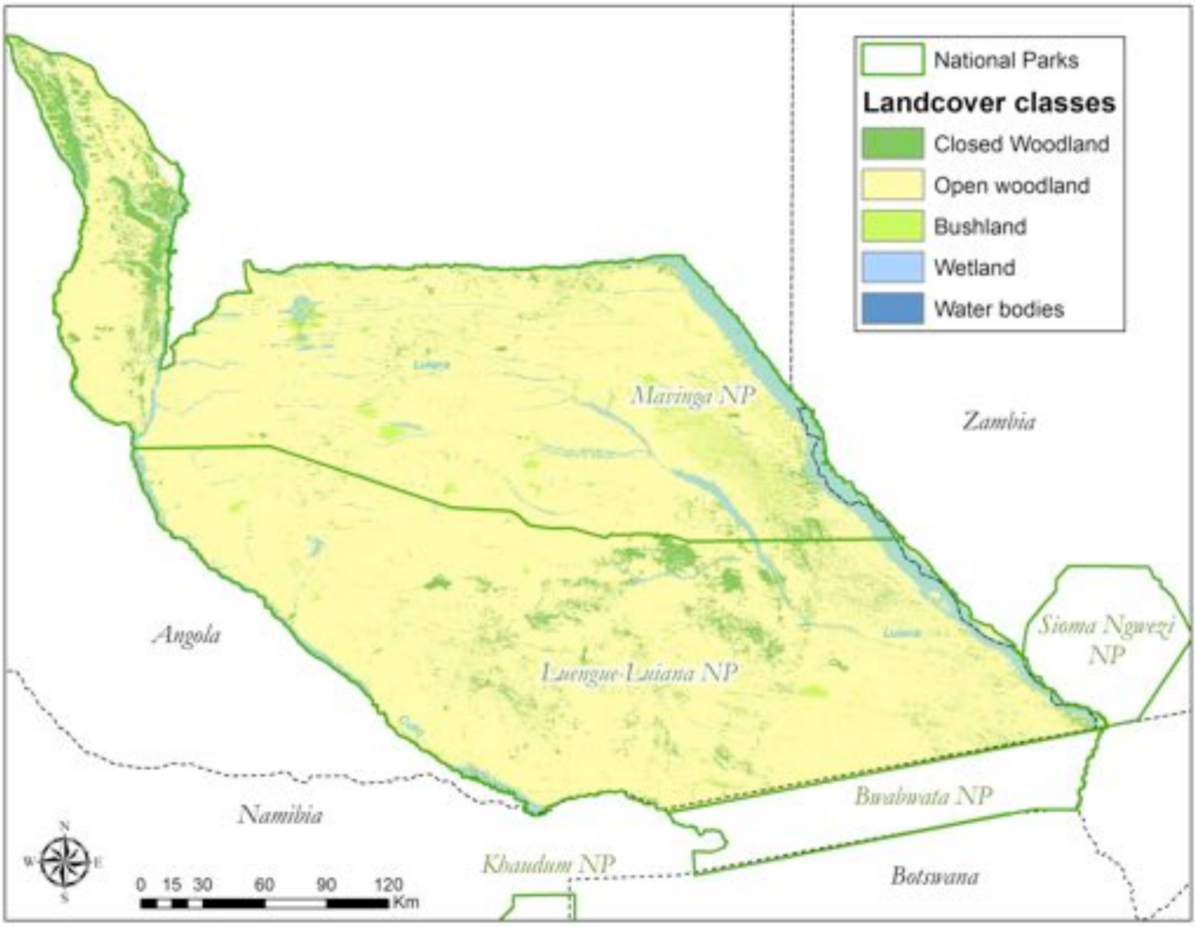

Figure 3. Five main habitat types occurring within Luengue-Luiana and Mavinga National Parks, Angola (adapted from SAREP (2016)).

During the first and only aerial surveys of Luiana Partial Reserve (now part of Luengue-Luiana National Park) in 2002-2004, researchers detected small populations of elephant, giraffe and buffalos; even several lions and leopards were seen from the air (Chase & Griffin, 2011).

In 2008, Luis Verissimo reported on a mammal species composition assessment of the Mucusso Partial Reserve (part of the Luengue-Luiana National Park), when neither lions nor cheetahs were reported in the area north of Mucusso. This mammal list was added to our own records and appears in Appendix 1. It has several species added to it that were recorded during our spoor and camera trap surveys.

Survey methods

SPOOR SURVEYS – FIELD DATA COLLECTION

To meet our objectives of determining large carnivore distribution and abundance, as well as larger ungulate distribution and relative abundance, we employed vehicle-based carnivore spoor counts that provide a cost- and time-effective means to establish the distribution and abundance of large carnivores over large spatial scales (Funston et al., 2010; Thorn et al., 2010). Most large carnivores exhibit extensive movements along roads and other linear features, such as firebreaks and other cutlines, and because prior studies have identified strong linear relationships between large carnivore population densities and the frequency of tracks along spoor transects, spoor

transects are a robust means to predict large carnivore densities and population sizes (Funston et al., 2010). For herbivores, we selected a group of high profile or important lion prey species and recorded their tracks, as for large carnivores. These included African elephant, giraffe, African buffalo, roan and sable antelopes, eland, kudu and zebra.

Within accessible areas of Luengue-Luiana and Mavinga National Parks, we distributed spoor transects as evenly as possible using a grid cell approach, with grid cells measuring 15 x 15 km (Figure 4). Within each grid we used all available roads, firebreaks, etc., which had substrates suitable for tracking. Surveys were conducted by one field team comprised of experienced researchers and, where available, local wildlife authority staff. The team included two to four skilled observers seated on custom-made tracker seats fastened to the bull-bars of the survey vehicle. Teams began transects at dawn to provide ideal tracking conditions, and the survey vehicle was driven at a maximum speed of 12 km/h during transects.

We surveyed a transect line of ca. 15 km length in each grid, and the survey team usually completed two or sometimes even three grids per day. Along each transect, the team recorded tracks of all the large carnivores, as well as those of elephants and other select large herbivores. All direct observations of wildlife were also recorded. The team furthermore recorded all observations related to human impact on the area, such as track records and direct observations of people and livestock, as well as the presence of food crops and settlements.

SPOOR SURVEYS – DATA ANALYSIS

We used detection/non-detection data from spoor transects in Luengue-Luiana and Mavinga national parks, Angola, to model occupancy probability of 5 large carnivore and 8 herbivore species. Occupancy can be defined as the proportion of sites occupied by a species, or the probability that an individual site is occupied (MacKenzie et al., 2006). We used the latter definition in this analysis.

We divided the study area into 434 15 x 15-km grid cells, with each cell representing a sampling unit (see Figure 4). Sampling unit size (225 km^2) was based on estimates of large carnivore home range size in the region (*unpublished data*). The choice of sampling units at the scale of home range size is common in analyses of occupancy across large spatial scales (Karanth et al., 2011) as it allows for monitoring of the proportion of potential home ranges occupied by the target species.

We aimed to cover 15 km of spoor transects in each sampling unit. However, around 40% of grid cells were not accessible by road, and in some accessible cells only few kilometres of road were available. In total, we conducted 3,364 km of spoor transects between July 2015 and October 2016, practically using all open roads within the Luengue-Luiana and Mavinga National Parks (Figure 4). Transects covered 239 of the 434 sampling units (55%), and average transect length in each sampling unit was 14 km. For each transect, we recorded the detection and non-detection of spoor of thirteen target species for every 500-m segment.

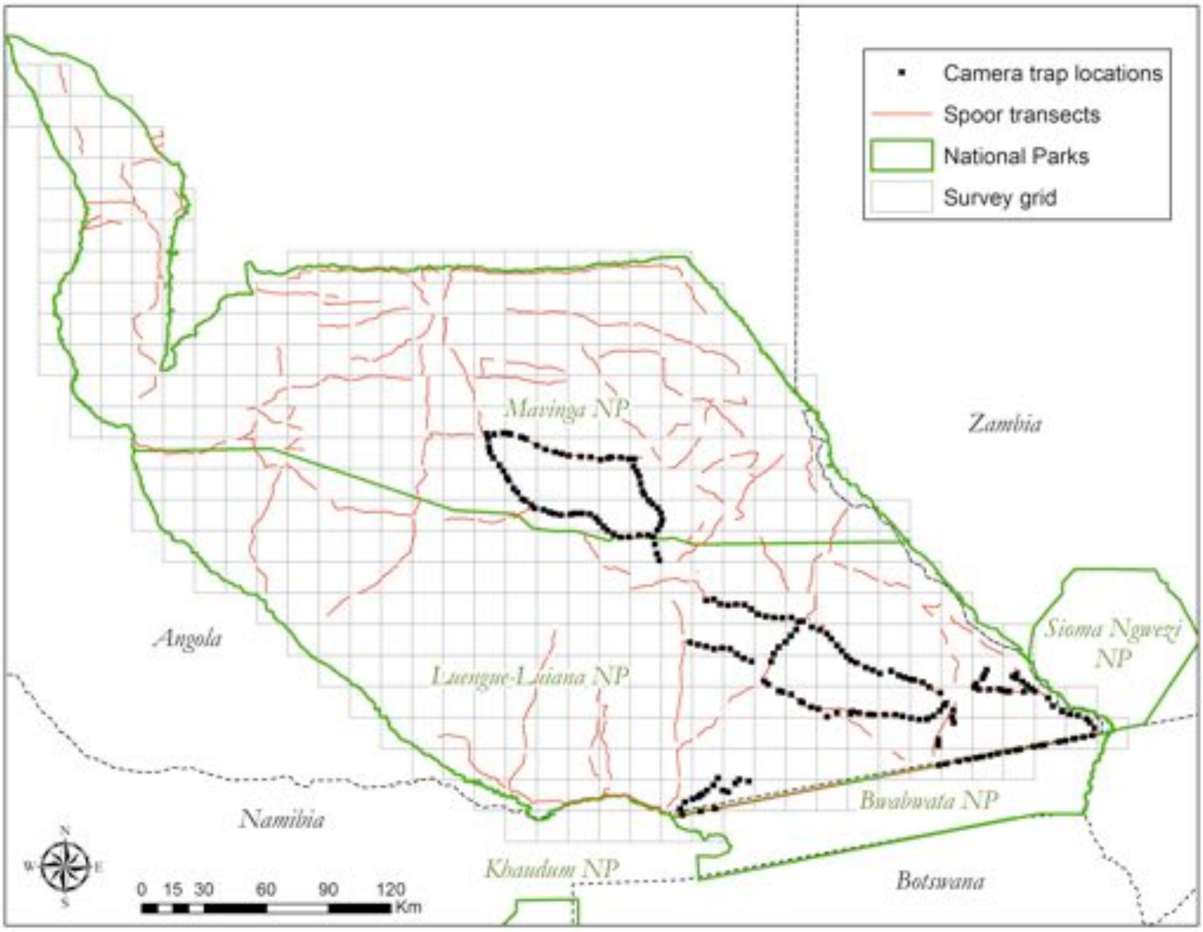

Figure 4. Within the boundaries of Luengue-Luiana and Mavinga National Parks, Angola, transects to count the frequency of 13 species of large carnivores and herbivores were conducted wherever possible within 15x15 km grid cells.

We hypothesized that four covariates would best predict species occupancy: latitude, distance to well-protected area (namely Bwabwata and Sioma Ngwezi National Parks), distance to settlement, and distance inside protected area. Distance inside protected area was calculated such that distances inside a protected area border had positive values, and those outside had negative values. We predicted that occupancy would increase at lower latitudes, with proximity to other well-protected areas and to protected area cores, and with distance away from human settlements. All covariates were calculated at the sampling unit level and were standardized such that the magnitude of regression coefficients could be compared within and among competing models (Schielzeth, 2014).

We predicted that probability of detection would be affected by five covariates: length (as some transects failed to reach the full 15-km length), number of livestock sign per 500-m segment, number of human sign per 500-m segment, proportion of 500-m segments with livestock sign, and proportion of 500-m segments with human sign. We predicted that probability of detecting spoor would increase with transect length and decrease with signs of humans and livestock.

We analysed transect survey data using a single-season, single-species correlated detection occupancy model in program PRESENCE v 11.8 (Hines, 2006). Our approach was to model covariates hypothesized to affect detection (p) first while holding occupancy (psi) constant, and

then use the detection model with lowest AIC in models testing the significance of occupancy covariates (Karanth et al., 2011).

In modelling occupancy (psi) we tested the covariates in an all-possible-subsets approach (additive only, no interactions), excluding variables from the same model if correlated at $|r| > 0.70$. Latitude and distance to well-protected area were highly correlated ($r = 0.93$) and could not be used in the same model.

CAMERA TRAPPING – FIELD DATA COLLECTION

We only used camera trapping as a survey technique in areas found to be rich in mammal species during our spoor surveys (see Figure 4). These camera trap surveys had three main objectives. Firstly, we aimed to gather additional information on species richness, particularly for smaller mammals that are difficult to detect and identify using spoor surveys. Camera traps are considered the ideal tool for species' inventories targeting terrestrial mammals >1kg, and even locally rare species are usually detected if trapping effort is high enough (generally >1,000 trap days) (O'Brien et al., 2003; Tobler et al., 2008). This enabled us to establish a complete species list for this understudied part of Angola, for mammals above 1 kg, thus excluding bats as well as smaller rodents and insectivores.

Secondly, we aimed to map the relative abundance of mammals across the entire area included in the camera trap survey, to identify local hotspots particularly for the rarer mammal species. In camera trap surveys, the relative abundance of a species across an area can easily be established through the photographic rates (number of photographs/100 trap days) said species shows across trap locations (Silveira et al., 2003; Rovero & Marshall, 2009).

Thirdly, for naturally marked and globally threatened species such as leopards, we aimed to derive an additional estimate of population density using capture-recapture statistics on individuals identified by their pelage patterns (Balme et al., 2009), for comparison with the density estimate derived from our spoor data (see above).

The distribution of our camera traps is shown in Figure 4. We used Panthera V6 camera traps, and deployed single traps at 252 locations. At each location, cameras were attached to a tree roughly at knee height, facing a vehicle track or game trail. Some cameras targeting water points were set up somewhat higher, to avoid tempering by baboons and permit the filming of the entire water body. We respected a spacing of 4 km between traps, using a 4x4 km grid overlaid on our study area to guide trap placement in the field. Each trap remained set up for approximately 5 weeks (range: 2–46 days; average 33 days). One camera was burned in a bush fire, one camera was destroyed by spotted hyaenas, and 30 cameras were stolen.

CAMERA TRAPPING – DATA ANALYSIS

To determine capture rates, we accounted for an independence threshold to as much as possible avoid over counting or double counting. To do so, we applied a thirty-minute limit on captures such that whenever multiple images of the same species were taken they were only recorded as one capture. When larger herds of ungulates or groups of large carnivores passed the cameras, we captured them within that thirty-minute threshold, and assigned those captures as one capture, but took the highest number of counted individuals and assigned it to that record. For instance, we recorded five photographs of impala within a 10-minute period in groups of 1, 1, 3, 1, 8 individuals. We then assigned that as one capture record of impala, with a total of 8

individuals. There might have been more impala, but they might have also doubled back and got photographed more than once.

Individual leopards were identified based on their unique coat patterns, allowing us to compute a population density estimate for the camera trap sampling zones. The first step was to catalogue all camera-trap images using PantheraR and camtrapR (Niedballa et al., 2016), within the R Statistical Environment (R Core Team, 2013). Once each leopard was identified we followed standardised capture re-capture analytical methods, and hierarchical model formulation, described by Goldberg et al. (2015) and Royle et al. (2009). The model relates the observations, y_{ijk}, of individual *i* in trap *j* during sampling interval *k* to the latent distribution of activity centres. Observation, y_{ijk}, took the value of one for a capture, and zero if not captured, to produce a capture history for all individuals in all traps over all sampling intervals. Multiple detections of the same individual, within the same sampling period, were taken as a single capture. Individuals could be captured on multiple traps during a sampling interval (24 hours). We followed the formulation of the observation process used by Goldberg et al. (2015), Gardner et al. (2010), and Russell et al. (2012).

Our spatially-explicit capture-recapture models were implemented within a Bayesian framework using data augmentation (Royle & Young, 2008; Goldberg et al., 2015). Data augmentation adds a sufficiently large number of all-zero capture histories to create a dataset of size *M* individuals (Goldberg et al., 2015). Augmentation was considered large enough when the number of augmented individuals did not truncate the posterior estimates of population size (Goldberg et al., 2015; Proffitt et al., 2015). Data augmentation in this study was set to 500. We chose a uniform prior distribution from 0 to *M* on population size (Goldberg et al., 2015). Starting values for parameters were: $\sigma = 1$, $\theta = 0.75$, $\ln(\alpha_0) = 0$, $\beta = 0$, $\Psi = 0$, Ψ_{sex} = proportion of males sampled. We used improper priors $(-\infty,\infty)$ for α_0 and all β parameters, $(0, \infty)$ for σ, (0.5, 1) for θ, and (0, 1) for Ψ and Ψ_{sex}. Models were fit using Markov chain Monte Carlo (MCMC) methods within R, using the SCRbayes package (available at: https://sites.google.com/site/spatialcapturerecapture/scrbayes-r-package).

