Improving the tourist experience in Queen Elizabeth Protected Area: addressing the invasive species and re-assessment of the tourism tracks with specific reference to lions

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Abstract

This report summarizes the analysis conducted to re-assess the current tourism circuits with specific reference to lions in the Queen Elizabeth Protected Area (QEPA) to guide park management on how to improve the tourism experience amidst the changes in the park ecosystem. The study examined the abundance and distribution of large mammals species (e.g. Uganda kob, Elephant, Buffalo, Topi, Warthog, Waterbuck, Giant forest hog, Hippopotamus) based on the aerial surveys conducted in 2010, 2014 and 2018, and the lion occurrence and ranging patterns observed during the monitoring of satellite-collared individuals as a proxy for tourism potential. We also considered factors that have diminished the tourism experience and satisfaction inside the park such as road density, the abundance and distribution of three main invasive plant species (*Dichrostachys cinerea*, *Imperata cylindrica*, and *Lantana camara*) that are known to have the highest impact on ecosystem functioning and ranging patterns of prey and predators among others in QEPA. We examined the management strategies and actions, including the reconfiguration of the current tourism circuits to create new ones.

The highest tourism potential in the northern sector of QENP was noted to occur in the areas located between Hamukugu, Kasenyi, Katunguru and Kikorongo villages comprised mainly of grassland and wooded grassland habitats followed by the southern bank of Kazinga channel stretching from Mweya to Kyambura Wildlife Reserve dominated by bush/scrub and woodland habitats. In the southern (Ishasha) sector, a part of QENP characterized by grasslands and bush/scrub habitats. The lowest tourism potential areas were observed to occur in the habitats located East of Muhokya and Kasese town which are dominated by swamps and woodlands followed by the areas located between Kikorongo, Katunguru, Kabatoro and Katwe, known to have woodland and grassland habitats, and areas east of Kasenyi which are dominated by woodland and grassland habitats.

Plant surveys conducted during 2009 and 2017, showed that there has been an increase in the extent of occurrence of invasive species namely *Dichrostachys cinerea*, *Imperata cylindrica* and *Lantana camara*. Most of the increase in the abundance of *D. cinerea*, *I. cylindrica* and *L. camara* overlaps with areas where low species richness and abundance of large mammals was observed. The areas with low tourism potential and invasive species are therefore negatively affecting tourism experiences.

Using Species Distribution Modeling, the highest relative suitable habitat for *Dichrostytchis cinrea* was predicted to occur in the northern sectors of the park, mainly along Kazinga channel, the habitats between Mweya, Kabatoro, Katunguru, most of Kyambura wildlife Reserve and the area between Kikorongo and Muhokya. The predictor variables with the highest importance in model contribution were pH, nitrogen, minimum temperature of coldest month and precipitation of Coldest Quarter. The results for community composition from the Mantel tests showed that there is no relationship between *Dichrostytchis cinrea* and the species richness of plants in the study area. However, the distribution of *Dichrostytchis cinrea* affects the abundance of herb cover in the plots surveyed.

Lion ranging patterns were estimated using the Kernel Utilization Distribution method by computing the 50% and 95% contours. The 95% contours represent the boundaries of the range within which there is a 0.95 probability of finding the collared lion while the 50% contours (core area) represent areas used more frequently compared to other areas in the home range. The 50% core home ranges were estimated to vary between 8.7km^2 and 109km^2 (average: 49.6 km2) in the northern sector, 10.8km^2 to 166.2 km^2 (average: 76.6 km^2) in the Ishasha sector, and the 95% contours varied between 77 – 699 km^2 (average: 302km^2) in the northern sector and between 46 – 838km^2 (average: 351km^2) in Ishasha sector for the 2018-2019 movement patterns. The largest 95% contour (838km^2) ranges into Virunga National Park in the Democratic Republic of Congo. Mudumba et al., 2015, estimated the ranging patterns (2006 to 2011) of the two prides (7 collared individuals) in the Ishasha sector to vary between 7.2 – 20 km^2 for the 50% core home range with an average of 1.9km^2 and 32 – 61 km^2 for the 95% home range with an average of 43.1km^2. Comparing the home ranges (50%, 95%) using a T-test showed that there was no significant difference in the ranging patterns between the 2006-2011 and 2018-2019 ranging patterns for lions in the Ishasha sector.

Prey abundance and movement is among the major divers of the home range size. The recent aerial surveys (Lamprey, 2018) conducted in QEPA indicate that the population of the Uganda kob which was identified as the most preferred prey for lions in the Ishasha sector (Mudumba et al., 2015), has increased from 12,987 individuals in 2014 to 21,217 individuals in 2018. The 50% ranging patterns of all the collared lions overlap with areas high in Uganda kob density and corresponds to the previous prides identified during the 1997/998 and 2008/2009 lion census in the study area (Dricuru, 1999; Omoya et al., 2013). This shows that the lion home ranges have remained consistent over the 13-year period.

It is evident that there has been an increase in the distribution and abundance of invasive species in study area which has led to a reduction in the amount of suitable habitat that could be available for the grazers in the park and has subsequently negatively affected tourism experiences. *Dichrostachys cinerea* increased by 74%, *imperata cylindrica* increased by 64%, and *Lantana camara* increased by 119% over the eight-year period. Therefore, conservation actions in the park should be prioritized to target the control of the invasive species from further increasing the extent of occurrence. Control will both provide additional habitat for grazers, improve tourism experience and potentially minimize human wildlife conflicts.

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Introduction

The magnitude and rate of biodiversity loss is likely to be exacerbated by the interaction of climate change and invasive species (Settele et al., 2014). A shift in the distributional patterns and abundance of plants and animals across their ranges has been observed due to climate change impacts (IPCC., 2014). Invasive plant species have significantly contributed to the loss of biodiversity and altered the functioning of ecosystems in many parts of the world (IPCC, 2019, Settele et al., 2014). It is estimated that about 50% of Uganda's biodiversity was lost between 1975 and 1995 due to habitat conversion and unsustainable utilization as assessed from the Global Living Planet Index (Pomeroy et al., 2017).

Biodiversity loss in Uganda is mainly attributed to habitat conversion for agriculture and human settlement, unsustainable utilization of resources for fuelwood, timber, charcoal, poaching and the emerging threats of climate change and invasive species (NEMA, 2016). Queen Elizabeth Protected Area is a biodiversity hotspot with a total known list of 96 mammals species, 620 species of birds, 34 species of reptiles, 28 amphibian species, 950 species of plants (Plumptre et al., 2007; Plumptre et al., 2010, MTWA, 2011) and is Uganda's most popular tourism destination (Weiss & Messerli, 2012).

The lion monitoring and research team constituted by Uganda Wildlife Authority(UWA), Uganda Carnivore Program (UCP), and Wildlife Conservation Society observed that lions movements both males and females have increased, moving 10-30 km in a day within and outside the park resulting in human-lion conflicts. Some of the reasons for this increased movement, in the recent past is attributed to colonization of the suitable habitat for the prey by invasive species. The major invasive plant species that have been recorded in the park include *Dichrostytchis Cinrea*, *Lantana camara, Opuntia Vulgaris*, *Chromoleana odorata*, *Prosopis Julifora*, *Cymbopogon nardus* and *Imperata cylindrica* (Kirunda, 2018, MTWA, 2011). All these combined, are hypothesized to have resulted in a dramatic shift in the concentration and distribution of large mammals in the park, including parts of Kyambura, west of lake George and among others, which has reduced to the number sites in the park where large mammals can be viewed by tourists.

This study assessed:

1. Potential areas for establishment of new tourism circuits, in order to diversify the experiential tourism experience for the tourists.

