Biodiversity Surveys of Murchison Falls Protected Area

Murchison Falls. A.J.Plumptre/WCS

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August 2015

WILDLIFE CONSERVATION SOCIETY

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EXECUTIVE SUMMARY

This report summarises the findings of a biodiversity survey of Murchison Falls Protected Area (MFPA - including Murchison Falls National Park, Bugungu and Karuma Wildlife Reserves). The survey shows that MFPA is rich in species and biodiversity with a total known list of 144 mammal species, 556 bird species, 51 reptile species, 28 known amphibian species with an additional 23 to identify (51 species), and 755 plant species. This makes this conservation area relatively biodiverse in the region although not as diverse as some of the parks further south in the Albertine Rift, such as Queen Elizabeth and Virunga National Parks which also have savannah ecosystems. These surveys have greatly increased the known number of species for the conservation area, doubling the previously known number of reptile species and significantly increasing the number of mammal, bird and plant species from previously published lists. It is likely therefore that with extra survey effort more species could be found given the short duration and limited sampling of our surveys.

While species richness and diversity is high, the number of species that are restricted range (Albertine Rift endemic) or globally threatened on the IUCN global redlist are not so many and mostly restricted to the mammals, birds and plants. It is potentially possible that the amphibian species that are currently being identified using genetic material may prove to be species of conservation concern or even new species. Of the species we have found for MFPA there are two Endangered and four Vulnerable mammal species; four Endangered and seven Vulnerable bird species; two amphibians are Data Deficient, and eight Vulnerable and seven Albertine Rift endemic plant species.

Bugungu Wildlife Reserve was particularly rich for certain taxa, notably birds, amphibians and plants, proving to be richer than Murchison Falls National Park for these taxa. It also contained many of the endemic and threatened plant species. This is likely a result of its varied habitats and its proximity to Budongo Forest, but identifies it as being a place of particular conservation value in the landscape.

ACKNOWLEDGEMENTS

We would like to thank many people who helped WCS implement these surveys. The Conservation Area Manager of Murchison Falls Protected Area, Mr. Tom Okello was very helpful in organizing logistics for the field teams and providing advice on where teams could access safely. We are grateful to the field assistants who collected the data for these surveys, particularly: Moses Gonya, Nabert Mutungire, Julius Kyamanywa, Conslate Alezuyo, Wilber Lukwago and Akoth Sisiria and to the UWA rangers who also took part in the data collection. We also thank Richard Musumererwa Amooti for ably cooking for all the field teams, and Sam Mulondo, Bosco Kirama and Wilson Muhumuza for driving the survey vehicles. Robert Kityo at the Makerere University Museum identified the small mammals for this survey and Mathias Behangana identified the reptiles and amphibians.

We want to thank The Norwegian Government for the financing of this work through NEMA and UWA and Tullow Oil for their financial support for the surveys in Bugungu WR and in the human modified areas. We are grateful to Uganda Wildlife Authority for permission to carry out the surveys in the Murchison Falls Protected Area.

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INTRODUCTION

The Murchison Falls Protected Area (MFPA) includes the Murchison Falls National Park (MFNP - 3,898 km^2), Karuma Wildlife Reserve (Karuma WR - 678 km^2) and Bugungu Wildlife Reserve (Bugungu WR - 474 km^2). The two wildlife reserves are contiguous with the national park and together form a conservation unit that encompasses 5,045 km^2 of natural habitat, Uganda's largest landscape of protected areas (figure 1).