To account for individual, sex-specific effects, we included a sex covariate within all models. Although cubs (< 12 months old) were occasionally captured on the camera-traps, we only included adults and sub-adults within our analyses. All analyses were run using a statespace of 20 km. Models were run for 30,000 iterations, with a burn-in of 5,000. To reduce autocorrelation, we thinned the MCMC chains by skipping every other iteration, resulting in 12,500 iterations in our posterior sample. We evaluated model goodness of fit using a standard Bayesian *P*-value approach (Royle et al., 2013). Convergence of the MCMC chains were assessed by examining posterior parameter-wise traceplots and histograms. The mean and 95% credibility intervals, for each model parameter, were then computed from these converged samples (Goldberg et al., 2015).

THREATS TO LARGE CARNIVORES AND OTHER WILDLIFE SPECIES

During the survey all human habitation was noted and an attempt was made through both casual conservation (open ended interviews) to assess the livelihood patterns of the respective communities. Additionally, all signs of activities typically regarded as illegal in a national park were noted where opportunistically observed. No concerted or specific sampling method was employed to collect this information.

TOURISM POTENTIAL

During the survey two methods where employed to make subjective assessments of the tourism potential. The first was an exploratory mission by PF and Stefan van Wyk. Here all the major routes in the former Luiana Partial Reserve and areas extending to Licua and Mucusso were driven and subjective assessment of tourism potential made. This area is described later in this report as an 'important habitat zone' in central/eastern Luengue-Luiana National Park.

The second assessment, only conducted in 2016 and thus not including the former Luiana Partial Reserve, identified 'potential tourism sites' while conducting the extensive spoor survey of both parks. Potential tourism sites were simply locations that SM thought might be aesthetically pleasing to tourists. Each site was rated either 2, 3 or 4; with 2=average, 3=pleasant and 4=outstanding. The measure was entirely subjective and should be used only as a starting point for future exploration. No effort was made to explore appealing areas extensively on foot. For the purpose of this report we only mapped potential tourism sites with value of 3 or 4 and in some cases mapped scenic areas as buffered line files as most of the scenic drives followed rivers.

Results

SPOOR SURVEYS – POPULATION SIZE ESTIMATES OF LARGE CARNIVORES

In total, we recorded 2646 spoor detections across 13 species in Luengue-Luiana and Mavinga National Parks, conducting transects in 239 of 434 sampling units (55%) (Table 1). Leopard, sable and roan antelope were detected in over 40% of sampled survey units, while zebra, lion and kudu were detected in <5% of surveyed sampling units (Table 1).

The most frequently recorded large carnivore species was the leopard, followed by the spotted hyaena and African wild dog (Table 1). Tracks of cheetah and especially lion were very rarely observed, and for both species largely restricted to Luengue-Luiana National Park. For lions, the number of tracks recorded was too low to produce reliable estimates of population density using the equations developed by Funston et al. (2010), and refined for small samples Winterbach et al. (2016). Consequently, population densities were only calculated for cheetahs, leopards, spotted hyaenas and African wild dogs (Table 2).

SPOOR SURVEYS – OCCUPANCY ESTIMATES FOR ALL PRIORITY SPECIES

Correlated detection occupancy models were successfully applied for buffalo, elephant, spotted hyaena, leopard, roan, sable, and wild dog. Single-season, single-species models that did not incorporate spatial dependence were fit for giraffe (n = 55 detections), cheetah (n = 54 detections), eland (n = 33 detections), and lion (n = 30 detections), as these species had insufficient data for the more heavily parameterized correlated detection models. Model results that do not incorporate spatial dependence should be interpreted with caution, as the violation of independence will underestimate standard errors and may falsely suggest covariate relationships where they don't exist. No occupancy models were fit for zebra (n = 12 detections) and kudu (n = 7 detections) due to paucity of detections.

Species occupancy was associated with more southerly latitudes (buffalo, roan, sable and wild dog), proximity to well-protected areas (cheetah, elephant, giraffe, spotted hyaena, and lion; magnitude of effect was particularly large for elephant), proximity to protected area interior (buffalo, eland, elephant, giraffe, leopard, roan, and sable), and distance from human settlements (eland, elephant, spotted hyaena, leopard, and roan) (Table 3).

Table 1. Large carnivore (n = 5) and large herbivore (n = 8) species surveyed in Luengue-Luiana and Mavinga National Parks, Angola, from July 2015 to October 2016.

	Number of detections	Proportion of surveyed sampling units with detection
Large carnivores		
Leopard	626	47.7
Spotted hyaena	495	28.9
Wild dog	197	21.3
Cheetah	54	10.5
Lion	30	2.9
Large herbivores		
Sable	413	51.5
Roan	298	41.0
Elephant	319	36.8
Buffalo	107	19.3
Giraffe	55	10.9
Eland	33	8.8
Zebra	12	3.4
Kudu	7	2.5

Table 2. Spoor transect data, population density and abundance estimates for the five large carnivores across Luengue-Luiana and Mavinga National Parks, Angola 2015/16.

Species	No. of fresh tracks	Spoor density (tracks/100 km)	Population density (inds/100 km^2)	Population estimate
Lion	3	0.08	n.a.	n.a.
Cheetah	16	0.56	0.2	151 ± 101
Leopard	66	1.93	0.6	518 ± 190
Spotted hyaena	92	2.89	0.9	776 ± 345
African wild dog	90	2.23	0.7	599 ± 260

Detection of five species increased with increasing transect length (buffalo, elephant, spotted hyaena, leopard, and roan), and detection of four species increased with less frequency of human sign per 500-m segment (spotted hyaena, leopard, roan, and sable) (Table 3). Detection covariates could not be fit to five species (cheetah, eland, giraffe, lion, and wild dog) due to lack of data.

Occupancy predictions were mapped across the study area for large carnivores (Figures 5-9) and large herbivores (Figures 10-15). Maps were also produced for carnivore and total species richness, in which a site was considered occupied by a species given predicted probability of occupancy > 0.50 (Figures 16-17).

Table 3. Estimated regression coefficients for occupancy models for 11 large carnivore and herbivore species in Luengue-Luiana and Mavinga National Parks, Angola, July 2015 to October 2016.

	Model coefficients on occupancy (psi)										Model coefficients on detection (p)					
			Latitude		Distance to well-protected PA		Distance to settlement		Distance inside PA				Transect length		Number of human sign per 500-m segment	
	Intercept	SE	β	SE	β	SE	β	SE	β	SE	Intercept	SE	β	SE	β	SE
Buffalo	-2.94	0.61	-3.01	0.65					0.78	0.34	0.41	1.43	0.41	0.25		
Cheetah	-2.39	0.35			-1.20	0.32					-2.93	0.19				
Eland	-2.10	0.38					1.08	0.33	0.71	0.32	-3.20	0.27				
Elephant	-2.42	1.00			-7.28	1.30	2.76	1.03	2.89	0.73	-0.88	0.19	0.16	0.07		
Giraffe	-6.97	1.51			-4.93	1.16			1.85	0.52	-2.65	0.16				
Hyaena	-0.75	0.31			-1.52	0.28	1.04	0.34			1.13	0.21	0.31	0.12	-0.61	0.30
Leopard	1.44	0.78					1.99	0.85	0.60	0.24	0.96	0.21	0.30	0.09	-0.42	0.18
Lion	-5.23	1.17			-2.21	0.90					-1.80	0.21				
Roan	0.46	0.31	-0.22	0.08			0.20	0.09	0.28	0.07	-1.06	0.36	0.32	0.10	-0.31	0.17
Sable	0.70	0.33	-0.66	0.22					1.25	0.44	-0.68	0.18			-0.20	0.12
Wild Dog	-0.94	0.26	-0.93	0.24							0.96	0.36				

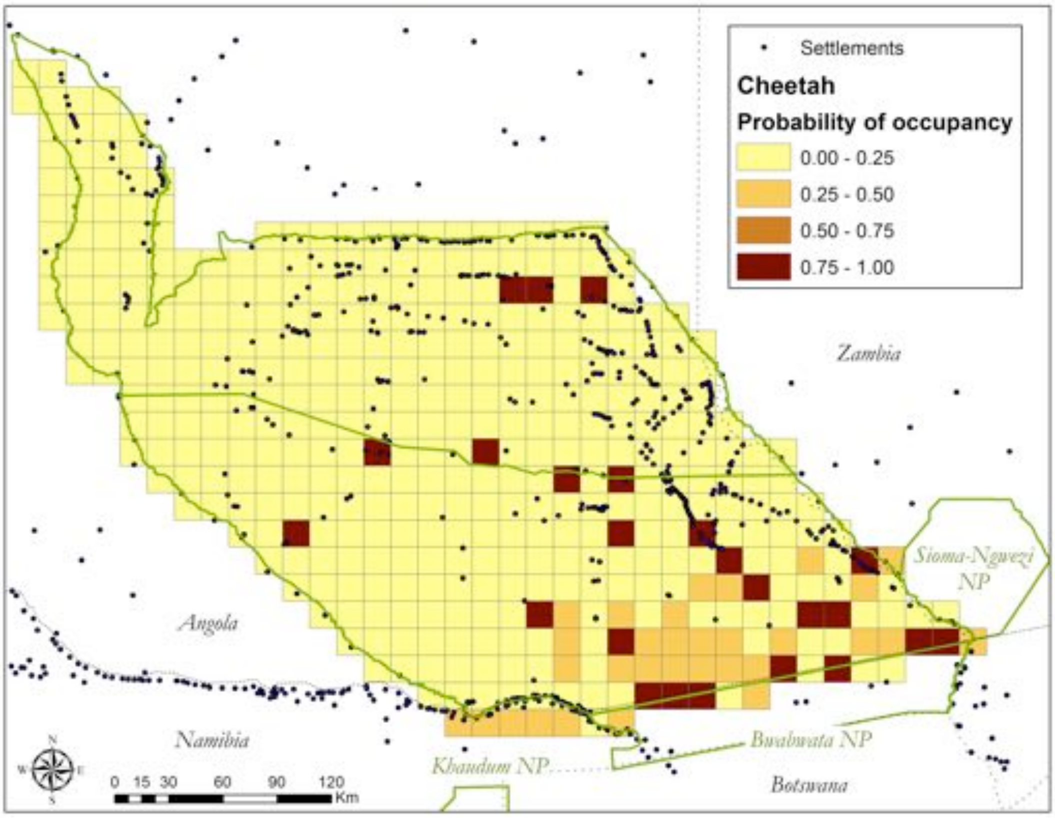

Figure 5. Predicted probability of cheetah occupancy in Luengue-Luiana and Mavinga National Parks, Angola, based on spoor transects.

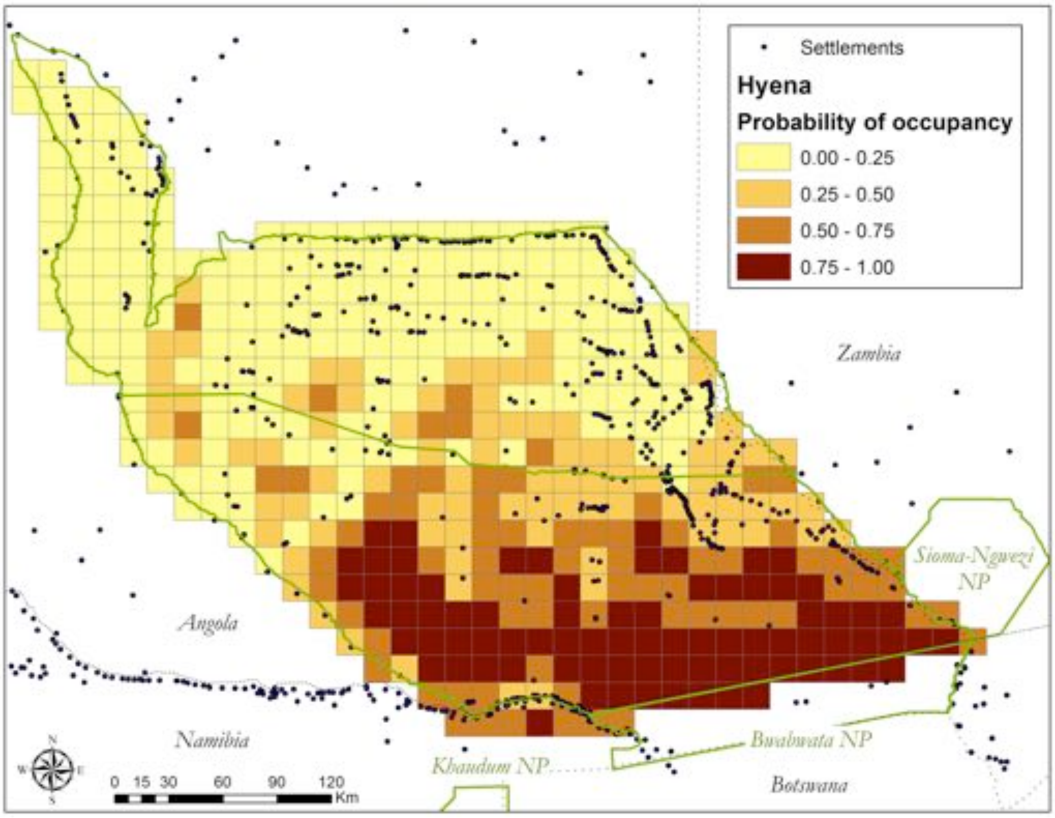

Figure 6. Predicted probability of spotted hyaena occupancy in Luengue-Luiana and Mavinga National Parks, Angola, based on spoor transects.

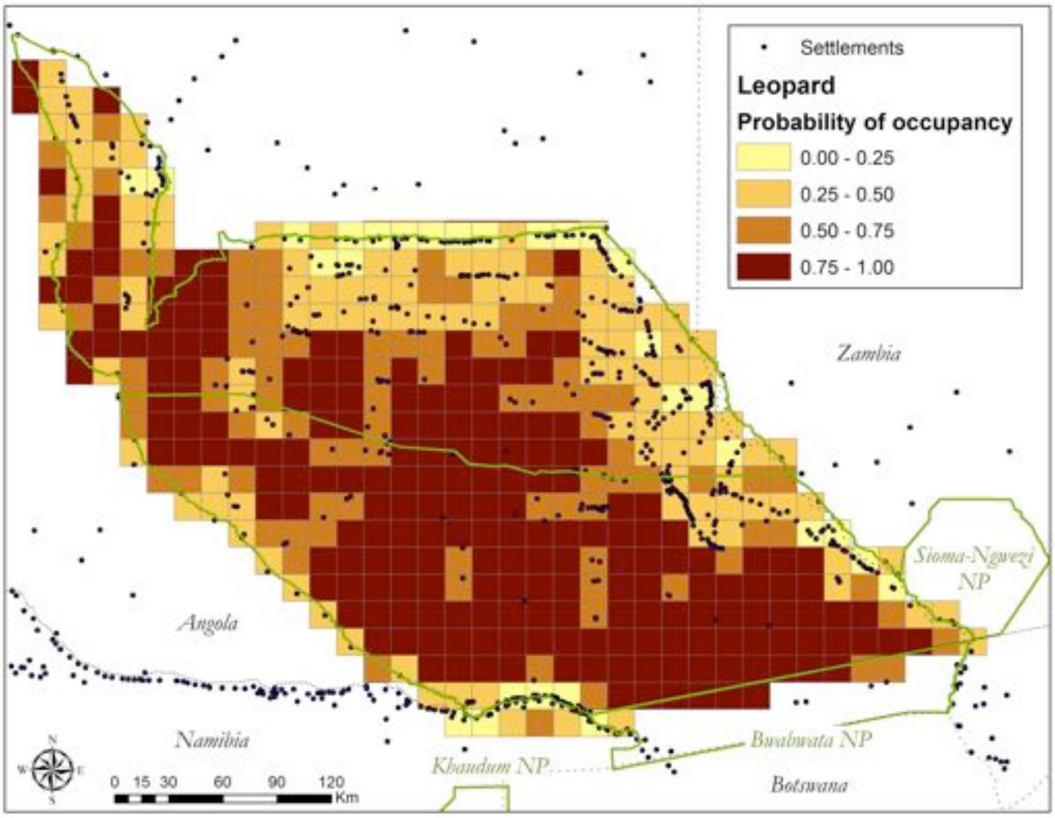

Figure 7. Predicted probability of leopard occupancy in Luengue-Luiana and Mavinga National Parks, Angola, based on spoor transects.