2. Extent of distribution of some of the major invasive plant species (*Dichrostytchis Cinrea*, *Imperata cylindrica, Lantana camara)* inside the park

3. Ranging patterns of lions in relation to prey species

Study area

Queen Elizabeth Protected Area (QEPA), Uganda lies along the equator and is located in the Albertine Rift, southwestern Uganda (Figure 1). It is comprised of Queen Elizabeth National Park (QENP; 1,978 km^2), Kyambura (157 km^2), and Kigezi Wildlife Reserves (330 km^2). The altitude varies between 913-1365m and the vegetation is characterized by savannah grasslands, open and closed woodlands, open and dense scrub, swamps and tropical high forest. QEPA experiences a tropical climate with two wet seasons (March to May; September to November) and two dry seasons (December to February; June to August). The mean temperature ranges between 22°C and 29°C across all seasons and the mean annual rainfall ranges from 750mm to 1250mm.

In the 1960's QENP had the highest biomass density of large mammals ever recorded for terrestrial areas (Petrides & Swank., 1965). Most of the large mammal biomass was comprised of elephant, hippopotamus, buffalo, waterbuck, Uganda kob, Bushbuck, Reedbuck, Warthog and duiker (Petrides & Swank., 1965). Population of large mammals has been fluctuating since the 1960's and as such, the density and distribution of large mammals in park has had an impact on the structure, dispersal, recruitment and maintenance of the different vegetation types (Plumptre et al., 2010).

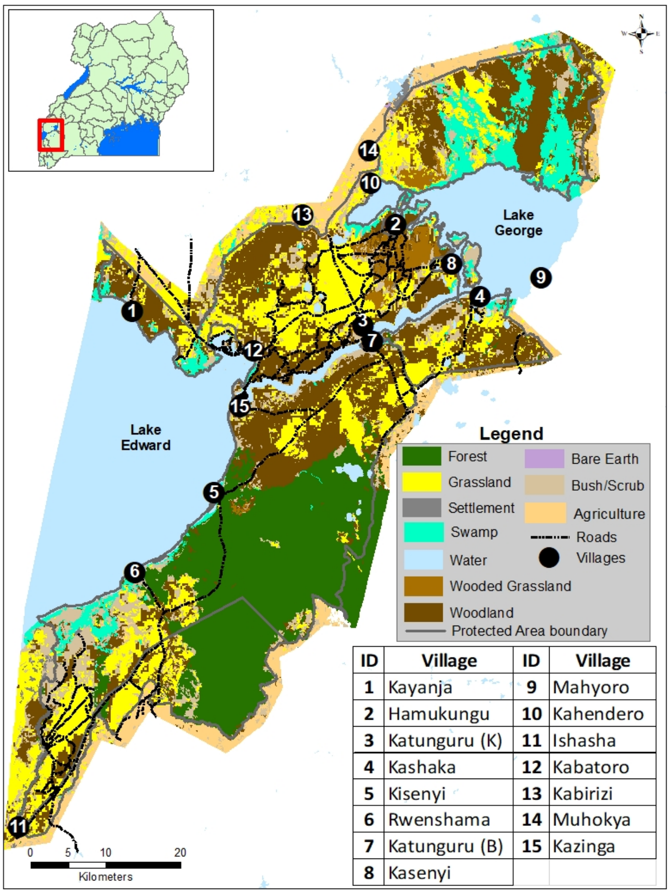


Figure 1: Study area

Methods

Mapping potential tourism areas

The distribution of large mammals in QEPA was mapped over an 8-year period (2010, 2014 and 2018) using aerial survey counts (Plumptre et al 2010, Wanyama, et al 2014, Lamprey, 2018) as a proxy for tourism potential to re-assess tourism routes. The density for each species' was assigned to a 2.5 km survey grid (Figure 2) used during the 2010 and 2014 aerial surveys. The spatial analysis was conducted using a geoprocessing tool (spatial join) in ArcGIS 10.5. The following large mammals were mapped as a proxy for tourism potential: Uganda kob, Elephant, Buffalo, Topi, Warthog, waterbuck, Giant forest hog and hippopotamus

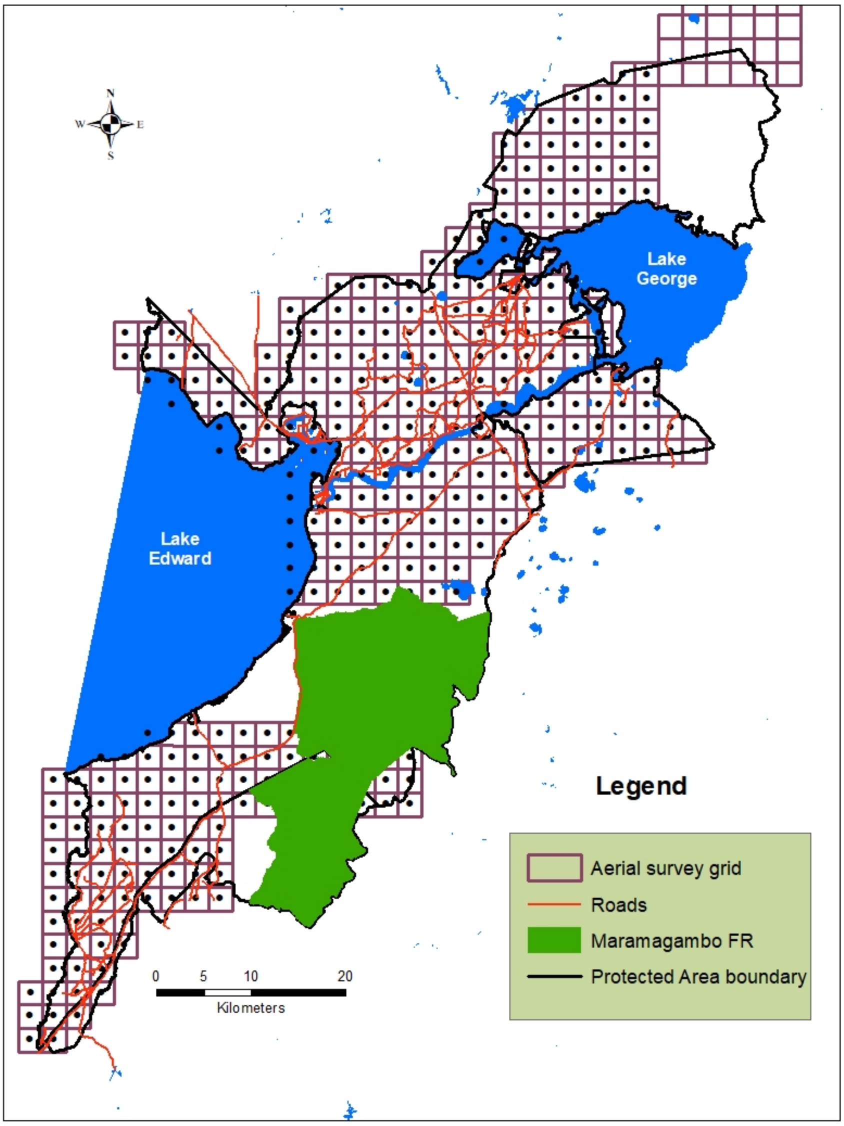


Figure 2: Aerial survey grid

Invasive plant species

A plant survey was carried out over two-time periods (2009, 2017) covering 194 and 136 plots respectively. All trees, herbs, shrubs and lians were enumerated and more than 70% of the plots were revisited. The radii of the plots were 2m, 2.8m, 10m, 14m, 20m and to 56 m (Plumptre et al 2010, kirunda et al 2018). The vegetation cover of herbs, shrubs and lians was recorded following the Braun-Blanquant system.