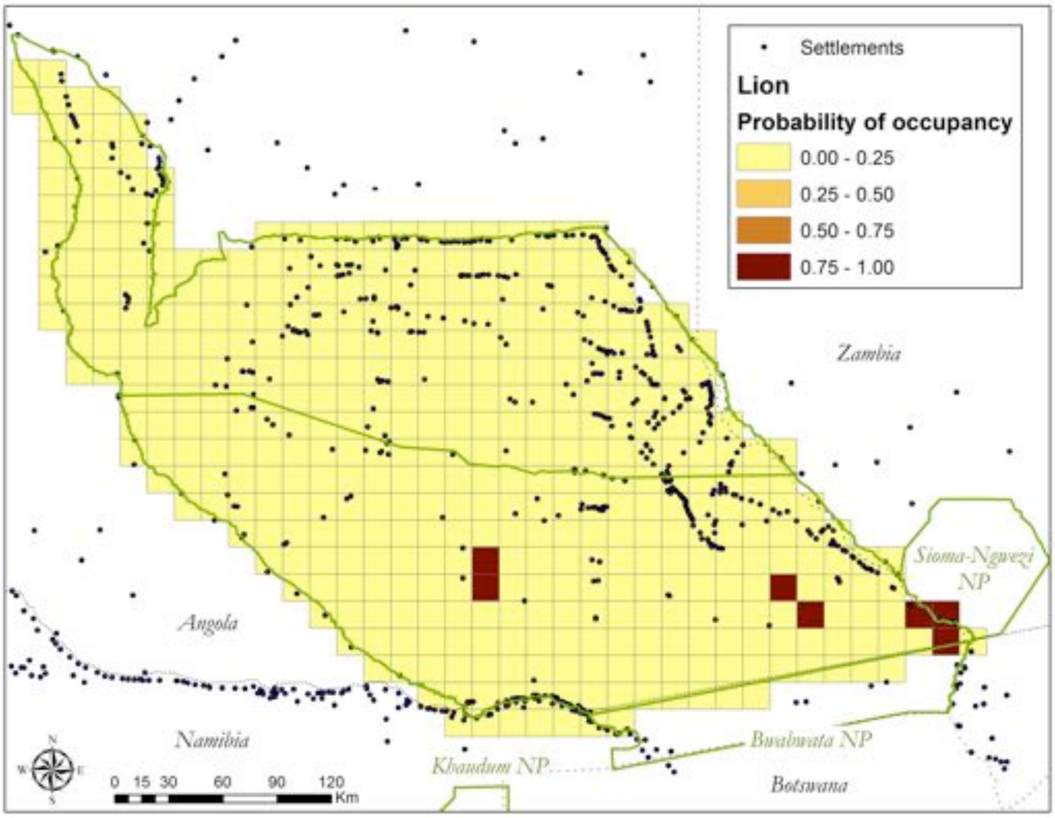

Figure 8. Predicted probability of lion occupancy in Luengue-Luiana and Mavinga National Parks, Angola, based on spoor transects.

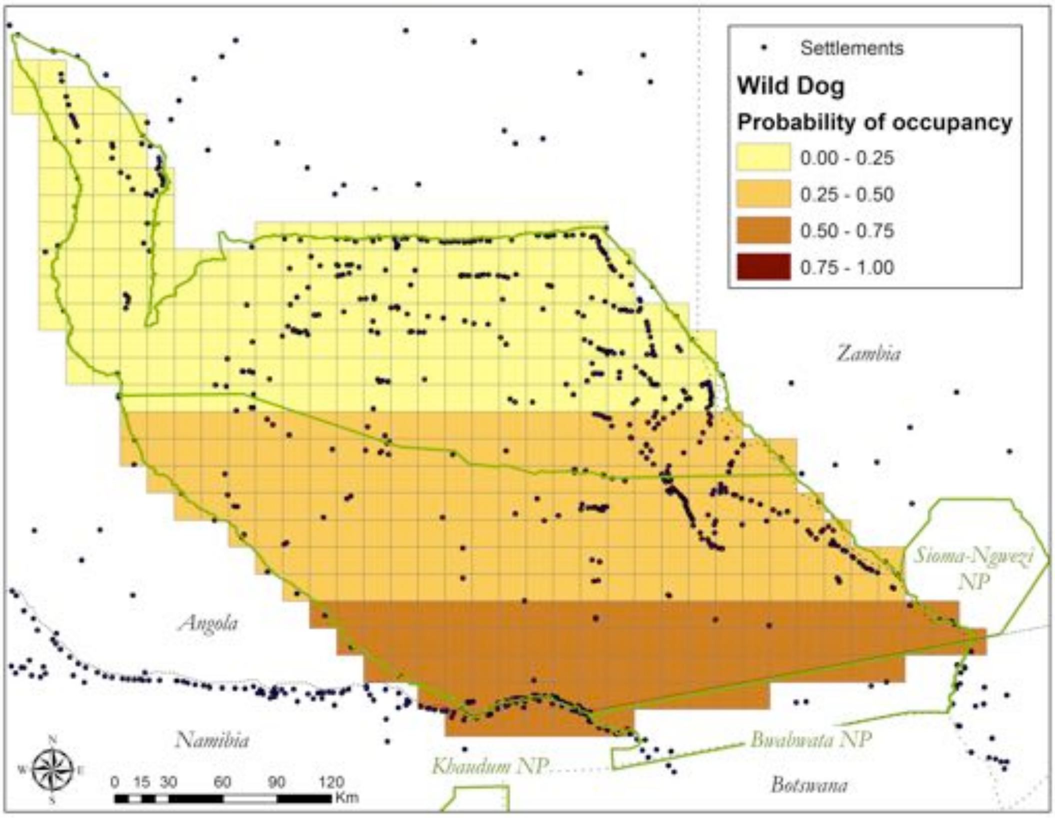

Figure 9. Predicted probability of African wild dog occupancy in Luengue-Luiana and Mavinga National Parks, Angola, based on spoor transects.

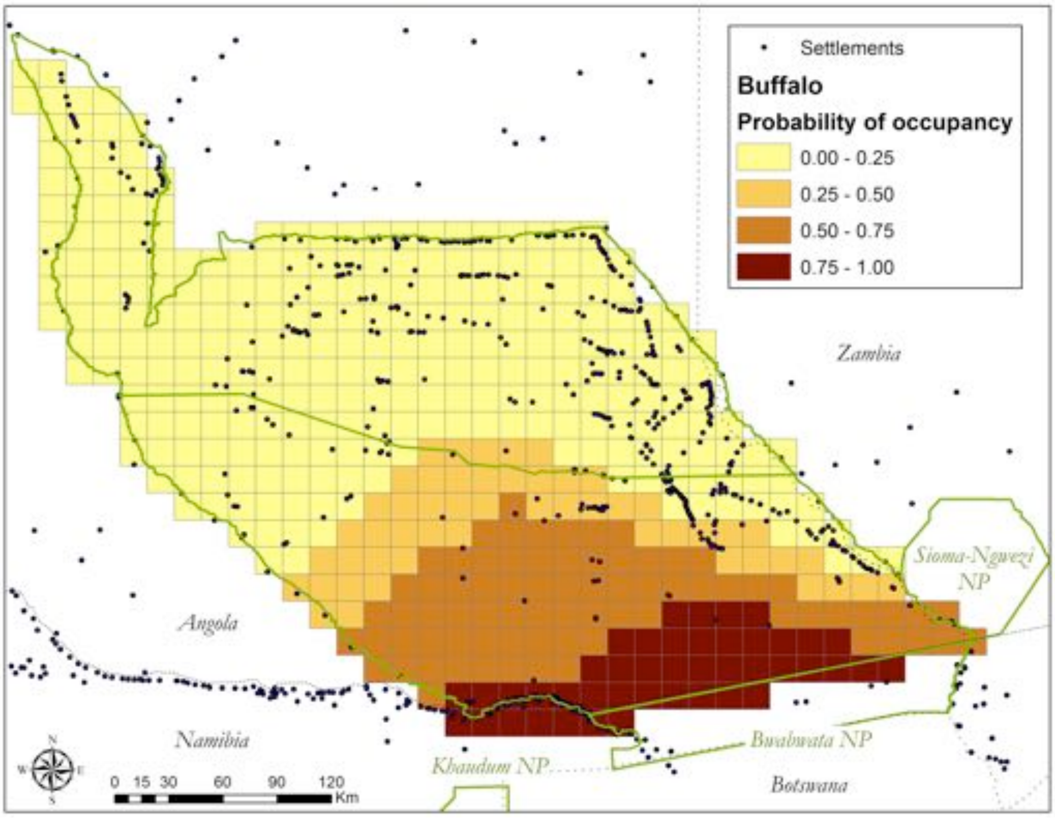

Figure 10. Predicted probability of African buffalo occupancy in Luengue-Luiana and Mavinga National Parks, Angola, based on spoor transects.

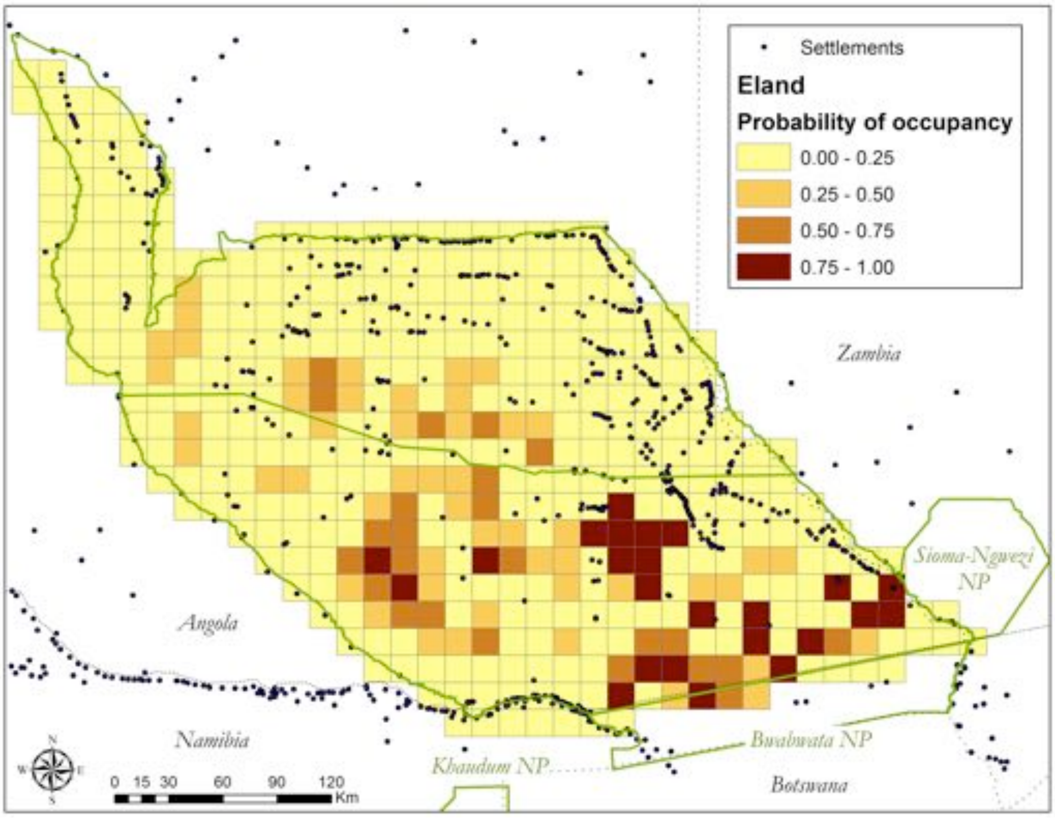

Figure 11. Predicted probability of eland occupancy in Luengue-Luiana and Mavinga National Parks, Angola, based on spoor transects.

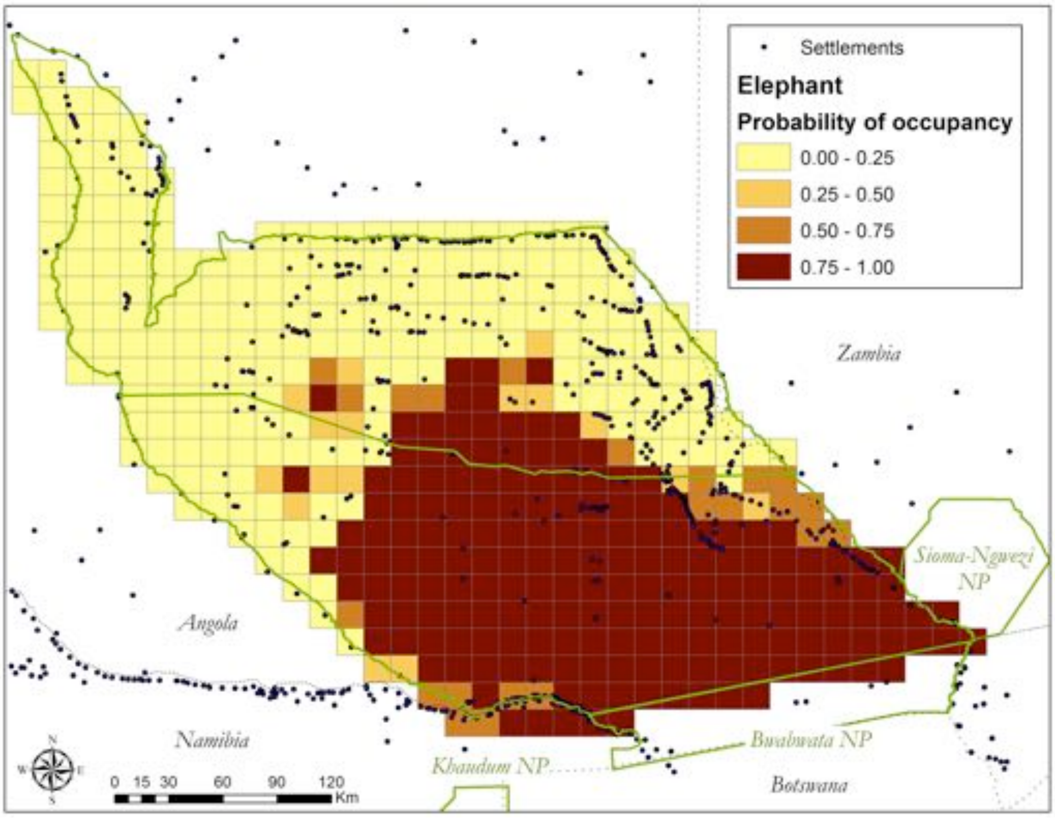

Figure 12. Predicted probability of elephant occupancy in Luengue-Luiana and Mavinga National Parks, Angola, based on spoor transects.

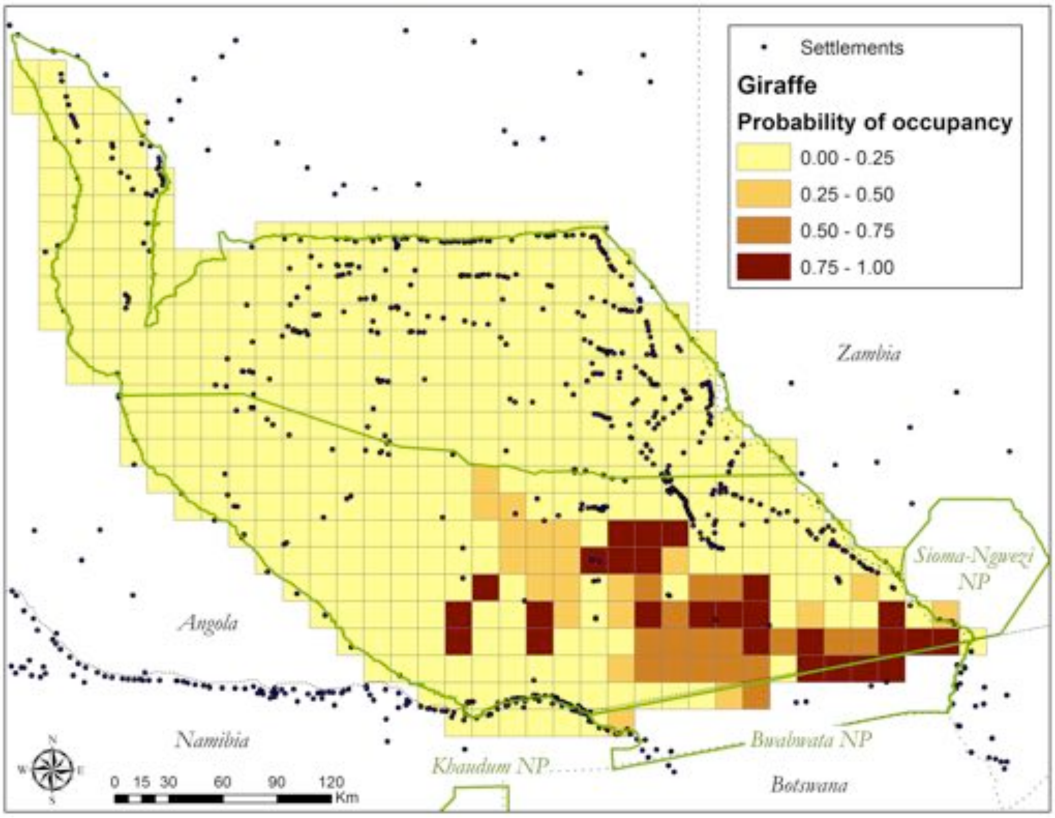

Figure 13. Predicted probability of giraffe occupancy in Luengue-Luiana and Mavinga National Parks, Angola, based on spoor transects.

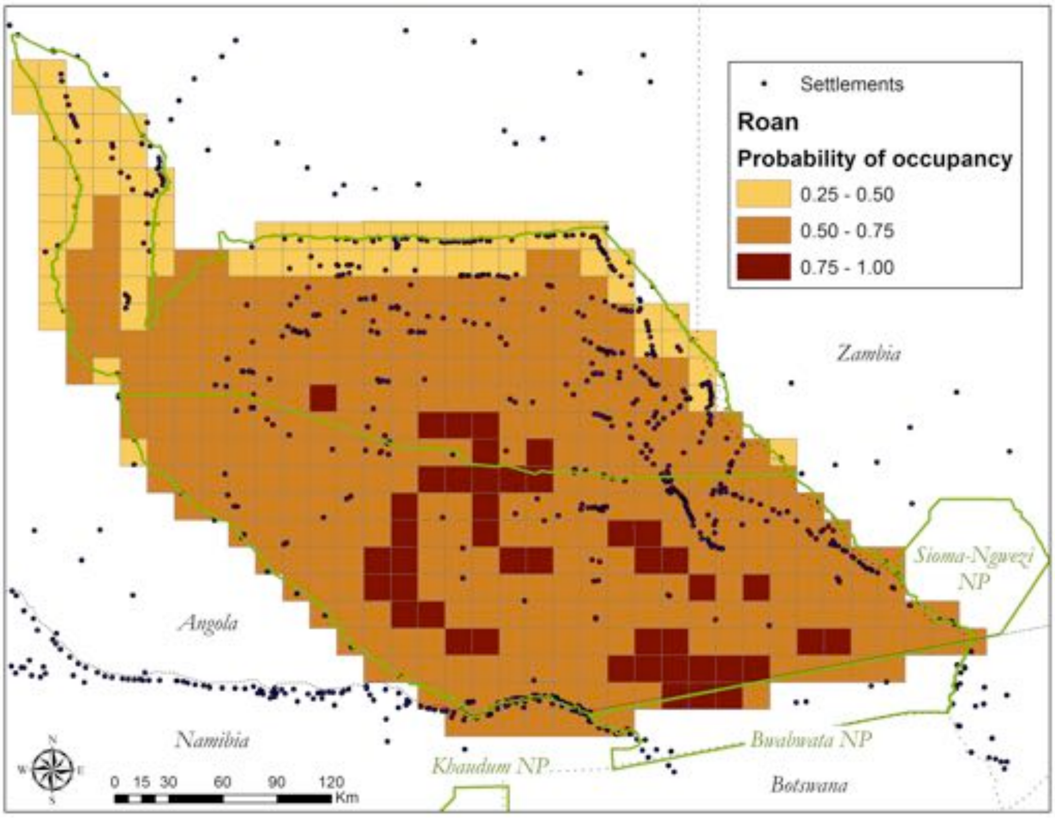

Figure 14. Predicted probability of roan occupancy in Luengue-Luiana and Mavinga National Parks, Angola, based on spoor transects.

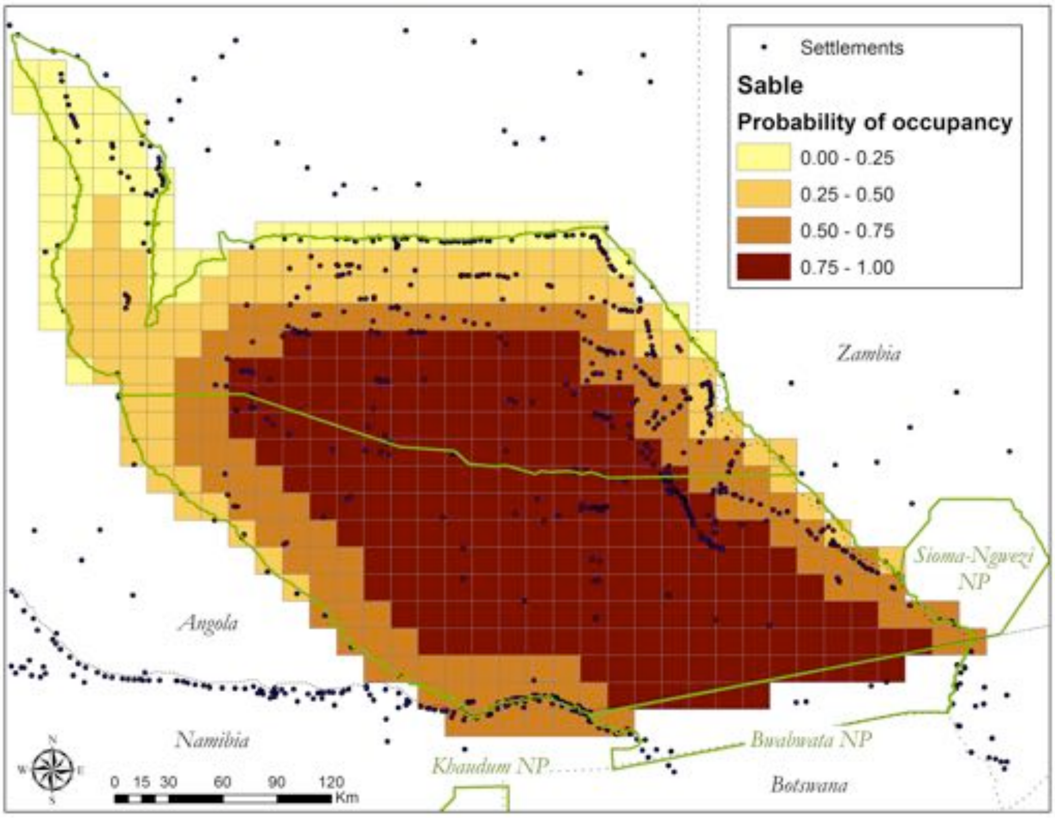

Figure 15. Predicted probability of sable occupancy in Luengue-Luiana and Mavinga National Parks, Angola, based on spoor transects.

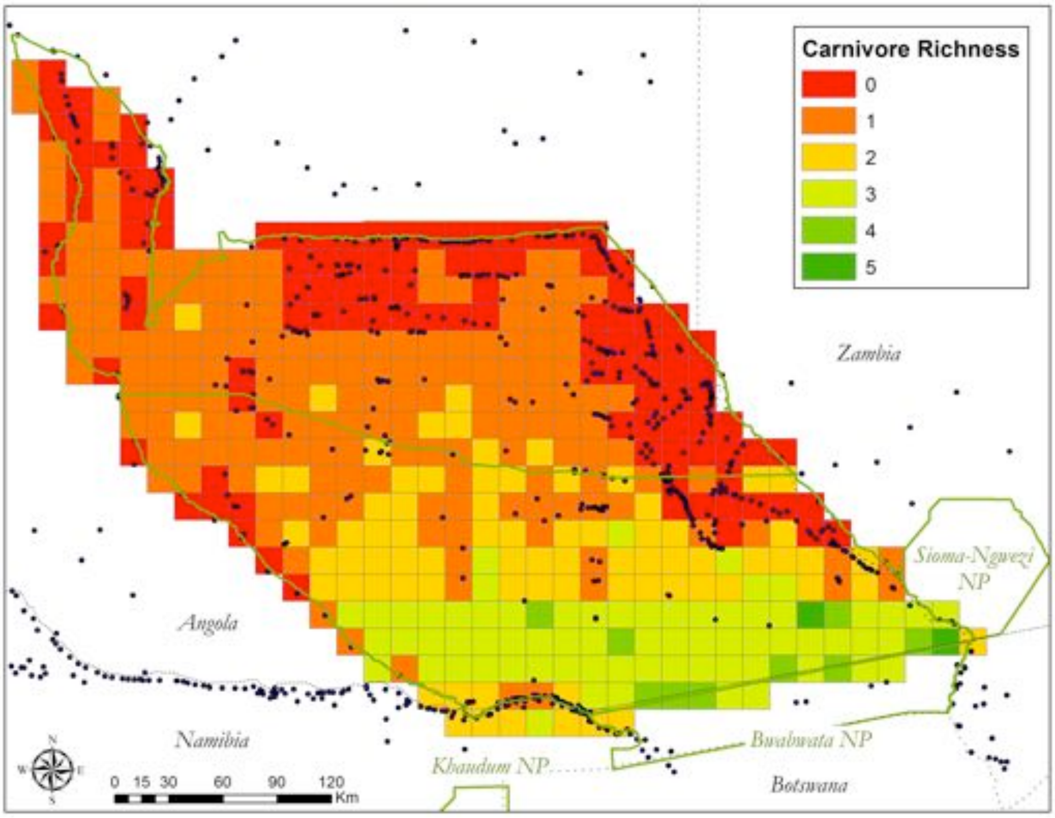

Figure 16. Large carnivore richness in Luengue-Luiana and Mavinga National Parks, based on occupancy estimates for five target species. A site was considered occupied if estimated occupancy probability was > 0.50.

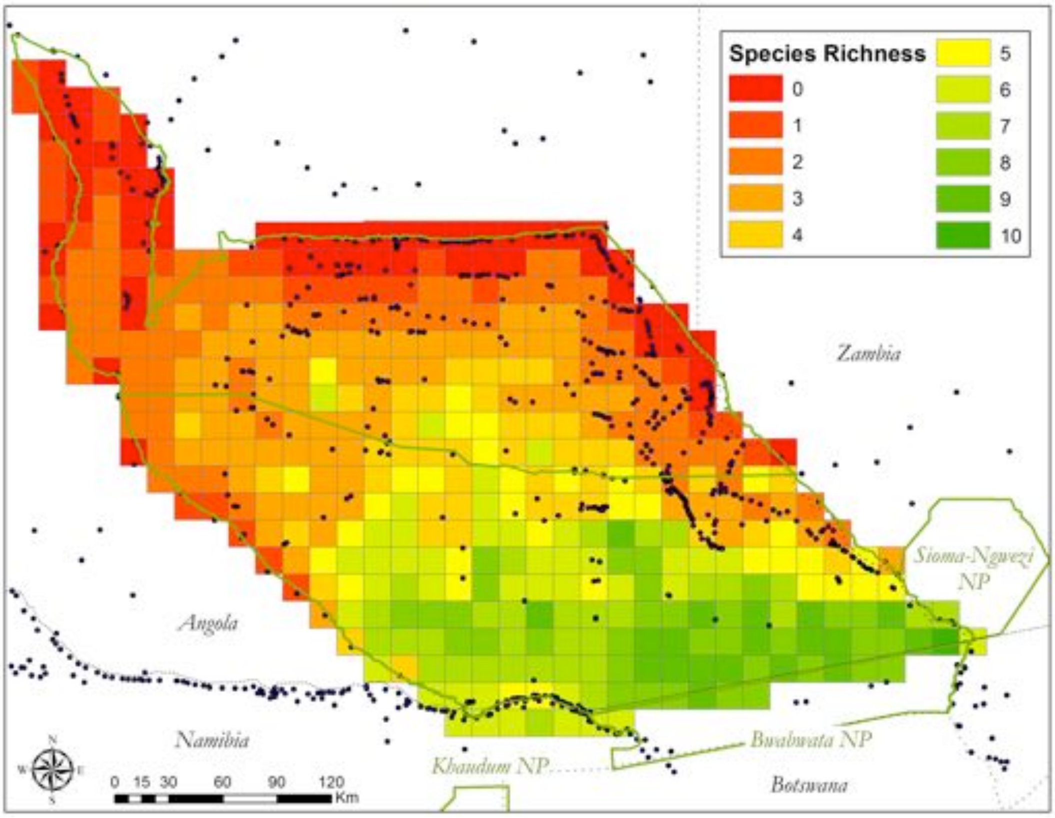

Figure 17. Estimated species richness in Luengue-Luiana and Mavinga National Parks, based on occupancy estimates from 11 large carnivore and herbivore species. A site was considered occupied by a target species if estimated occupancy probability was > 0.50.

CAMERA TRAPS

The total area covered by four sampling zones with camera-trap stations within Luengue-Luiana and Mavinga National Parks amounted to of 27,500 km^2. Three of these were in Luengue-Luiana, and the forth in Mavinga, just north of Licua (see Figure 4). The survey ran from July 1st 2016 to October 9th 2016, and sampling effort comprised 9,626 camera-trap nights. A total of 288,479 photographs were recorded, of which 237,910 were blanks (most triggered by vegetation moving in the wind). Of the remainder, 37,032 were considered independent captures (see definition above). A total of 51 different species were recorded (Figure 18). Large carnivores (128 stations; Figure. 19a), small carnivores (178 stations; Fig. 19b), large ungulates (110 stations; Fig. 19c), and small ungulates (174 stations; Fig. 19d) were photographed at 62%, 86%, 53%, and 85% of camera-trap stations, respectively.

Camera trap rates

Although the camera trap survey was only conducted in a relatively small part of Luengue-Luiana and Mavinga National Parks (see Figure 4), the results for the camera trap rates closely reflect those of the spoor survey, the only anomaly being that lions were recorded more frequently than were cheetahs (Table 4). However, on inspecting the photographs, the same groups of lions were recorded on several incidences, particularly a coalition of two adult males near Licua.

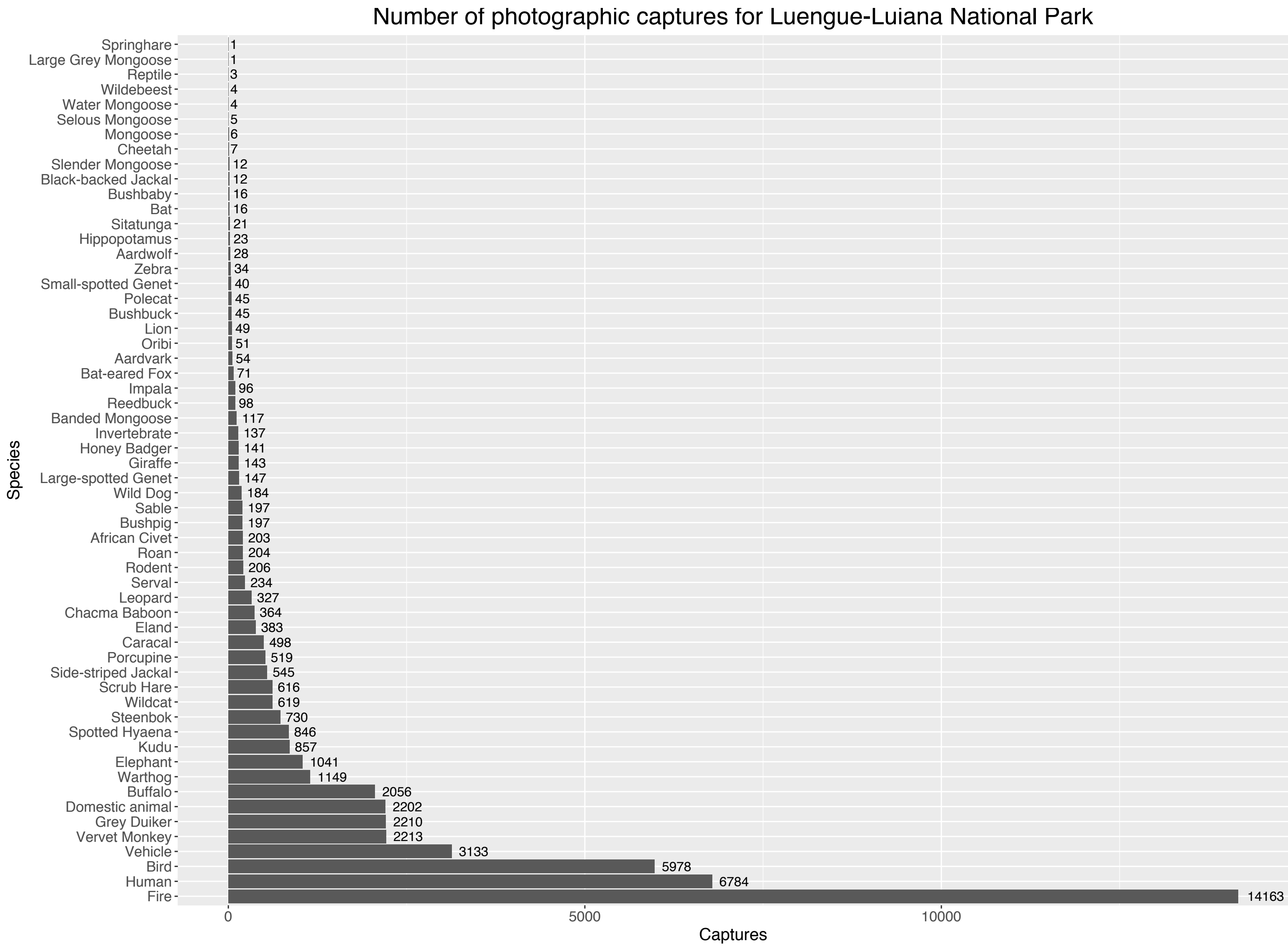

Figure 18. Photographic capture rates of species recorded within Luengue-Luiana and Mavinga National Parks, Angola. Blank images were removed (n = 237,910)