During the 2017 survey, a total of 29 invasive plant species were recorded compared to 15 invasive plant species in 2009 (Kirunda, B, 2018). The invasive plant species were classified according to their impact on tourism, ecosystem functioning and biodiversity (Kirunda, B, 2018). The major invasive plant species that were identified to have the highest impact on ecosystem services include: *Dichrostachys cinerea, Imperata cylindrica, Chromolaena odorata, Parthenium hysterophorus, Cymbopogon nardus, Lantana camara and Prosopis juliflora.* A spatial overlay analysis was used to assess how *Dichrostachys cinerea*, *Imperata cylindrica,* and *lantana camara* could be influencing the distribution of large mammals in the study area (Figure 3).

Species Distribution Modeling

BIOMOD Species Distribution Modeling platform was used in assessing the factors that could be influencing the spread of *Dichrostytchis Cinrea* in the study area. BIOdiversity MODelling (BIOMOD) is a platform for ensemble forecasting of species distributions (Thuiller et al., 2009). Due to the variations in the results obtained from the different Species Distribution Modeling algorithms (Elith et al 2006; Elith et al 2009; Elith et al 2011), the use of ensemble models has been proposed among the solutions (Thuiller et al., 2009). BIOMOD is one of the most widely used ensemble species distribution platforms and provides access to 10 models ; Generalized linear models, Generalized additive models, Multivariate adaptive regression splines, Classification tree analysis, Mixture discriminant analysis, Artificial neural networks, Random forests, Boosted regression tree, Bioclimatic envelope, Maxent (Hao et al., 2019; Thuiller et al., 2019)The BIOMOD platform allows to fit presence- absence and, presence-background models (Thuiller et al., 2009). A total of 6 models were calibrated using presence- absence and presence-background data. Presence data for *Dichrostytchis cinrea* between the two survey periods (2009, 2017) was aggregated to increase the number of presence records. During the 2009 surveys, *Dichrostytchis cinrea* was recorded in 27 out of the 194 plots that were surveyed while in 2017, it was recorded in 47 out of the 136 plots that were surveyed.

Predictor variables

A total of 19 bioclimatic predictor variables for the current climate conditions (1970-2000) were obtained from worldclim database and clipped to the study area (Fick & Hijmans., 2017). Other environmental variables that are known to influence the distribution of *Dichrostytchis Cinrea* were also considered. A study carried out in Zimbabwe found that plots that had been invaded by *Dichrostytchis Cinrea* were positively correlated with Ph, Nitrogen, Phosphorus and Potassium.

(Mudzengi et al., 2014). Soil variables (Ph, Nitrogen, Phosphorus and Potassium) were obtained from the Africa Soil Grids online resources (ISRIC, 2019). A pairwise correlation coefficient was carried out to reduce collinearity and only variables with less than (±0.75) correlation were retained. The final predictor variables that were selected are Temperature Seasonality (bio4), minimum Temperature of Coldest Month (bio6), Precipitation of Driest Month (bio14), Precipitation Seasonality (bio15), Precipitation of Warmest Quarter (bio18), Precipitation of Coldest Quarter (bio19), nitrogen, Ph, phosphate and potassium.

Community composition: Dichrostychis cinrea

The relationship between the abundance of *Dichrostychis cinrea* and species richness of plants in the survey plots was assessed using the Mantel test. The mantel test is one of the fundamental spatial statistic tests that is used in inference about ecological patterns (Fortin et al, 2002). The Mantel test was used to assess how the distribution, abundance and establishment of the *Dichrostytchis Cinrea* could have impacted the species richness of other plants in the plots and percent cover of herbs.

Home range analysis: Lions

Telemetry data was analyzed for the period between 2006 - 2011 and 2018 - 2019. The 2006/2011 data was collected by tracking radio collared individuals by vehicle and recording their geographic location while the most recent (2018/2019) movement data has been collected using collars that send geographic data through satellite that can be accessed through the internet. A Utilization Distribution model was used to estimate the home range radio collared individuals in the study area (Calenge, 2011). A UD model is a "bivariate function giving the probability density that an animal is found at a point according to its geographical coordinates" (Calenge, 2011). The output from the Utilization Distribution (UD) is the probability of space use by the collared individual. The relative intensity with which the animals use their home ranges is not uniform. In this study, the home range extent is represented by the 95% contour and the core home range by the 50% contour (Clapp & Beck, 2015).

The delineated 95% contour corresponds to the minimum area in which the probability to find the animal is equal to 0.95 while the 50% contour extent represents areas in the home range that are used more frequently compared to other areas in the home range (Samuel, et al 1995). All location data obtained within 24hrs of collaring the animal were discarded to reduce the possibility of outliers. AdehabitatHR package (R statistical software) was used for home range analysis (Calenge, 2011), and ArcGIS for mapping purposes.

Results

Tourism potential

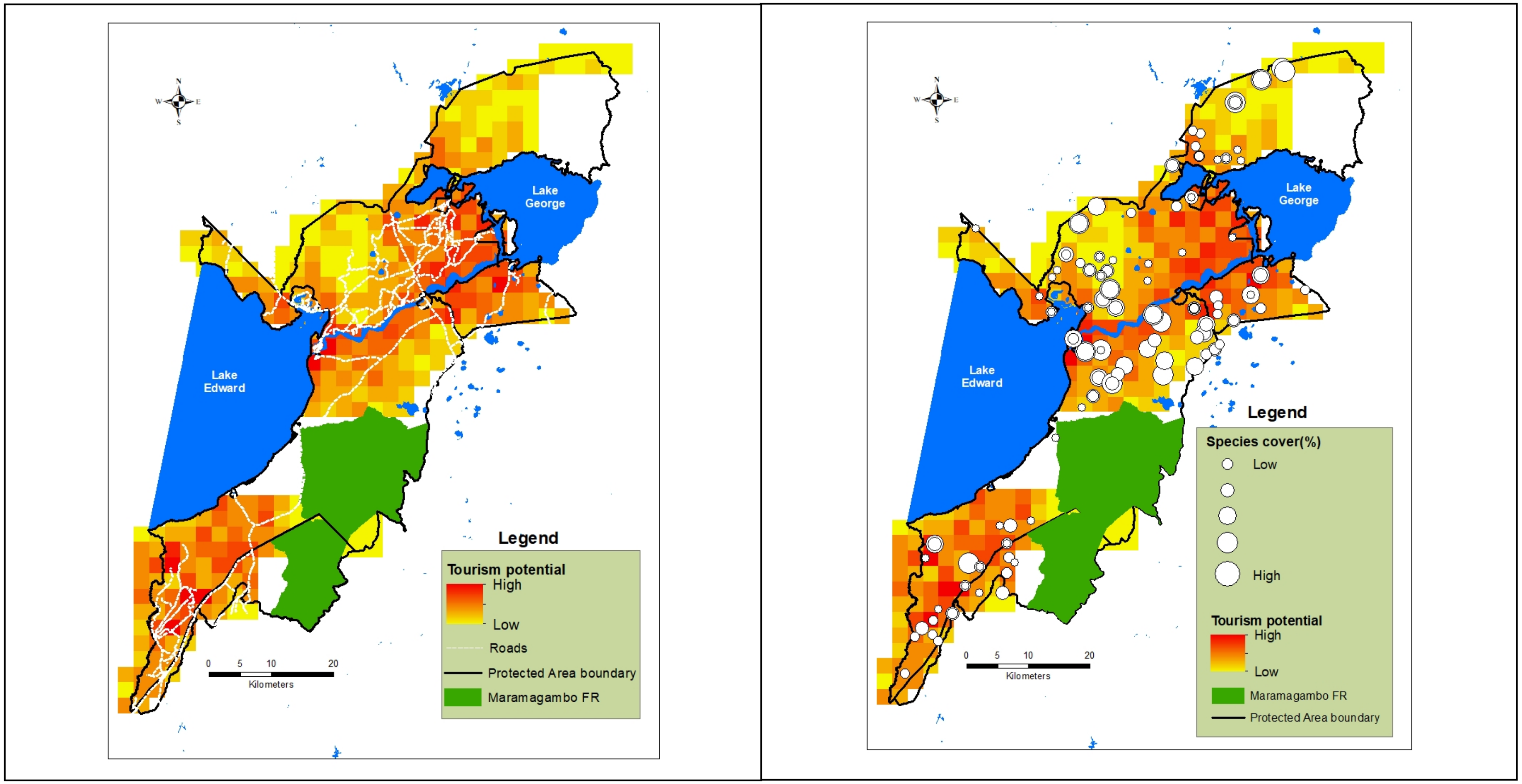


Figure 3: Tourism potential (left) and abundance of the three major invasive plant species (right)

The highest large mammal species richness was recorded in the area located between Hamukugu, Kasenyi, Katunguru and Kikorongo villages, along the southern bank of kazinga channel and in the Ishasha sector (Figure 3). The lowest large mammal species richness was observed in the area between Kikorongo, Katunguri and Kabatoro, the area east of Muhokya village and the area east of the road from Kasenyi to Katunguru (Figure 3). Invasive species overlap with areas low in large mammal species richness (Figure 3).

Invasive plant species distribution

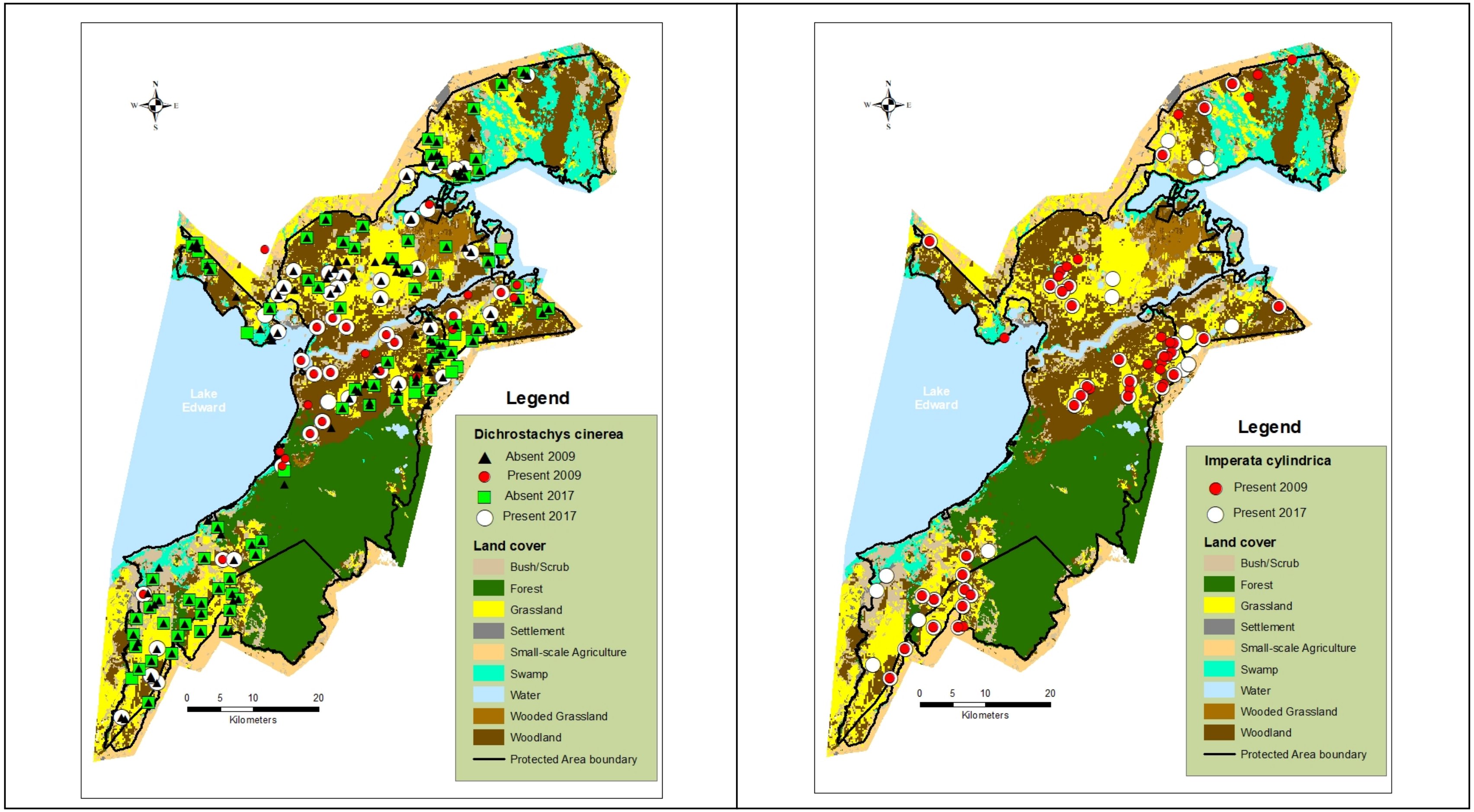


Figure 4: Presence and absence of Dichrostachys cinereal (left), and Presence of *Imperata cylindrica* during the 2009 & 2017 surveys

The two maps illustrate how *Dichrostachys cinerea and Imperata cylindrica* have increased in abundance and distribution between the 2009 and 2017 surveys(Figure 4). The spatial distribution of *Dichrostachys cinerea* increased by 74% while *imperata* cylindrica increased by 64% during the period from 2009 to 2017 comparing the sampled plots.