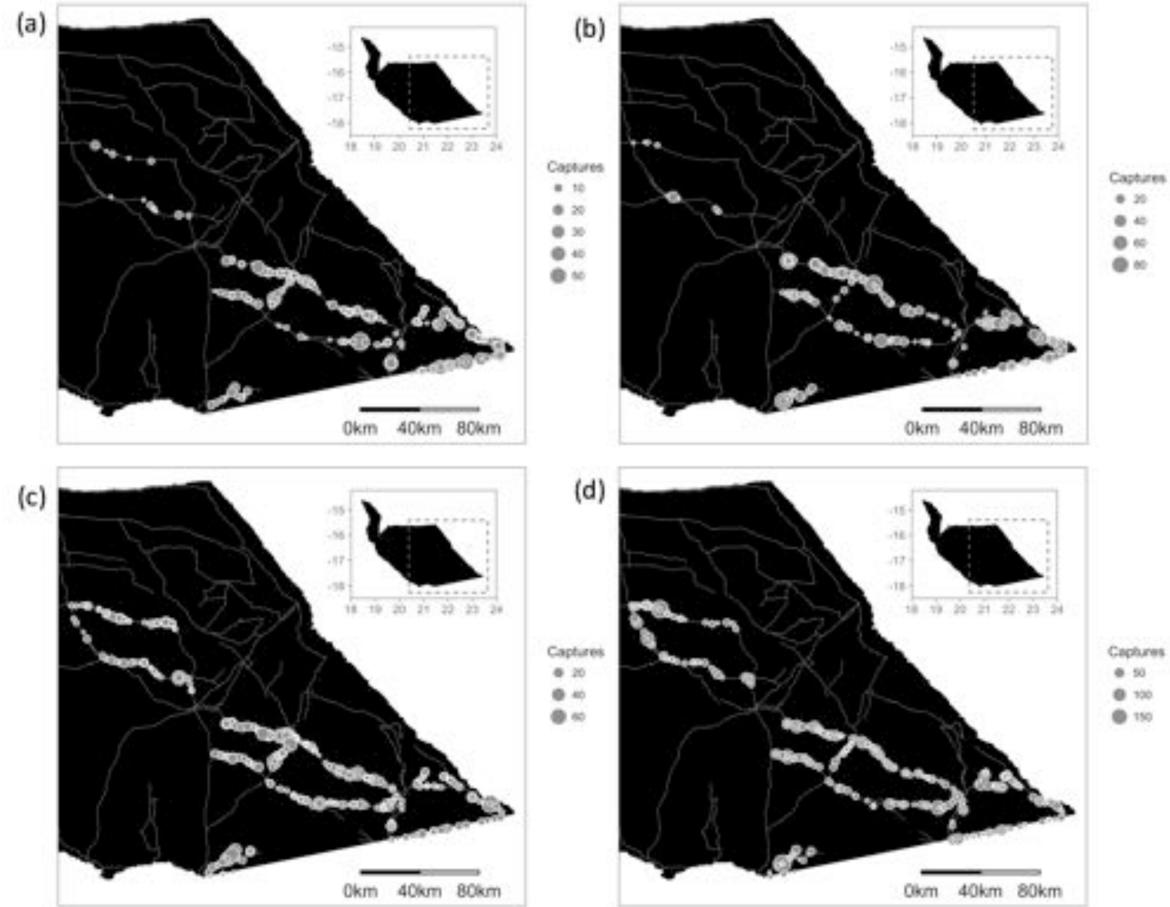

Figure 19. Relative capture frequencies of large carnivores (a), small carnivores (b), large ungulates (c; >100 kg female body mass), and small ungulates (d; <100 kg female body mass). The inset represents area with Luengue-Luiana and Mavinga National Parks were the cameras where placed with the camera-trapping focal zone depicted by the dashed grey box.

For small carnivores (<20 kg) a good diversity of the typical savanna species was recorded, with African wild cat being the most numerous. The side-striped jackal is predominantly a woodland species and was far more common than the black-backed jackal, which was comparatively rare (Table 4). Caracal and serval where both well represented cat species within the sample, as were both genets and civet. Two species of genet were identified, small and large spotted. Mongoose species included banded, dwarf, large grey, Selous's, slender and water.

In contrast with large carnivores, we did not record large ungulates (>100 kg adult female average mass) on camera traps at the same rates we did on spoor transects (see Tables 1 and 5). Marked differences included substantially higher numbers of kudu, much more than simply a group size effect. Furthermore, buffalo and elephant were more prevalent in the camera trap sampling zones. Within the small ungulates, common duiker, steenbok and warthog were particularly prevalent, with several other antelope species being relatively less numerous (Table 5). Several other species recorded on camera trap are listed in Appendix 1.

Table 4. Camera trap rates in the four sampling zones in Luengue-Luiana and Mavinga National Parks, Angola, July to October 2016.

Species	Number of captures
Large carnivores	
Spotted hyaena	464
Leopard	221
African wild dog	75
Lion	21
Cheetah	2
Small carnivores	
African wildcat	505
Side-striped jackal	388
Caracal	307
Civet	182
Serval	177
Large-spotted genet	147
Honey badger	98
Mongoose spp.	49
Bat-eared fox	46
Small-spotted genet	40
Polecat	38
Aardwolf	20
Black-backed jackal	11

Signs of human activity were regularly captured on the camera traps, with vehicles having been recorded 1805 times, domestic animals 600 times, and humans on foot 1119 times (see Figure 18). Many of these captures would have been repeated at numerous cameras as most cameras where placed along the better access roads and tracks in the sampling areas, and all forms of recorded human activity would have been largely linear with people and their livestock travelling largely from one locality to another.

Spatially explicit capture recapture

For leopards, we identified 120 individuals captured on 188 occasions during the survey period. Of these, 24 were classed as adult females, 55 as adult males and 41 as adults of unknown sex. Spatially-explicit capture-recapture analysis estimated the population density to be 1.5 (SD ±0.14) leopards per 100 km^2. The model had sufficient iterations for MCMC to converge, and reported a Bayesian P-value of 0.60, suggesting a reasonable model fit. Additional survey years will be key to improving this density estimate and future trends.

Table 5. Camera trap rates of large (>100 kg adult female mass) and small (<100 kg) ungulates in the four sampling zones in Luengue-Luiana and Mavinga National Parks, Angola, July to October 2016.

Species	Number of captures
Large ungulates	
Elephant	219
Kudu	176
Buffalo	148
Eland	104
Roan	97
Sable	65
Giraffe	41
Zebra	10
Wildebeest	8
Hippopotamus	5
Small ungulates	
Grey duiker	1006
Warthog	289
Steenbok	262
Bushpig	116
Common reedbuck	51
Oribi	49
Bushbuck	27
Impala	20
Sitatunga	15

THREATS TO LARGE CARNIVORES AND OTHER WILDLIFE SPECIES

Throughout the survey area, human settlements (n = 535) were particularly concentrated along the Luiana River system, and along the Cubango and Cuito Rivers in the west (Figure 20). In the north-west, human settlements were predominantly located between Longa and Cuito Cuanavale Rivers. There were also scattered settlements along the west bank of the Cuando River, with people living on islands within wide valley of marshlands. In total, 327 settlements were noted within Mavinga, and 208 within Luengue-Luiana National Park.

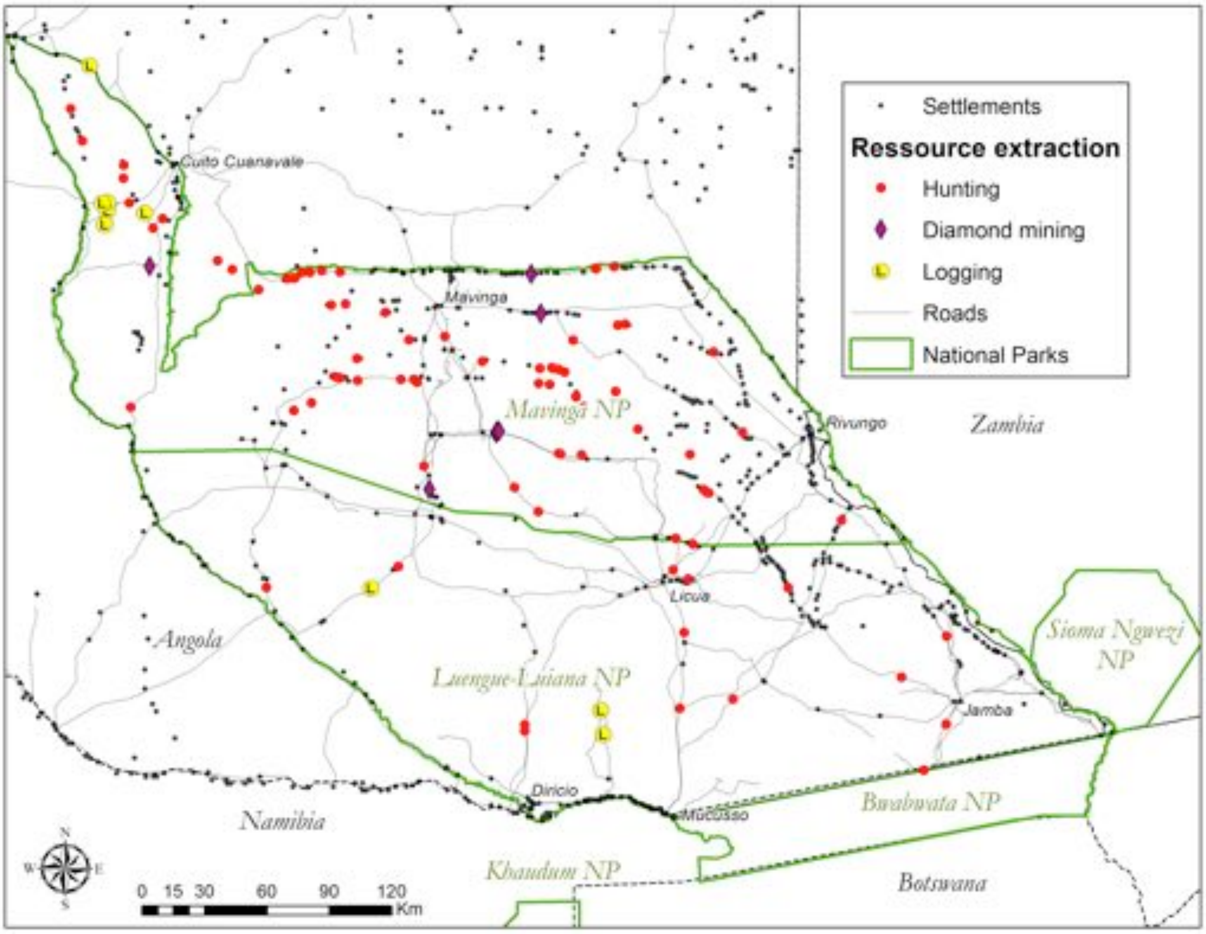

Figure 20. Map depicting the locations of all settlements and road/tracks within Luengue-Luiana and Mavinga National Parks, Angola, with all signs of bushmeat hunting (poaching), timber harvesting and diamond mining symbolised from July 2015 to October 2016.

Throughout both parks, roads vary from gravel surfaces to mere bush tracks connecting settlements either taking relatively direct routes through the surrounding woodland, or following rivers. More than 4,000 km of road or track was accounted for and traversed by our sampling teams (Figure 20). Most of the human population outside of the larger towns was concentrated in small settlements, with fewer than a hundred people per settlement. The towns such of Mavinga, Rivungo, Licua and Cuito Cuanavale are each relatively large and have experienced various levels of development. Most households practice subsistence agriculture, in a slash and burn practice. Some households also sell natural resources such as reeds and thatch grass.

Among the activities that would typically be regarded as illegal in most national parks, we recorded bushmeat hunting (n = 83), diamond mining (n = 7), fishing (n = 1), and one incidence of devil's claw harvesting (a consignment of several hundred kilograms). Furthermore, we recorded 10 localities where presumably permitted private logging companies were extracting *Baikiaea plurijuga*, *Burkea africana*, and *Pterocarpus angolensis* within the area. Bushmeat hunting was recorded in three contexts; 1) people seen hunting in the bush or evidence that they had been such a shell casings and gin traps (n = 20), 2) small bushmeat hunting/processing camps with meat drying racks (n = 46), and 3) evidence of bushmeat in villages or small settlements (17) (see all locations in Figure 20). In total, 82 specimens of 19 different mammals and one reptile species where observed as poached bushmeat (Table 6). Numerous records of various poached bird species were also made.

Table 6. List of species and numbers of each found opportunistically as poached bushmeat in Luengue-Luiana and Mavinga National Parks, Angola.

Species	**Number of carcasses found**
Grey duiker	19
Warthog	12
Roan	11
Unknown	7
Waterbuck	6
Sable	4
Kudu	3
Porcupine	3
Bushpig	2
Civet	2
Eland	2
African wild cat	2
Aardwolf	1
Caracal	1
Cheetah	1
Honey badger	1
Pangolin	1
Python	1
Reedbuck	1
Scrub hare	1
Vervet monkey	1
TOTAL	**82**

TOURISM POTENTIAL

According to our subjective assessments, there are large areas of Luengue-Luiana that presently have tourism potential either in the form of four-wheel drive routes with remote campsites (see Figure 21), or for more stationary activities, such as around the one lodge being built at Sasha on the Cuando River. There is also potential for campsites and small lodges along the Cubango and Cuito Rivers, with sport fishing on the Cuito River being a current tourism drawcard. Throughout Mavinga National Park, we noted many sites of tourism potential that were either scored as pleasant or outstanding (Figure 21). See Discussion for further interpretation of tourism potential within Luengue-Luiana and Mavinga National Parks.

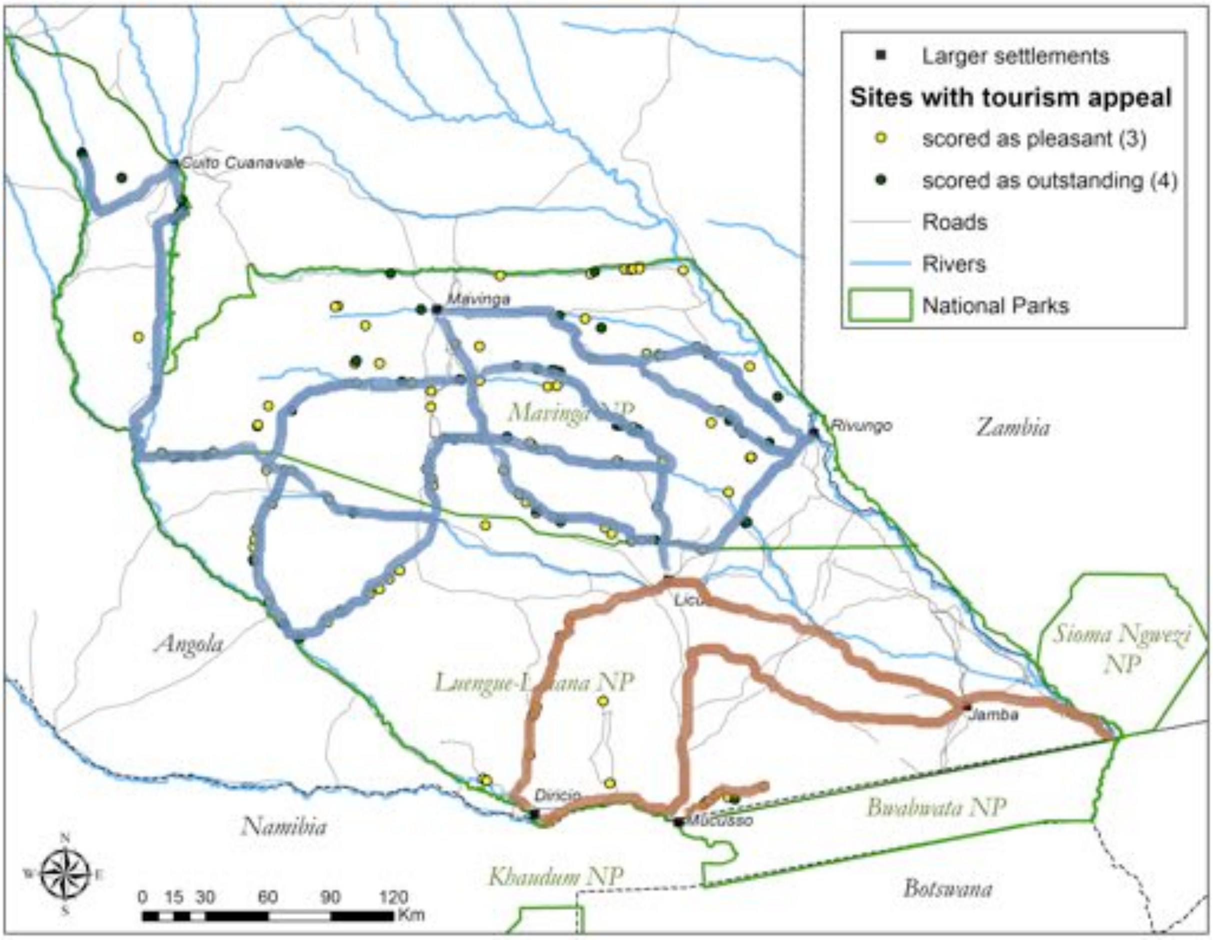

Figure 21. Potential tourism sites and routes within Luengue-Luiana (brown tracks) and Mavinga (blue-grey tracks) National Parks, Angola.