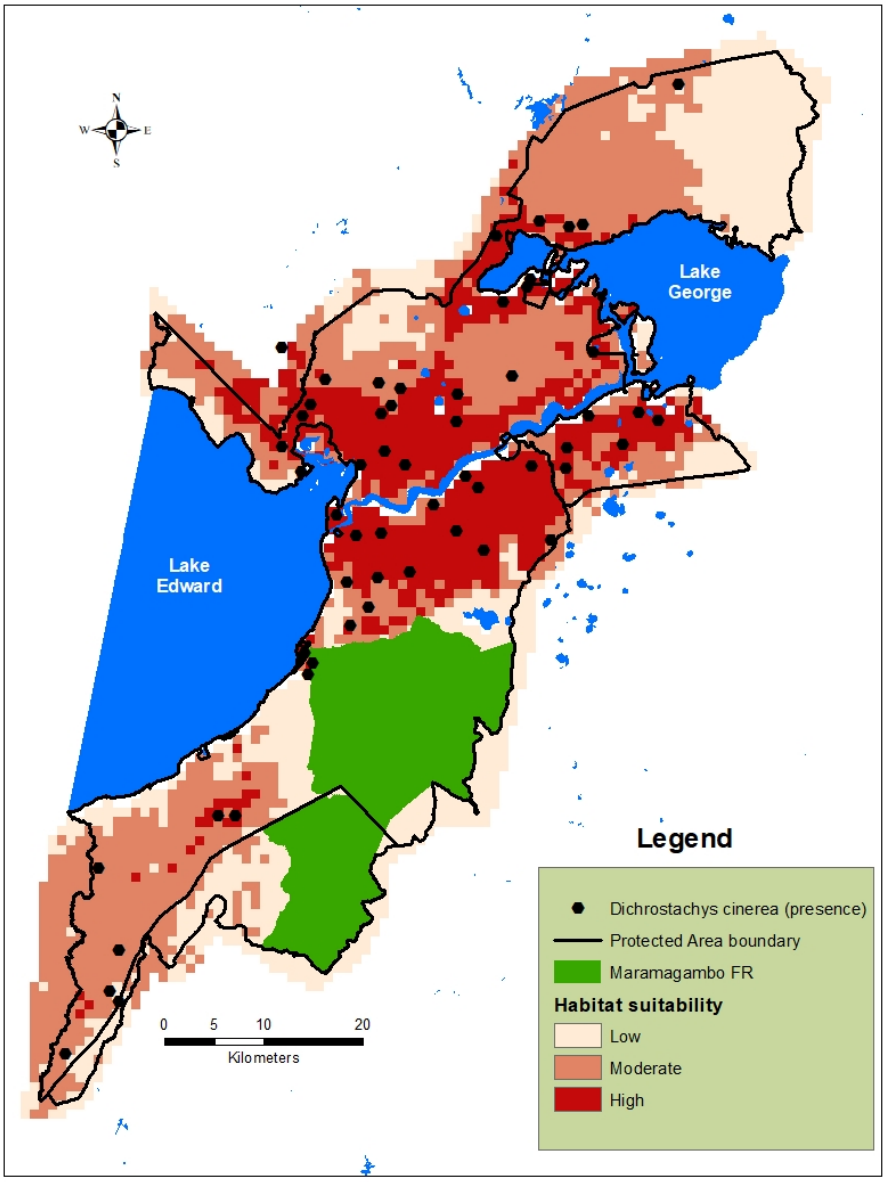


Figure 5: Predicted potential distribution of *Dichrostachys cinerea*

The relative suitable habitat was obtained by computing the average of the six models used in model calibration. The actual and potential suitable habitat for *Dichrostytchis Cinrea* was predicted to occur in the northern sector of the protected area mainly along Kazinga channel, crater lakes, the area located between Katunguru, Kabatoro and Mweya, and in Kyambura wildlife Reserve and the area between Kikorongo and Muhokya (Figure 5). The variation in relative suitable habitat for *Dichrostytchis cinrea* in the study area was mostly influenced by pH, nitrogen, minimum temperature of coldest month (Bio6) and, precipitation of coldest quarter (Bio19). The Mantel z statistic showed that there is no relationship between *Dichrostytchis Cinrea* abundance and plant species richness. (P= 0.123). However, there was a relationship between *Dichrostytchis Cinrea* abundance and herb cover with the Mantel z statistic significant at (P= 0.011).

Dichrostytchis cinrea occurs in dense impenetrable thickets and therefore does not allow any other plant species to emerge from the undergrowth.

Home ranges: Lions

Analysis of ranging patterns of lions for the period (2018-2019) period is shown in the Table 1. The average 50% core home range was estimated at 61.7km^2 with range of 8.7 – 166.2 km^2 and the average for the 95% contour interval was 324km^2 with a range of 46 – 838km^2 (Figures 6, 7). The ranging patterns for the 2006 to 2011 were combined for all lions as individual identification was not available. Therefore, the results are not comparable at an individual level but are important at explaining community level dynamics. However, a previous analysis of ranging patterns (2006 to 2011) at individual level for the same prides in the Ishasha sector estimated home ranges to vary between 7.2 – 20 km^2 with an average of 11.6km^2 for the 50% core home range and 32 – 61 km^2 for the 95% home range with an average of 43.1km^2. For the northern sectors (two individuals), the 50% home range varied between (9.5 – 12.5km^2) with an average of 11.0km^2 (50%) and 26 – 43km^2) with an average of 39.5km^2.

Table 1: Estimated ranging patterns (50% to 95% contours (km^2)

Tag	Sector	Home range level	2018 – 2019 Km2
Tag2526	North	50%	30.85
		95%	155.98
Tag2632	North	50%	109.47
		95%	699.39
Tag2572	North	50%	48.37
		95%	359.36
Tag2675	North	50%	50.68
		95%	219.94
Tag2676	North	50%	8.72
		95%	77.19
Tag2633	Ishasha	50%	166.19
		95%	838.51
Tag2635	Ishasha	50%	65.26
		95%	259.07
Tag2570	Ishasha	50%	64.78
		95%	263.47
Tag2677	Ishasha	50%	10.81
		95%	46.14

Density of prey species

The abundance and distribution of prey species in the study area has been fluctuating considering aerial survey data collected since the 1960's (Plumptre, et al 2010). A recent aerial survey carried out in 2018 (Lamprey, 2018) has shown that most of the prey species have increased in abundance compared to the 2014 counts. Buffalo increased by 8%, Uganda kob increased by 39%, warthog by 26% and waterbuck by 45% (Table 2).

Table 2: Abundance of prey species 2006 - 2018

Species	2006	2010	2014	2018
Buffalo	14,858	8,128	15,771	17,141
Uganda Kob	20,971	8,483	12,987	21,217
Topi	1,521	262	2049	1,974
Warthog	1,388	1,466	1,456	1,963
Waterbuck	3,548	2,483	2,981	5,456

Uganda kob was identified as the most preferred prey for lions in the Ishasha sector during the 2005 to 2011 analysis of ranging patterns of two prides and habitat use (Mudumbu, et al 2015). Uganda kob comprises between 57 to 62% of the lion kills (Table 3) (Mudumbu, et al 2015). The distribution of Uganda Kob was mapped using the aerial surveys of 2010, 2016 and 2018 to assess lion ranging patterns (Figures 6, 7). The mapping results show that high densities of Uganda kob overlap with the 50% core home range of lions in Ishasha sector and the northern section of park in the area located between Katunguru, Kashaka, Kasenyi, Hamukungu and Kikorongo villages.

Table 3: Symbols ## refers to prey preference and prey avoidance#.

Species	Jacobs' index (SE)	Availability (%) (SE)	Prey (%) (SE)	% kill (SE)
Buffalo *Syncerus caffer*	0.22 (0.08)#	37.22 ± 2.87	7.38 ± 1.05	30.00 ± 1.35
Kob *Kobus kob*	0.33 (0.08)##	47.25 ± 4.18	14.81 ± 0.89	59.06 ± 1.15
Topi *Damaliscus lunatus*	0.19 (0.15)#	8.09 ± 1.80	1.69 ± 1.20	6.17 ± 1.54
Warthog *Phacochoerus africanus*	0.072 (0.30)#	1.43 ± 0.30	0.75 ± 1.09	2.88 ± 1.40
Waterbuck *Kobusellipsiprymnus*	0.59 (0.09)#	6.00 ± 1.13	0.38 ± 1.31	1.73 ± 0.52

Adopted from (Mudumbu, et al 2015)

Additionally, the analysis of habitat use (2006 - 2011) showed that lions in the Ishasha sector preferred grassland and wooded grassland habitats (Mudumbu, et al 2015). The distribution of grassland and wooded grassland habitats overlap with the 50% core home ranges of lions (Figure 8). These are the same areas, which have the highest density of kobs.