Discussion

SPOOR SURVEY

Although at 84,400 km^2, Luengue-Luiana and Mavinga constitute the largest contiguous national park complex in any one country in Africa, the spoor survey we conducted covered a substantial proportion of both parks (55 %). This method has been shown at many other sites to give a very good indication of large carnivore density, distribution patterns and the effect of underlying drivers on density (Funston et al., 2010). We are thus confident that the large carnivore population estimates presented in this report closely approximate the actually abundances, and that the distribution patterns accurately reflect those on the ground.

Lion abundance

While we expected many areas of both parks to be severely depleted due to the consequences of the three decades' civil war, and subsequent ongoing bushmeat extraction by people living in the parks, we did not expect that this would have had such a conspicuously devastating effect on lion abundance. Right across both parks, lions have been all but decimated with only a small pocket of lions living along the Cuando River south of the Luiana River and some lion activity in the Licua area. Although we cannot be absolute that lions occur nowhere else in the parks, we are confident that they do not occur in any reasonable numbers anywhere.

The most direct correlate with lion density in protected areas is typically the relative biomass of

medium to large ungulates (Ferreira & Funston, 2010). Lions typically show a preference for species in the weight class 190-550 kg; generally showing a preference for buffalo, giraffe, wildebeest, zebra and gemsbok (Hayward & Kerley, 2005). Species outside the preferred weight range are generally avoided and do not contribute much biomass to the diet of lions. Species within the preferred weight range, but that are not significantly preferred by lions, include roan and sable antelope, as well as eland. This is because these either defend themselves with their horns (roan and sable), occur at very low density, or, in the case of eland, occur in large herds that have increased vigilance.

Although we could not derive estimates of absolute prey abundance, the spoor survey resulted in relative measures (indices) of abundance. We found that typically rare (and non-preferred) species such as roan and sable where three to four times more abundant than were preferred species such as buffalo, giraffe and zebra; with gemsbok and wildebeest being almost non-existent. Thus although lions are clearly vulnerable to various forms of illegal hunting (Everatt et al., 2014), we argue that it is primarily the very low biomass of preferred prey species that is so severely limiting lions within both parks. The preferred prey species for lions that occurred in some abundance (buffalo and giraffe) had a strongly southern distribution, with only non-preferred species (roan, sable, eland) having wider distributions across both parks.

Spotted hyaena abundance

Contrasting strongly with lions, and other members of Africa's large predator guild, spotted hyaenas do not preferentially prey on any species (Hayward, 2006). Although spotted hyaenas have a similar but lower preferred prey weight of 56-182 kg, they do not preferentially prey on species favoured by lions such as zebra, and juvenile buffalo and giraffe. However, the dietary niche breadth of the spotted hyaena is similar to that of lions, and the two species have quite substantial actual and preferred prey species overlap (Hayward, 2006). Hayward (2006) argues that this results in spotted hyaenas displaying highly flexible and unselective prey choice, which is thought to be a reason for their success throughout their range.

Across both parks, spotted hyaenas were the most successful large carnivore, estimated to occur at an average density of about 0.92 individuals/100 km^2; equating to a population estimate of 776 ±345 individuals. In relative terms this suggests that spotted hyaenas occur at densities 25-76 times higher than that of lions (our course estimate notwithstanding), and must therefore be accessing a different prey source than lions. Research in the adjoining Bwabwata National Park, Namibia, indicates that in order of preference spotted hyaenas there predate on southern reedbuck, buffalo calves, impala, tsessebe and lechwe (Lise Hanssen, *unpublished data*) more than on larger ungulate species. We surmise the same occurs across both Luengue-Luiana and Mavinga National Parks, accounting for the much higher spotted hyaena densities. In terms of distribution, spotted hyaenas had a greater probability of occurrence throughout Luengue-Luiana (correlating to proximity of other protected areas) and only occurred in parts of Mavinga that were further away from human settlements (showing significant lack of presence close to human settlements). This was somewhat similar for lions that only occurred in areas far away from human settlements and in areas supporting preferred prey (buffalo and giraffe) along the Luengue, Luiana and Cuando Rivers.

Cheetah, leopard and wild dog abundance

Of the five larger carnivores, wild dogs and cheetahs exhibit the greatest dietary overlap and smallest dietary niche breadth, while lions and leopards have the broadest dietary niche breadth (Hayward & Kerley, 2008). Within the large carnivore guild, species with narrower niche width (cheetahs and wild dogs) experience greater extinction risk than species with wide dietary niche

(lions, leopards and spotted hyaenas). This is thought to be due to behavioural and morphological specializations of both cheetahs and wild dogs, which limit the prey available to them and increases the potential for dietary competition (Hayward & Kerley, 2008). The result is that in most ecosystems, species with wider dietary niche are typically more abundant than species with narrower dietary niche.

Across Luengue-Luiana and Mavinga National Parks, this pattern did not hold true. While spotted hyaenas were the most abundant species, as expected, wild dogs (599 $\pm$ 260) were estimated to be more numerous than lions and leopards (518 $\pm$ 180). Furthermore, lions occurred at even lower density than cheetahs (0.2 cheetahs/100 km^2; 151 $\pm$ 101 individuals). We surmise that this pattern was induced largely by the following circumstances: 1) the preferred prey of is greatly so diminished, 2) the highly preferred prey of leopards such as impala was relatively less common, 3) the slightly larger ungulates such as common reedbuck, tsessebe, lechwe, and juveniles of roan and sable on which wild dogs would most likely prey were more common than impala (creating dietary overlap with spotted hyaenas), and 4) that cheetah largely subsist on smaller preferred prey such as grey duiker and steenbok.

While four of the large carnivore species' distributions were strongly correlated with more southern latitudes and thus proximity to other protected areas, leopards were widely distributed throughout both parks. However, all five large carnivore species strongly avoided or were absent/diminished in areas around human settlements. Combined, these factors resulted in the large carnivore guild having a higher probability of occupancy in the southern half of Luengue-Luiana National Park than the northern half of the park, and even less presence in Mavinga National Park. Although this strong affiliation with southern latitudes may seem to indicated a proximity preference to other protected areas, we argue that proximity to other parks may be somewhat analogous to proximity to human settlements with the lowest number of human settlements occurring in the southern half of Luengue-Luiana National Park, and the highest number of human settlements in Mavinga National Park.

This pattern was largely replicated amongst the six ungulate species we modelled. Only roan and sable displayed patterns of occupancy that somewhat included Mavinga National Park. While it is likely that habitats throughout both parks perhaps suit roan and sable antelope more so than the other species, the analyses indicated that proximity to the protected interior and proximity to human settlements were the most important determinants of both ungulate distribution and relative abundance. Roan and sable are both ecologically sensitive species tending to avoid areas frequented by high density competing ungulates such as buffalo, wildebeest and zebra (Owen-Smith & Mills, 2008), which might explain their wider occupancy distribution across both parks. Both species tended to avoid human settlements, but with their shy and elusive behaviour it is possible that roan and sable are better able to avoid human detection and hunting pressure. Thus we surmise that the low numbers of typically more abundant ungulates (such as buffalo, giraffe, wildebeest and zebra), which are all preferred lion prey, are the result of excessive and sustained human hunting pressures. This extraction of bushmeat for both personal use and commercial purposes is clearly the biggest threat facing both parks, and is clearly particularly intense in Mavinga. The observed pattern is also similar to what is often documented in parks depleted by bushmeat poaching in West and Central Africa, where water-dependent large ungulates such as buffalo, waterbuck and western kob (ecological equivalent to impala) are rapidly reduced by poachers targeting dry season water reservoirs. In contrast, the less water-dependent species, such as roan and hartebeest, which are less predictable for hunters in their movements, soon outnumber the more water-dependent species, which would generally be more abundant in such mesic systems under natural conditions. This underlines that particularly dry

season water reservoirs such as marshes, wetlands and major river courses need to benefit from stricter protection, due to their utmost importance for the water-dependent species, which are very vulnerable to poachers at such spots.

CAMERA TRAP SURVEY

Although we only conducted the camera trap survey across roughly one 3rd of the two parks, the results largely re-affirmed the relative ratios on large carnivores and large herbivores recorded during the spoor survey. Amongst the large carnivores the only anomaly was that of lions and cheetahs, with lions having a proportionally higher camera capture rate than cheetah, while for cheetahs we obtained more spoor records. However, in the spoor survey tracker skill resulted in the same individual being recorded no more than once on the same transect, whereas in the camera trap survey the same individual might walk past multiple cameras during the sampling period. Thus, for example, if lions where particularly active in the area around several cameras this would inflate the capture rate estimate and we suggest that this was indeed what happened, and that cheetah are in fact the more abundant of the two species in this landscape.

When inspecting each lion photographed on camera trap, we only felt sure of the unique identify of seven individuals. These included two adult males along the Luengue River near Licua, three subadult males between Boafe and Sasha along the Cuando River, and one large adult male along the Namibia/Angola border about ten kilometres west of the Cuando River. An additional three subadult males were known to utilize the Cuando River margins from the Kwando Core Area to the Luiana River as they were radio-collared. These lions were not caught on camera trap, but had previously dispersed into the area from the Kwando Core Area, Bwabwata National Park, Namibia.

Thus, a minimum estimate of 10 known lions was the lowest possible estimate. No doubt there are some other lions in other parts of both parks, but we found no confirmed proof of this. We thus conclude that possibly between only 10-30 lions might occur in both parks, with some anecdotal reports of lion tracks along the upper reaches of the Cuito River (Steve Boyes, *pers. comm.*). These results contrast starkly with the unsubstantiated estimate of 1905 lions for that region of south-east Angola cited by Riggio et al. (2013). Although we have nothing to compare the 2015/16 survey against, there must have been a relatively high lion population in this part of Angola at one point in time to leave estimates of >1000 lions lingering in the minds of experts from the area. It also begs the question as to why there are so few lions. We argue that it is primarily because suitable lion prey is so scarce, and that lions and their prey were persecuted intense in earlier times.

The camera trap survey was conducted in four sampling units that we had identified as having the best potential for wildlife in Luengue-Luiana National Park, and in a small area of Mavinga National Park north of Licua. It was therefore not surprising that the density estimates for leopards here (1.5 leopards/100 km^2) were higher than those from the spoor survey conducted over both entire parks, which included heavily depleted areas. Specifically, the camera trap survey was conducted in areas of low human habitation and several important rivers. The capture rates of other large carnivores were also high here.

The camera trap survey indicated the presence of at least 20 species of small (<20 kg) mammalian carnivores with the two parks, although further species of mongoose (yellow and white-tailed) may yet be recorded (see Appendix 1). Cape clawless and spotted necked otters are known to occur in both the Cubango and Cuando Rivers, and possibly in other smaller rivers

within both parks, resulting in at least 22 small and 5 large carnivore species in the two parks. Brown hyaenas may yet be found within Luengue-Luiana National Park, having recently been recorded on camera trap in the relatively nearby Mahango Core Area, Bwabwata National Park, Namibia (Lise Hanssen, *unpublished data*).

The well-represented small ungulate community indicates relative healthy numbers of common duiker, steenbok, warthog and bushpig, which no doubt explains the relative abundance of particularly cheetah, leopard and African wild dogs, which would prey mostly on these and the other small ungulate species, and at times the calves of larger ungulate species.

THREATS TO LARGE CARNIVORES AND OTHER WILDLIFE SPECIES

Clearly, long-term hunting and bushmeat poaching have severely impacted populations of larger herbivores and lions in both Luengue-Luiana and Mavinga National Parks. There is a culture of hunting meat that was found to be pervasive, widespread and largely accepted (not regarded as illegal by most people). In one incident we noted the carcass of a poached common duiker in a police vehicle from Mavinga, and no attempt was made to conceal it. Also, during our camera trap survey work along the Luangundo River, a vehicle from Rivungo was observed with the carcasses of many roan antelope, waterbuck and duiker on it. However, there was some suggestion that people there knew their activities where illegal, as 30 camera traps deployed in that sampling unit were stolen.

Looking at the pattern of species recorded in incidents of bushmeat poaching, these closely reflected the patterns of relative abundance detected in both the spoor and camera trap survey. The most common ungulates poached were either common smaller species (common duiker and warthog) or the locally relatively more abundant, but typically rarer species (roan, sable and waterbuck). Of the typically common species in savanna woodlands only a few kudu and eland carcasses where found poached, with no buffalo, giraffe, wildebeest or zebra in the sample. This is further indication that these typically common African ungulates are relatively rare in most areas of both parks, and currently do not support a meaningful lion population.

As with the camera trap survey results, there was a wide diversity of smaller mammal carnivore, omnivore and herbivore species in the sample of poached specimens, with small carnivores such as honey badger, aardwolf, and civet being noted. Two very concerning specimens include one cheetah and one pangolin skin. This was the only record of pangolin in the survey.

Although the logging of hardwoods was ostensibly under permit, we did not enquire further about quotas or level of extraction. But we did observe this to be intense as it seemed clear that in areas close to available trucking routes the extraction of all trees above about 20 cm in diameter was going on without abate. In neighbouring Namibia and Zambia, the governments have respectively either banned or are attempting to limit the extraction of hardwoods from protected areas or state land, but we got the impression that in parts of Cuando Cubango there may not have been much control being exerted. We recommend further investigation into the felling of hardwood trees, especially in south-central Luengue-Luiana National Park and in the area surrounding Cuito Cuanavale.

Recommended interventions to recover lions and other mammal populations

The area covered by Luengue-Luiana and Mavinga National Parks is truly vast (84,400 km^2) and comprises several relatively large settlements (e.g. Licua, Jamba, Mavinga, Mucusso, etc.), as well as an additional ≈ 530 smaller settlements. These settlements are strongly associated with the various river and drainage systems of north-eastern Mavinga National Park, with particularly heavy settlement along the Cuando, Luiana and Cubia Rivers. There is also very heavy settlement in the south-west along the Cubango River in Luengue-Luiana and some settlement in the north-west along the Cuito River in Mavinga National Park.

These communities are generally highly impoverished and strongly rely on subsistence activities like fishing and agriculture in alluvial and river fringe areas, which have clay deposits in the soils. A large part of their protein and earnings also comes from hunting wildlife within the protected area. There are thus many socio-economic difficulties facing this area, and it is going to be a challenge to balance wildlife protection and tourism development with that of human socio-economic improvement.

The data we gathered indicates that the entire area of Luengue-Luiana National Park is important for all large carnivore species, is an important dispersal range for African elephant, and is important for all the large ungulates we monitored, especially buffalo and giraffe. Although Mavinga National Park is heavily settled by people, we feel its potential should not be lost, and mechanisms to develop a wildlife based economy using similar principles as the conservancy system in Namibia could be applied (see below).

LUENGUE-LUIANA NATIONAL PARK

Within Luengue-Luiana National Park, we propose that some prioritisation of the conservation effort is developed with specific zones requiring different approaches. In line with recommendations on the management plan for Luengue-Luiana (2016), we support and propose the following:

1) Define high priority conservation buffers along the main rivers

This priority objective emphasises the importance of riverine habitats both for biodiversity conservation, as key winter access to water and other key resources for several large wildlife species, especially elephant and buffalo, and tourism development (see Figure 22).

We recommend that corridors of no human development are defined along each of these rivers and, where necessary, smaller settlements of people should be encouraged through financial incentives to vacate defined corridors. Ideally, we propose keeping between 70-80% of each river open for access by wildlife (as corridors), with a 1-kilometre buffer defined around each settlement defined as "human settlement". Besides such river corridors, there are also clusters of pans and small ponds which retain water well into the dry season, and which should also be kept free of human habitations and use. We already mapped several such areas during our surveys; however, a more comprehensive inventory of pans and other dry season water-points is required.

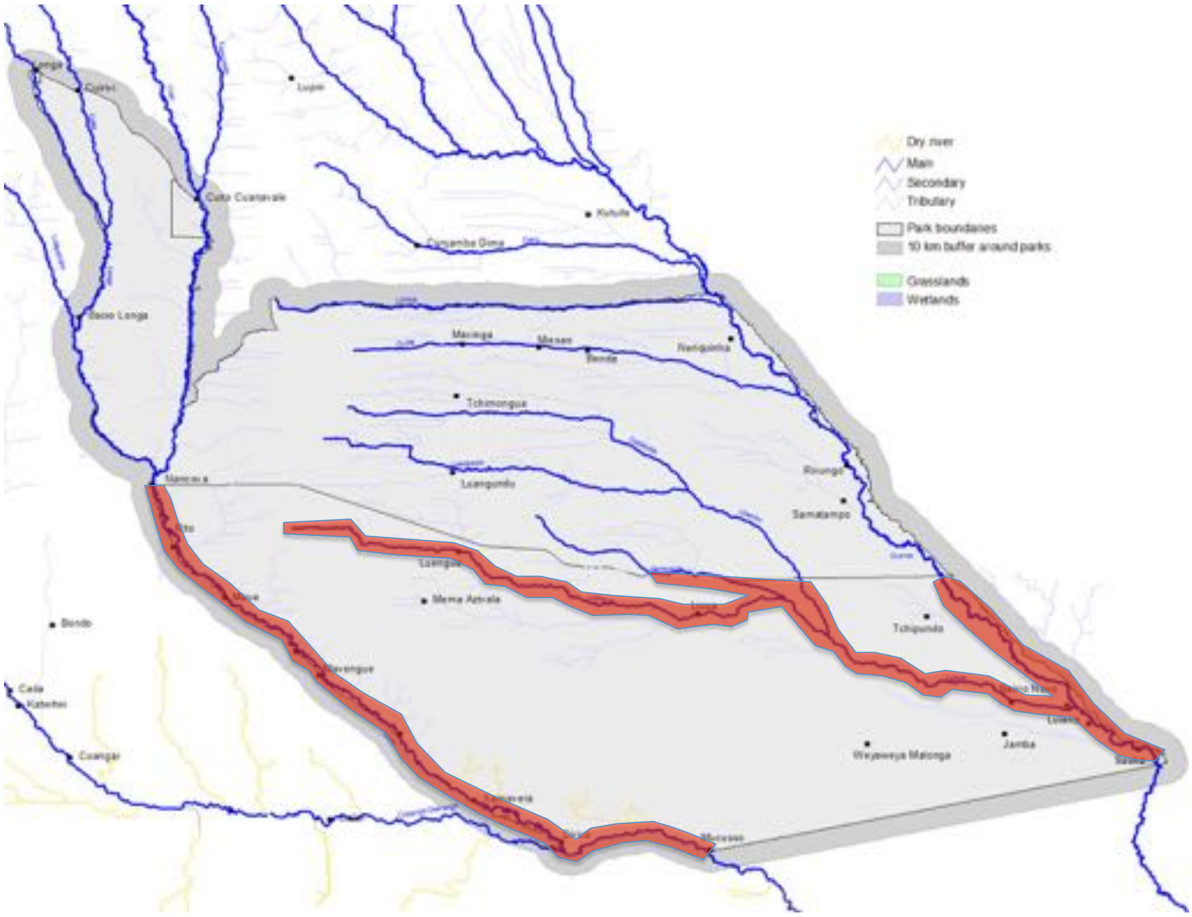

Figure 22. High priority conservation and tourism development zones in Luengue-Luiana National Park, Angola (adapted from the Luengue-Luiana National Park Management Plan, 2016).

These high priority zones offer the best potential for the development of tourism infrastructure in the form of lodges, with an established road network being used to link each. In certain high interest zones around each lodge, we propose the development of more comprehensive four-wheel-drive tracks to be used both for tourism and the deployment of law enforcement patrols.

2) Securing important habitat zones within Luengue-Luiana National Park

The entire area covered by Luengue-Luiana National Park away from the high priority river zones defined above is important (see Figures 23 and 27). Although we strongly advocate improved law enforcement and revised human settlement patterns throughout the park, we advise that an area corresponding to both the Luengue-Luiana National Park Management Plan (Figure 23) and the area defined by the KAZA Wildlife Dispersal Area stakeholder workshops (Figure 24) are prioritised for intensive wildlife protection, reduction of human settlements, mobile 4x4 tourism safari's and one tourist lodge. We propose to concentrate on site security in a way that will integrate conventional law enforcement with community game guards acting as agents of change to realize a community owned and operated wildlife tourism product that delivers benefits to the community as active conservation and business partners, and that will secure the recovery of wildlife populations.

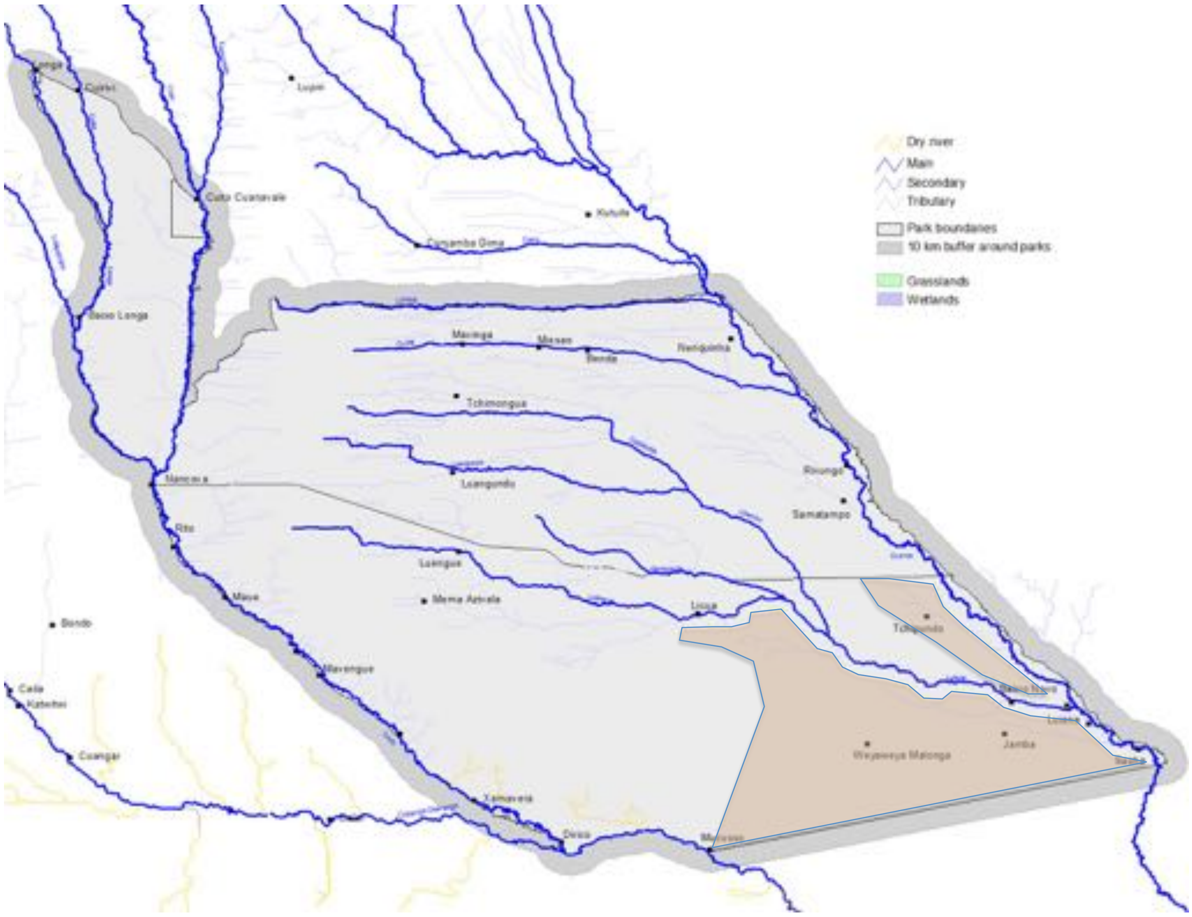

Figure 23. Important habitat and wildlife protection zone in Luengue-Luiana National Park, Angola (adapted from the Luengue-Luiana National Park Management Plan, 2016).

Within the IPZ we propose:

- Establishing an anti-poaching unit that is fully functionally equipped and trained to deal with tackling the organised crime syndicates poaching elephants.
- Encouraging and supporting cross border patrols and intelligence sharing.
- Integrating the efforts of community game guards and statutory wildlife police offices (WPO's) in designated areas to increase site security through both patrol effort and community compliance whereby community game guards act as active and empowered agents of change with communities.
- Strongly encouraging the completion and improvement of tourism infrastructure at Sasha and establish at least one small lodge possibly near Boafe.
- Linking the 4x4 tourism route in the important habitat zone (see below) with the IPZ habitat zone.
- Support the community run road maintenance team to maintain existing roads and establish additional patrol and game drive tracks.

It is worth noting that our probability of occurrence map for elephants (see Figure 12) strongly corresponds with the area use of six radio-collared elephants monitored by the NGO Elephants Without Borders from 2015 to 2017 (Figure 25).

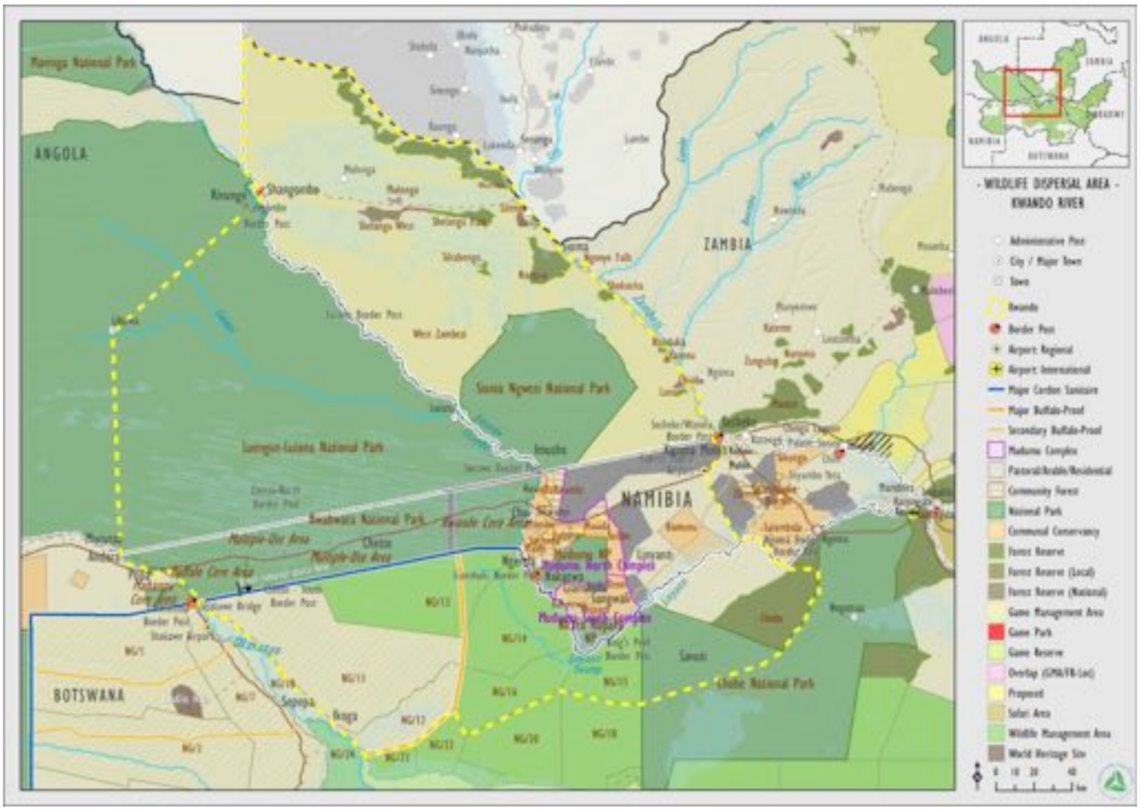

Figure 24. Boundary of the Kwando Wildlife Dispersal Area (adapted from reports by the Peace Parks Foundation, 2016).

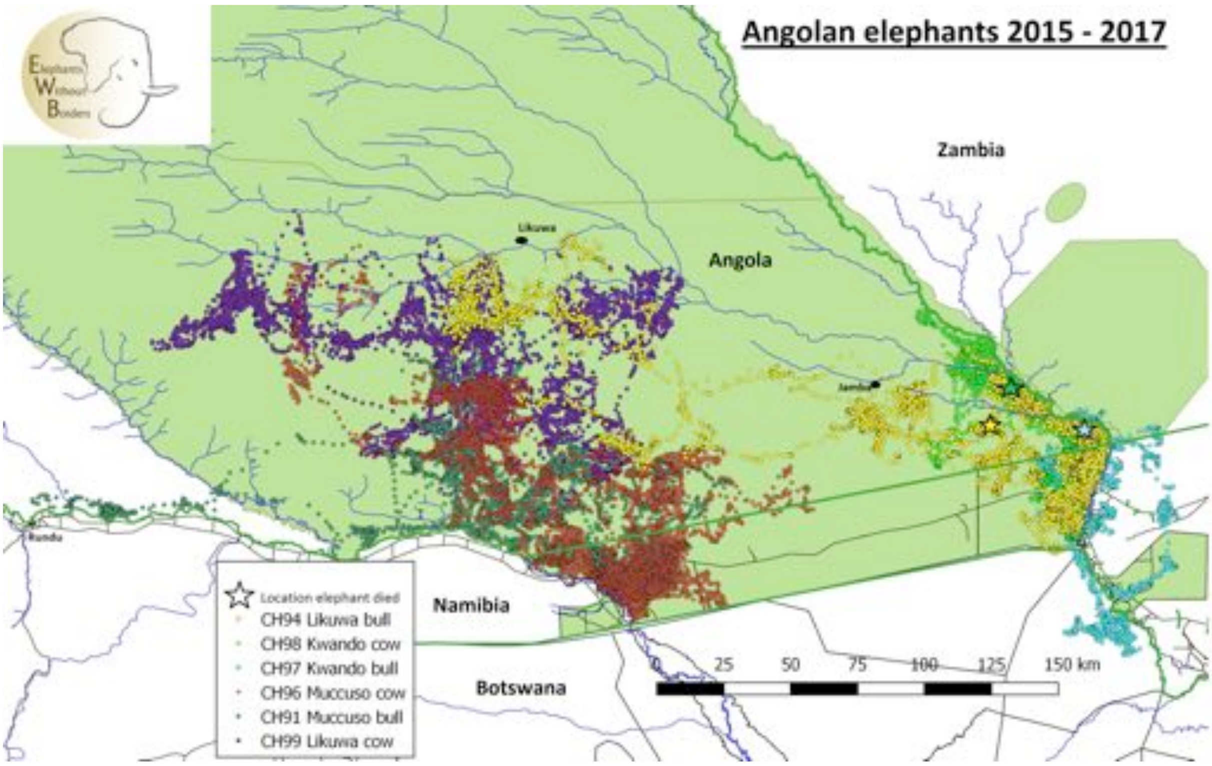

Figure 25. Area use by six radio-collared elephants monitored from 2015 to 2017 by Dr Mike Chase, Elephants Without Borders, Luengue-Luiana National Park, Angola.

Thus, not only is the central and eastern half of Luengue-Luiana National Park the most important area for four of the five large carnivore species, it is also the most important part of both parks for elephants (and buffalo/giraffe, see Figures 10 and 13). Key winter range for elephants includes the Luengue and Luiana Rivers in the interior of the park, and the Cuando, Cuito and Kavango on the edge of the park (Chase & Schlossberg, 2016). An aerial survey conducted in 2015 estimated that the overall elephant population for Luengue-Luiana was about 3409 ±801 elephants.

Comparing this to an area of the former Luiana Partial Reserve previously sampled in 2005, the elephant population there was estimated to have decreased by 31%, from 1827 to 1441 by 2015; a population decrease of 2.3% per year (Chase & Schlossberg, 2016). However, the fresh carcass ratio of 7% suggested a far steeper rate of decline due to elephant poaching, especially along the Cuando River (see Figure 26). However, in the Licua (along the Luengue River) area, Chase and Schlossberg (2016) estimated a population of over 500 elephants and a carcass ratio of just 4.3%, which is consistent with a growing population. Furthermore, the area around the Cuito and Kavango Rivers had an estimated 969 elephants, with a similarly low carcass ratio. These areas may thus have experienced less elephant mortality than areas further to the east, and further prioritizes the area along the Cuando River as the key important habitat zone most in need of increased law enforcement support.