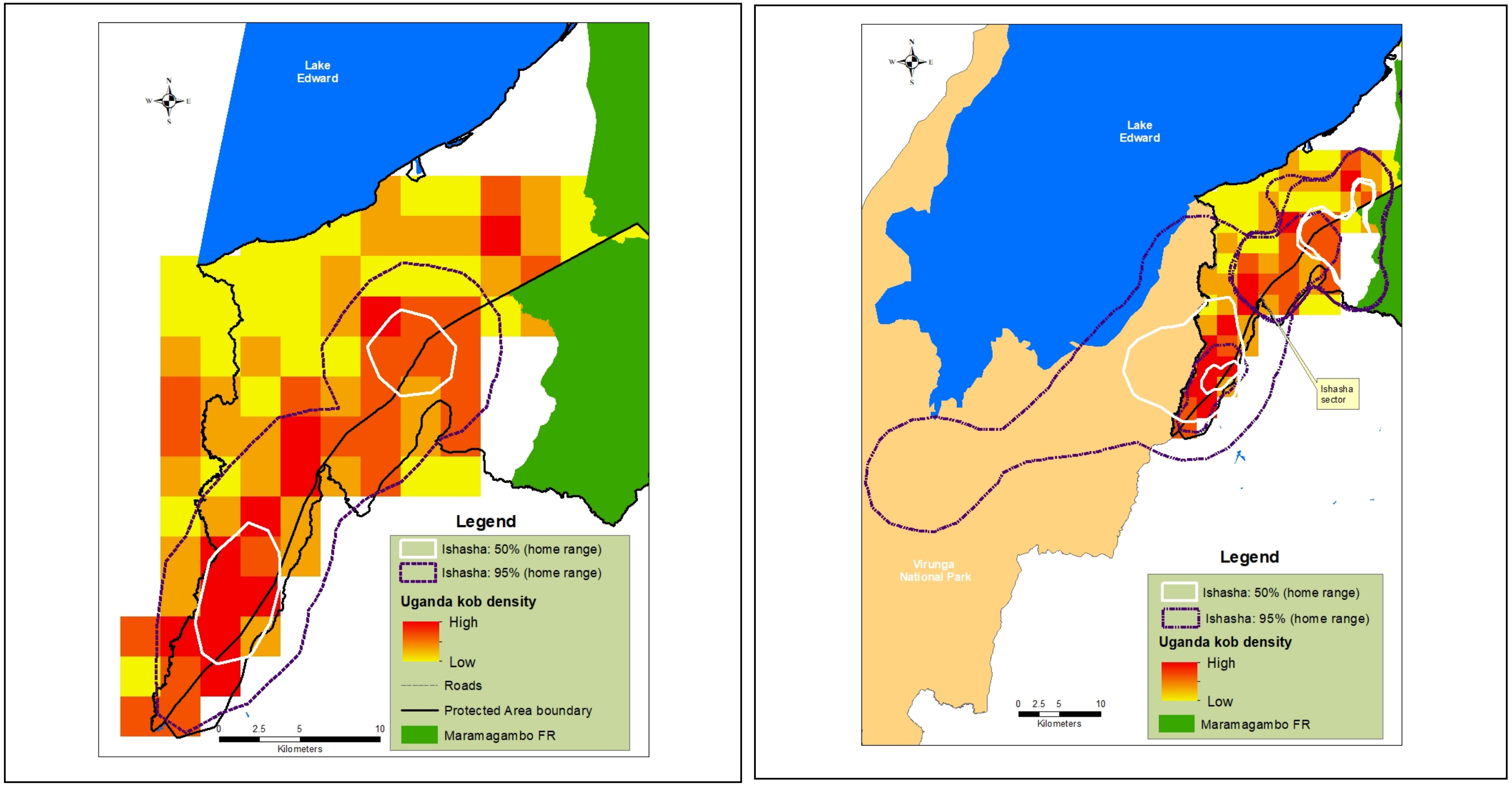
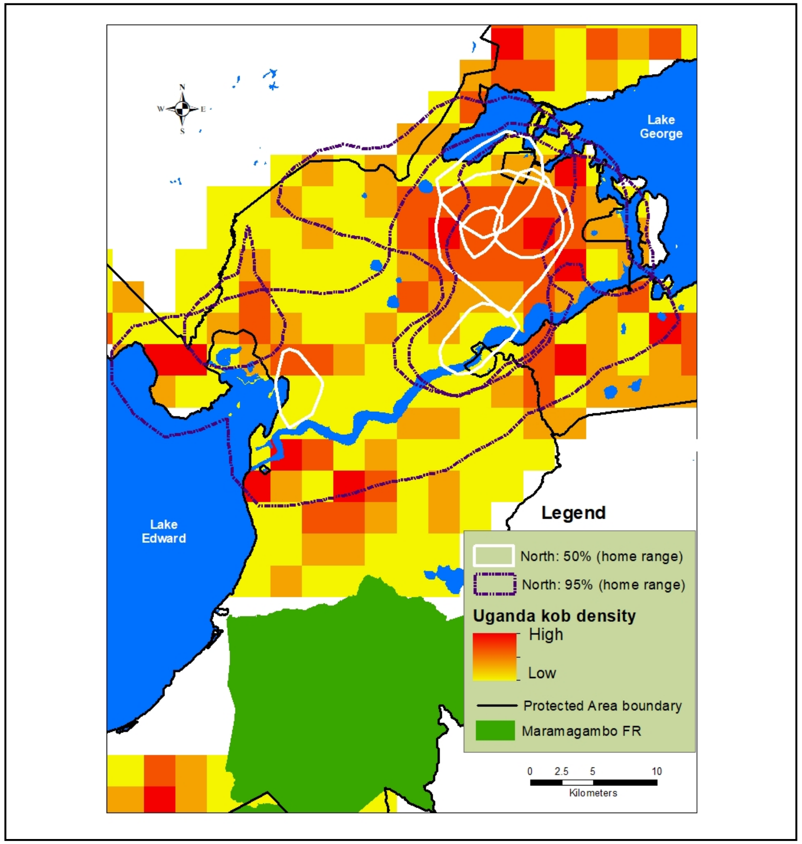


Figure 6: Ranging patterns for Ishasha lions (2006 – 2011) using combined location data (left) and the 2018-2019 ranging patterns for individual lions (right).

Comparing the home ranges (50%, 95%) using a T-test showed that there was no difference in the ranging patterns between the 2006-2011 and 2018-2019 estimates for lions in the Ishasha sector (t = -2.0068, df = 3.0214, p-value = 0.1378) for the 50% home range, (t = -1.8158, df = 3.0027, p-value = 0.1669) for the 95% home ranges. The 50% contour home ranges in the Ishasha sector, which represent areas that are used more frequently compared to other areas have been consistent over the 13-year period (2006 – 2019).



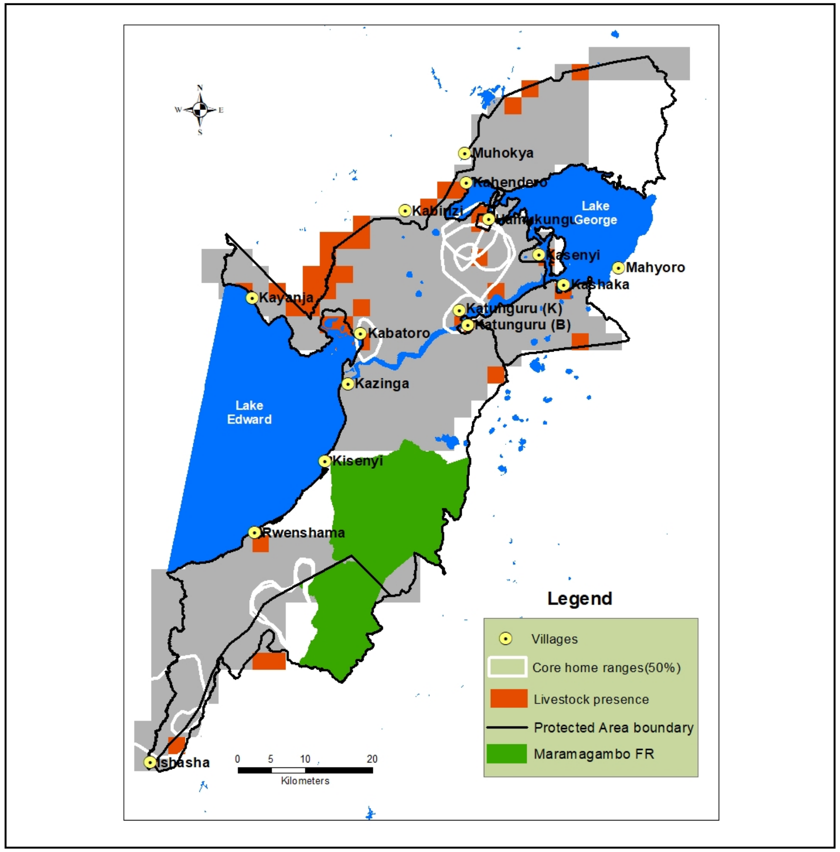


Figure 7: Ranging patterns for lions in the northern sector of QEPA (2018 – 2018) (left) and livestock density for the 2010, 2014, 2018 aerial surveys (right).

The ranging patterns of lions in the northern sectors are located in the area between Hamunkungu, Kasenyi, Katunguru and Kikonrongo (Figure 7). The area has a high density of Uganda kob, which is the most preferred prey of lions. Dricuru, 1999 and Omoya et al 2013, estimated five prides in the northern sector, however all the four collared lions in north seem to be from one pride corresponding to the Kasenyi pride. Additional the northern area has a high population density livestock, which is likely to lead to an increased human wildlife conflicts (Figure 7)

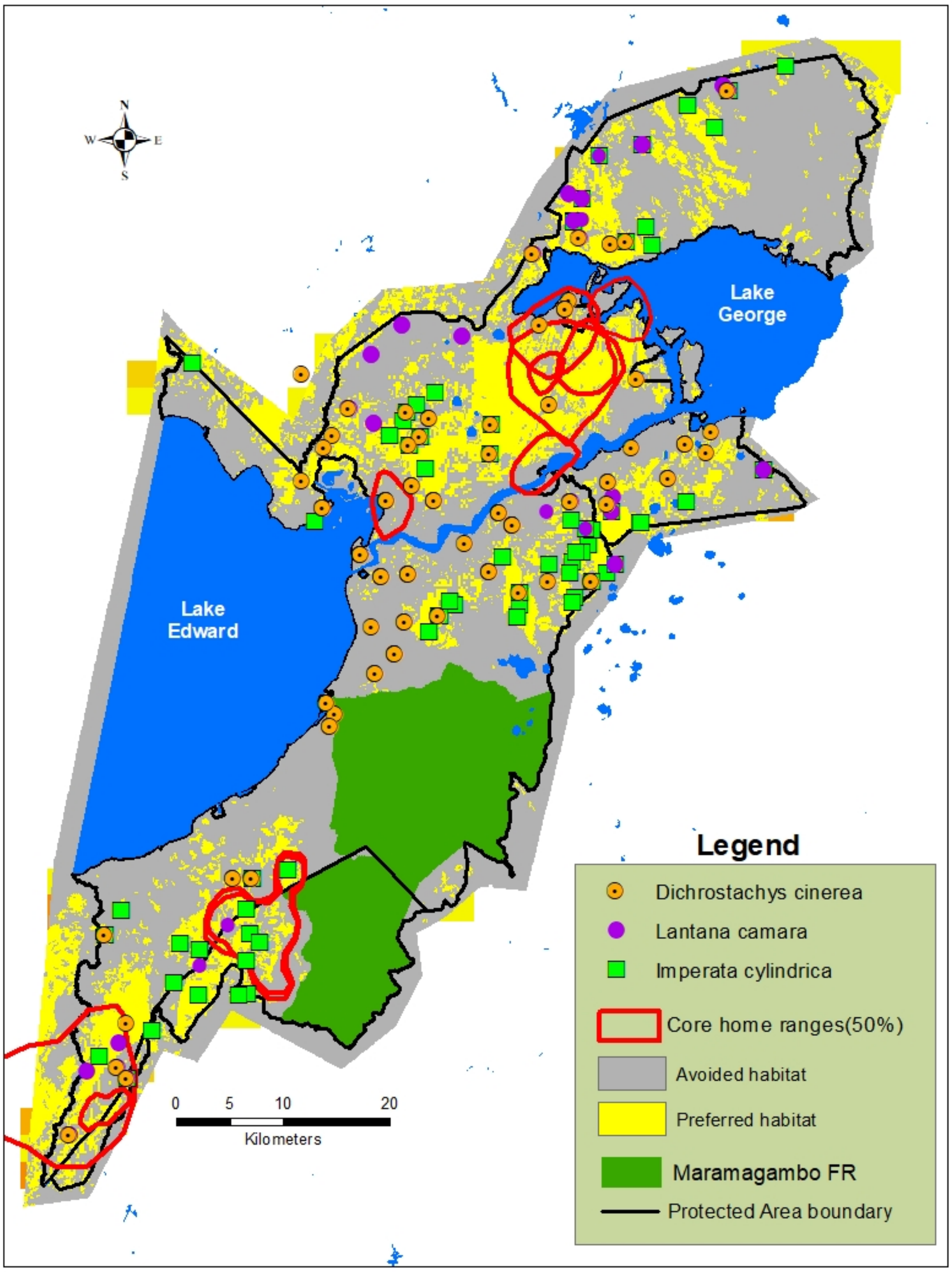


Figure 8: Distribution of preferred lion habitat (grassland, woodland grassland), 50% core lion home ranges and invasive species.

The preferred lion habitat overlaps with the 50% core homeranges for lions in both the southern and northern sectors of the park. The ranging patterns of lions in the Ishasha sector correspond to the 1997/1998 and 2013 census of lions in the park (Dricuru, 1999 and Omoya et al 2013)