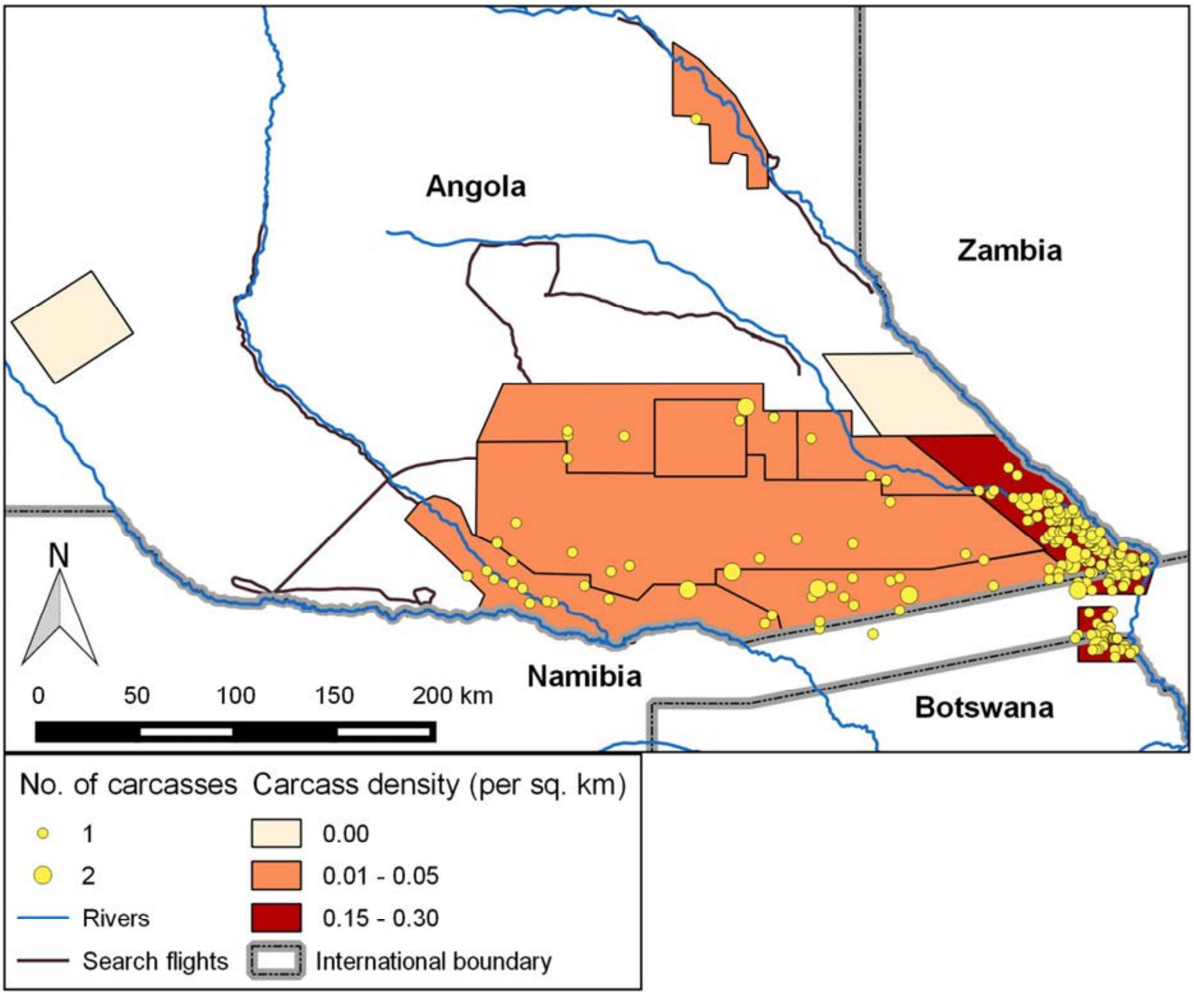

Figure 26. The distribution of all elephant carcasses in areas of Luengue-Luiana National Park, Angola, and adjacent Namibia and Botswana documented during a 2015 dry-season aerial survey (adapted from Chase and Schlossberg 2016).

To address the poaching of ungulates, especially larger ungulates that are preferred lion prey (notably buffalo, giraffe, zebra and wildebeest), and the rampant elephant poaching within the important habitat zone of Luengue-Luiana National Park (also known as the Kwando WDA in Angola), a number of intensive protection zones (IPZ's) could be defined. Within each, an anti-poaching unit (APU) would be established and functionally equipped. Broadly speaking, an APU would cover an area of between 2,000 and 10,000 km^2, in which an anti-poaching command centre/patrol base camp is established and in which at least three teams of game scouts are deployed. Each APU would be self-sufficient in terms of transportation, equipment, manpower, communication and deployment strategies, and would employ the SMART law enforcement monitoring tool.

An example of the steps to establish a functional APU within the Luiana IPZ might include:

1. Construct and develop a base of operations either at Boafé or Sasha
2. Installation of satellite internet or mobile phone capacity at the base of operations
3. Supply of one Toyota Land Cruiser pick-up/s to deploy scouts
4. Equipment, supplies and accommodation for three teams each of eight game guards
5. Construct and equip three game guard patrol camps across the IPZ

The KAZA Carnivore Conservation Coalition defined the establishment of a number of APUs, tourism development and socio-economic development as key initiatives to be funded within the Angolan component of the Kwando WDA. Law enforcement support would follow a strategic, information-led approach pioneered by Panthera and other partners at many other protected areas. The vision for protected area law enforcement would be not about catching poachers *per se*, but achieving defined and measurable objectives, such as rates of wildlife population increase.

This initiative would not be aimed at replacing park management but adding support and financial resources to the existing structure. This recognises that park management is the responsibility of the National Institute for Biodiversity and Conservation Areas (INBAC). The Luengue-Luiana National Park Management Plan (2016) indicates a current staff contingent of 81 rangers, which was expected to increase to 117. The Plan does recommend that the Angolan government considers obtaining some technical support from a professional organisation to help establish a robust management system for both parks. Notably this support would focus on:

- From key villages in the area, especially those identified as hotspots of bushmeat hunting, identify and employ community game guards who will be trained to patrol and remove snares/gin traps, record information and act as agents of change within their respective communities.
- Deploy, empower and capacitate the community game guards to gather intelligence on any syndicate based wildlife crime in the area.
- Incentivize the voluntary submission of guns, gin traps and other paraphernalia used to hunt wildlife.
- Support the community to develop a 4x4 tourism route with community owned and run campsites and wildlife and cultural ambassadors as guides for income generation (there are sufficient wildlife, historic and cultural resources in this area to achieve this in the immediate future).
- Support the community to establish a community run road maintenance and establishment team.
- Establishing a certified indigenous products industry (e.g. devil's claw)

3) Less important habitat zone

Although not unimportant, the western half of Luengue-Luiana National Park was classified in the management plan as being less important habitat (Figure 27). This decision, however, was not strongly supported by our assessment of current occupancy patterns of 11 assessed species. This area was of significant importance for leopard, spotted hyaena, African wild dog, elephant, roan and sable. It was not, however, as intensely occupied by lion, cheetah, buffalo and giraffe. We regard this area as being of vital importance especially for elephant, and can envisage buffalo populations increasing here, which could in turn lead to a recovery of lions.

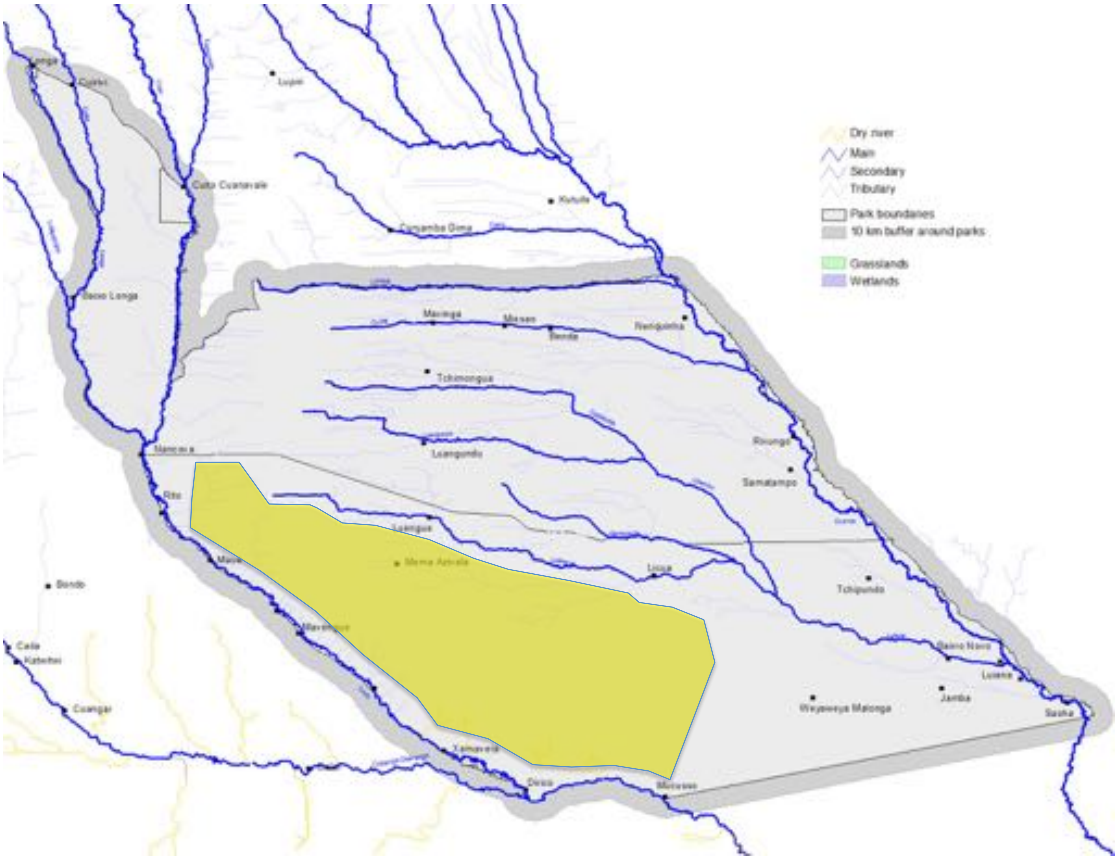

Figure 27. The western half of the Luengue-Luiana National Park was classified in the management plan (2016) as being less important habitat for conservation efforts (adapted from the Luengue-Luiana National Park Management Plan, 2016).

This area has the scenically attractive confluence of the Cuito and Cubango Rivers within it; an area which has been earmarked for tourism development and is extensively utilised by elephants in the dry season (see Figure 25). Clearly, improved anti-poaching support is needed throughout the area, and this is also perhaps the area within Luengue-Luiana National Park that might be best suited to the establishment of community conservancies.

The development of community conservancies could ensure direct benefit sharing with communities settled along the Kavango and Cuito Rivers, and controlled access to resources, such as devil's claw. Only one consignment of devil's claw was located during the survey, but it was very large and points to the possibly of regulated usage by communities if they were allowed to develop conservancies at Bwabwata, Mucusso and along the Cubango and Cuito Rivers.

Another area suitable for the development of a conservancy would be Licua, with the conservancy stretching north of the town to the Luangundo River (discussed below).

MAVINGA NATIONAL PARK

Large carnivore and other wildlife populations are generally very depleted throughout Mavinga National Park, and it is so heavily settled with human communities, such that at this stage there are limited conservation recommendations that we can make. However, we do see the potential for the model of conservation and human development that has been so successful in Namibia, and that we recommend for the western part of Luengue-Luiana National Park; the implementation of communal conservancies. Although Mavinga National Park is relatively more heavily settled than Luengue-Luiana, there nevertheless exists the opportunity to divide the space into ten or more conservancies. Within each, a conservancy committee would need to be established and the conservancy given the guidance and support to decide for itself what of a range of wildlife and resource use opportunities it wanted to develop. These could include, for example:

- Photographic tourism development
- Regulated use of wild plants
- Highly regulated use of timber
- Trophy hunting is currently illegal in Angola and wildlife populations are generally below sustainable offtake thresholds

It is worth noting that throughout Mavinga National Park we classified many areas as being either pleasant or outstanding in terms of scenic beauty, as one form of tourism potential index (see Figure 21). Admittedly, tourists would be hard pressed to see much wildlife in these areas at present, other than the odd roan or sable antelope, or smaller ungulate. However, there is one area in Mavinga that was extensively used by elephants, four of the five larger carnivores, and most of the larger ungulates (see Figures 15 and 16). This is the area north of Licua along the Canga and Luangundo Rivers. We classified this as an area of high tourism potential, but it was also the area in which the most conspicuous amounts of bushmeat poaching where recorded during the camera trap survey (and where 30 camera traps were stolen).

We suggest that this area is declared as the Licua Conservancy, and that resources are invested in empowering communities here to establish wildlife protection and wildlife and natural resource use models that are appropriate for the area and that are permitted in Angola. This could become the first trial conservancy in an Angolan national park, and set the scene for future conservancies in other parts of both parks. As mentioned above, we also recommend such a development around Mucusso in Luengue-Luiana. Both would be connected by a good quality 80 km gravel road, allowing easy access to NGO’s from Namibia, who could partner with the existing institution ACARDIR to foster these two conservancies. Discussions with the key NGO in Namibia, IRDNC, indicate a strong willingness to participate in such a development, but this can only occur if the Angolan government creates the necessary enabling environment.

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Appendix 1

Mammals >±1kg occurring in Luengue-Luiana and Mavinga National Parks, Angola

Common name	*Scientific name*	Observed			
		Camera trap	Opportunis-tically	Bushmeat	Reported by others
African lion	*Panthera leo*	X			
Leopard	*Panthera pardus*	X			
Cheetah	*Acinonyx jubatus*	X		X	
Caracal	*Caracal caracal*	X			
Serval	*Leptailurus serval*	X			
African wild cat	*Felis lybica*	X		X	
Spotted hyaena	*Crocuta crocuta*	X	X		
Aardwolf	*Proteles cristata*	X		X	
African civet	*Civettictis civetta*	X		X	
Small-spotted genet	*Genetta genetta*	X		X	
Large-spotted genet	*Genetta tigrina*	X		X	
Cape clawless otter	*Aonyx capensis*				X
Spotted-necked otter	*Lutra maculicollis*				X
Honey badger	*Mellivora capensis*	X	X	X	
Striped polecat	*Ictonyx striatus*	X			
Banded mongoose	*Mungos mungo*	X	X		
Dwarf mongoose	*Helogale parvula*	X	X		
Large grey mongoose	*Herpestes ichneumon*	X	X		
Slender mongoose	*Herpestes sanguinea*	X	X		
Selous's mongoose	*Paracynictis selousi*	X			X
Water mongoose	*Atilax paludinosus*				X
African wild dog	*Lycaon pictus*	X	X		
Black-backed jackal	*Canis mesomelas*	X			
Side-striped jackal	*Canis adustus*	X	X		
Bat-eared fox	*Otocyon megalotis*	X	X		
African elephant	*Loxodonta africana*	X	X	X	
Hippopotamus	*Hippopotamus amphibious*	X	X		
Giraffe	*Giraffa camelopardalis*	X	X		
African buffalo	*Syncerus caffer*	X	X		
Common warthog	*Phacochoerus africanus*	X	X	X	
Bushpig	*Potamochoerus larvatus*	X		X	
Eland	*Taurotragus oryx*	X	X	X	
Greater kudu	*Tragelaphus strepsiceros*	X	X	X	
Sitatunga	*Tragelaphus spekei*	X			
Bushbuck	*Tragelaphus scriptus*	X			
Roan antelope	*Hippotragus equinus*	X	X	X	
Sable antelope	*Hippotragus niger*	X	X	X	
Tsessebe	*Damaliscus lunatus*	X			
Lechwe	*Kobus leche*	X	X		
Common reedbuck	*Redunca arundinum*	X	X	X	
Steenbok	*Raphicerus campestris*	X	X	X	
Common duiker	*Sylvicapra grimmia*	X	X	X	
Aardvark	*Orycteropus afer*	X			
Ground pangolin	*Manis temminckii*			X	

Chacma baboon	*Papio cynocephalus ursinus*	X	X		
Vervet monkey	*Cercopithecus aethiops*	X	X	X	
Southern lesser galago	*Galago moholi*	X			
Scrub hare	*Lepus saxatilis*	X	X	X	
Tree squirrel	*Paraxerus cepapi*	X	X	X	
Spring hare	*Pedetes capensis*	X			
Porcupine	*Hystrix africaeaustralis*	X		X	
Greater cane rat	*Thryonomys swinderianus*	X			

*other mongoose that probably occur include yellow mongoose and white-tailed mongoose

Plate 3. Angolan carnivore biologist Dr Ezequiel Fabiano setting up a Panthera V6 camera trap with Carolyn Whitesell and Ivania Castro.

Biologisto Angolano Dr Ezequiel Fabiano, Carolyn Whitesell e Ivania Castro montado uma armadilha fotográfica (Panthera V6).

Plate 4. INBAC game scout retrieving a gin trap with Angolan trackers from the Mucusso community.

Fiscal do INBAC e rasteadores do comunidade de Mucusso removando uma armadilha d caca.

Plate 5. Geraldo Mayira from ACARDIR, Mucusso, Angola checking lion tracks with Carolyn Whitesell south-west of Licua.

Geraldo Mayira, do ACARDIR, Mucusso, Angola, e Carolyn Whitesell confirmando pegadas de leões da parte sudoeste de Licua.

Plate 6. Geraldo Mayira from ACARDIR, Mucusso, Angola setting up a Panthera V6 camera trap.

Geraldo Mayira, do ACARDIR, Mucusso, Angola, montado uma armadilha fotográfica (Panthera V6)

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African lion
Leopard
Cheetah
Spotted hyena
African wild dog
African wild cat
Caracal
Serval
Side striped jackal
Black backed jackal
Bat eared fox
Aardwolf
Honey badger
Striped polecat
Aardvark
African civet
Small spotted genet
Large spotted genet
Slender mongoose
Large grey mongoose
African elephant
Hippopotamus
Giraffe
Cape buffalo
Roan antelope
Sable antelope
Eland
Greater kudu
Burchell's zebra
Blue wildebeest
Sitatunga
Southern reedbuck
Impala
Grey duiker
Bushpig
Warthog
Porcupine
Chacma baboon
Vervet monkey
Springhare
Scrub hare
Bushbaby