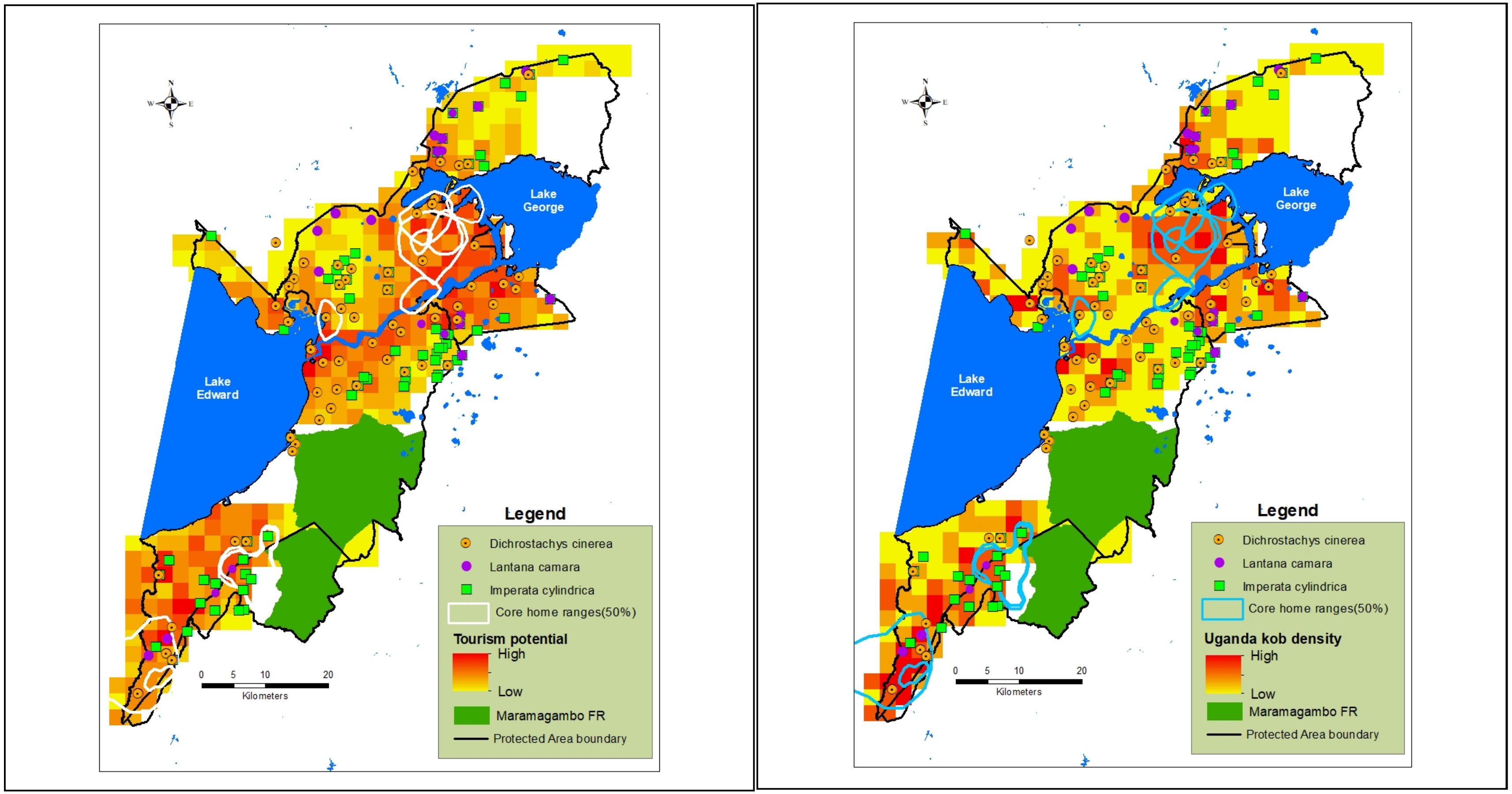


Figure 9: Distribution of large mammals, 50% core lion home ranges and invasive species.(left) and the distribution of Uganda Kob (preferred prey of lions), 50% core lion home ranges and invasive species.(right)

Areas with the highest mammal richness were located between Hamukugu, Kasenyi, Katunguru and Kikorongo villages, along the southern bank of kazinga channel up to Kyambura Wildlife Reserve and in the Ishasha sector. However, the distribution of Uganda Kob (preferred prey of lions) is located mainly in the areas between Hamukugu, Kasenyi, Katunguru and Kikorongo villages, and in the Ishasha sector (south) and east of Kigezi Wildlife Reserve. Lion ranges overlap with areas high in kob density.

Discussion

Tourism potential was mapped using aerial surveys of large mammals (elephants, Uganda kob, buffalo, warthog, giant forest hog, hippo, topi). The highest large mammal species richness was recorded in the habitats located between Hamukugu, Kasenyi, Katunguru and Kikorongo villages along the southern bank of kazinga channel from Mweya to Kyambura Wildlife Reserve and in the Ishasha sector (Figure 3).

The current tourism circuits overlap with high large mammal species richness survey grids located between Hamukugu, Kasenyi, Katunguru and Kikorongo villages in the north of the park and the Ishasha sector in the south. However, the areas located between Kikorongo, Katunguru, Kabatoro and Katwe, areas east of the road from Kasenyi to the Katunguru were observed to have low large mammal species richness (Figure 3). The low levels of large mammal species richness can be attributed to the presence of invasive plant species *Dichrostachys cinerea* and *imperata* cylindrica (Figure 4). Extent of occurrence for *Dichrostachys cinerea* has increased by 74%, while *imperata* cylindrica increased by 64%.during the period from 2009 to 2017 comparing the sampled plant plots (Figure 4**).**

Habitat changes in Queen Elizabeth Protected Area are well documented and the extent of grasslands and woodlands has been fluctuating in relation to the biomass of large mammals, fire frequency regimes and climate variables (Lock, 1993; Plumptre et al 2010; Plumptre et al 2017). A vegetation change analysis conducted for Queen Elizabeth National Park between 1970 -1988 showed that thickets of *Capparis tomentosa* and *Dichrostachys cinerea* were spreading and the changes were attributed to the decline in elephant populations due to civil war in the 1970's (Lock, 1993). However, results from this study show that habitat changes are dominated by invasive species. There has been an increase in the number and spatial extent of invasive plant species in Queen Elizabeth Protected Area (Kirunda, 2018). A total of 29 invasive plant invasive species were recorded during the 2018 surveys.

Dichrostythcis Cinrea is native to Africa and Asia and is among the invasive plant species that has the highest impact on ecosystem functioning (Mudzengi et al., 2014; CABI, 2019). The actual and potential distribution of *Dichrostythcis Cinrea* was estimated using BIOMOD an ensemble species distribution modeling platform. Suitable habitat for *Dichrostytchis Cinrea* was predicted to occur in the northern sector of the protected area mainly along the Kazinga channel, crater lakes, the area located between Katunguru, Kabatoro and Mweya, and in Kyambura wildlife Reserve. *Dichrostythcis Cinrea* produces seeds that can survive for a long time in the soil (> 5 years) and when an area is colonized, it forms dense impenetrable thickets, which are difficult to eliminate (CABI, 2019). The species can also be propagated by roots or root suckers.

The ranging patterns of lions estimated using the Kernel Utilization Distribution model, which produces the probability of space use of collared individuals, the home range was represented by the 95% contour and the core home range by the 50% contours. The 2018-2019 average 50% core home range was estimated at 61.7 km^2 with range of 8.7 – 166.2 km^2 and the average for the 95% contour interval was 324 km^2 with a range of 46 – 838 km^2. Mudumba et al 2015, estimated the ranging patterns (2006 to 2011) of the two prides in the Ishasha sector to vary between 7.2 – 20 km^2 for the 50% core home range and 32 – 61 km^2 for the 95% home range with an average of

43.1 km^2. A T-test comparing the ranging patterns for the Ishasha sector showed that there was no significant difference between the two time periods. There was not enough data to compare ranging patterns for the northern sector prides as the previous data collection was limited to two individuals. The estimated 50% ranging patterns overlap with areas that have a high density of Uganda kob, which is the most preferred prey of lions. The 50% ranging patterns of all the collared lions correspond to the previous prides identified during the 1997/998 and 2008/2009 lion census in the study area (Driciru, 1999, Omoya et al., 2013). This shows that the lion home ranges have remained consistent over the 13-year period. Additionally, previous collection of ranging data was limited to vehicle tracking and the new satellite data collection provides more location data. Therefore, ranging pattern results are not directly comparable to assess ranging pattern dynamics. Based on the aerial survey data we used to map the distribution and abundance of livestock, the resulted showed that the northern area has a higher population density of livestock compared to the Ishasha sector, which is likely to lead to an increase in human wildlife conflicts.

Conclusion

It is evident that there has been an increase in the distribution and abundance of invasive species in study area, which has led to a reduction in the available suitable habitat for mainly the ungulates that heavily depend on short grass in the park for food and has negatively affected tourism experiences. *Dichrostachys cinerea* increased by 74%, *imperata cylindrica* increased by 64%, and *Lantana camara* increased by 119% over the 8-year period. Most of the ungulates moved west of Lake George and deep inside Kyambura Wildlife reserve in search of food. As a result, the lions have also moved away from the known core conservation areas in search of the prey. Unfortunately, the newly colonized areas by the ungulates do not have tourism tracks, making it difficult for tourists to enjoy seeing lions, the most sought after species in QENP.

Recommendations to UWA management

Therefore, there is a need for a deliberate action made by UWA to increase the amount of preferred habitat available to grazers through conservation actions that directly target the control of invasive species in the park and subsequently improve the tourism experience of visitors. Areas with potential for development of new tourism circuits in Kyambura WR, portion of the park toward Kasese town, and areas north of East Lake Katwe could be explored for this purpose. This, however, will require reasonable investments and UWA alone cannot finance this work. We recommend a partnership between the private sector companies and UWA to be explored and development partners could support UWA with infrastructure development funds.

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