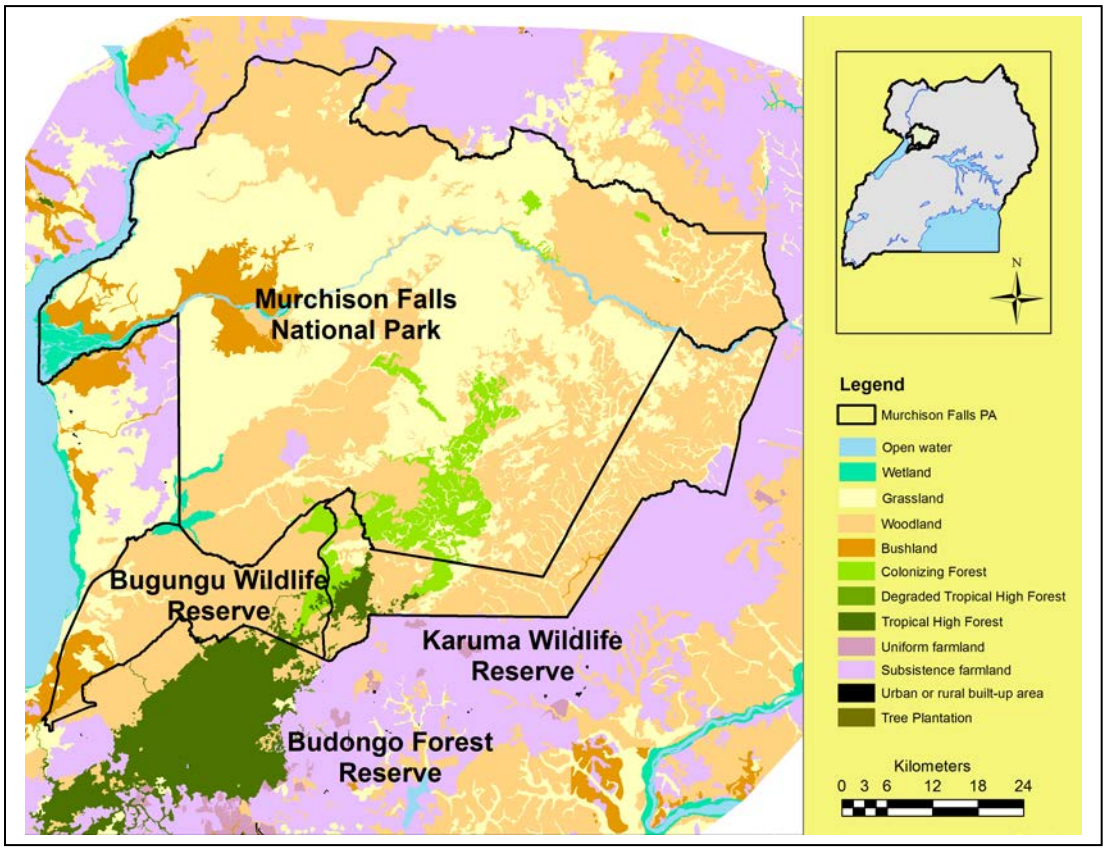

Figure 1. Map of the Murchison Falls Protected Area with the main vegetation types mapped.

When Samuel Baker discovered the falls in 1866 the banks of the Nile River which flows through the park were heavily populated. Outbreaks of Rinderpest and Sleeping Sickness in the late 1800s led to the out-migration of people and a government resettlement scheme from 1912 (Olupot *et al.* 2010). Murchison Falls National Park (MFNP) was established as the Bunyoro Game Reserve in 1910 and then gazetted as a national park in 1952. Karuma and Bugungu Controlled Hunting Areas were established in 1962 to allow sport hunting of elephants and other species and these became Game Reserves later in the 1960s and finally Wildlife Reserves in 1996 after the formation of the Uganda Wildlife Authority (UWA) from the merger of the Uganda National Parks and Game Department (Olupot *et al.* 2010). Following its creation as a national park, Murchison Falls became a significant tourism attraction in East Africa with more than 60,000 visitors coming to the park in the late 1960s and early 1970s.

MFPA was probably the hardest hit of any of the protected areas in the civil unrest of the 1970s and 1980s. Elephant numbers declined from 14,000 in the late 1960s to 250 in 1983/84. It was only following the establishment of the current government in Uganda and the stabilization of the rule of law that elephant and other large mammal numbers started to increase again. An aerial survey in 2014 by the Wildlife Conservation Society (WCS) and UWA showed Murchison's elephants now number about 1,300. The loss of so many elephants has led to the expansion of woodland and forest within MFPA (figure 1).

Research in the MFNP focused on large mammal ecology, particularly the 'problem of elephants' which occurred as elephants lost habitat outside the MFPA resulting in migration and a high density of elephants within the park. This led to major habitat alteration with the conversion of wooded areas to grassland. Culling of elephants over the years to reduce human-wildlife conflict allowed detailed research to be made on the reproduction and population dynamics of this species (Laws, Parker and Johnstone, 1975). No formal surveys of the biodiversity of the park were made however.

Published records for MFNP (Wilson 1995) showed the park to contain in the region of 76 mammal species, an observation that was probably an under-estimate given that surveys for small mammal species (bats, rodents and shrews) have only been conducted for some sections of the park, and 450 bird species (19 unconfirmed at the time). Biodiversity surveys were made of Bugungu Wildlife Reserve (Allan 1997) which focused on large and small mammals, birds, reptiles, amphibians and invertebrates. This survey recorded 227 birds for Bugungu WR (33 not seen in MFNP), 26 large mammals, fourteen species of rodent, five species of shrew and five species of bat (total of 50 mammal species). Of the ungulates a key finding was the red-flanked duiker (*Cephalophus rufiliatus*) in Bugungu WR which may not occur elsewhere in Uganda. Reptiles numbered 26 and amphibians 15 species with some remaining to be identified at the time of the report. 47 butterfly and 9 dragonfly species were also identified.

However, there has never been a comprehensive biodiversity assessment for MFPA as a whole. There have been some lists generated from surveys made for EIA's and some basic baseline surveys for the oil companies but nothing that has attempted to cover the whole conservation area. In 2014 WCS was requested by UWA to help them undertake a survey of the biodiversity of MFPA to provide a baseline for monitoring of future changes in the biodiversity of the landscape. Oil and gas exploration in MFPA has shown that there are significant reserves under the park and wildlife reserves and these are very likely to be exploited in the future. The Norwegian Government funded the Government of Uganda to support preparations for oil and gas production, part of which included support to baseline surveys. This report summarises the results of the baseline biodiversity surveys for MFPA. At the same time Tullow Oil was funding WCS to undertake baseline biodiversity surveys of Exploration Area 2 which included part of Bugungu Wildlife Reserve as well as the community land to the north and south west of this area. We have therefore included the results for Bugungu Wildlife Reserve surveys funded by Tullow Oil in this report.

The biodiversity surveys focused on terrestrial vertebrates and plants; mammals, birds, reptiles, amphibians and higher plants. While it would have been good to include other taxa the funds available for these surveys were limited and as a result we focused on these taxa which can be identified relatively easily because of good keys. While one objective was to compile a list of species for the park, the key objective was to map the diversity spatially across the park to highlight areas of species richness or that are important for threatened species.

METHODS

Survey Design

The software DISTANCE 6.0 was used to design a survey using a stratified-random sampling method of 3 km transects across the MFPA (Figure 2). Spacing of the transects was determined by the available budgets with closer spacing in Bugungu Wildlife Reserve and in human modified habitat in Buliisa District because of Tullow Oil funding for that site. Bird and plant teams aimed to reach as many transects as possible, given difficulties in accessing parts of MFPA, while reptile/amphibian and small mammal teams targeted fewer transects but ensured that the diversity of habitats were sampled. Six additional transects were added to sample rarer habitats in the Bugungu area and four transects that were initially planned had to be re-located because of difficulty of access.

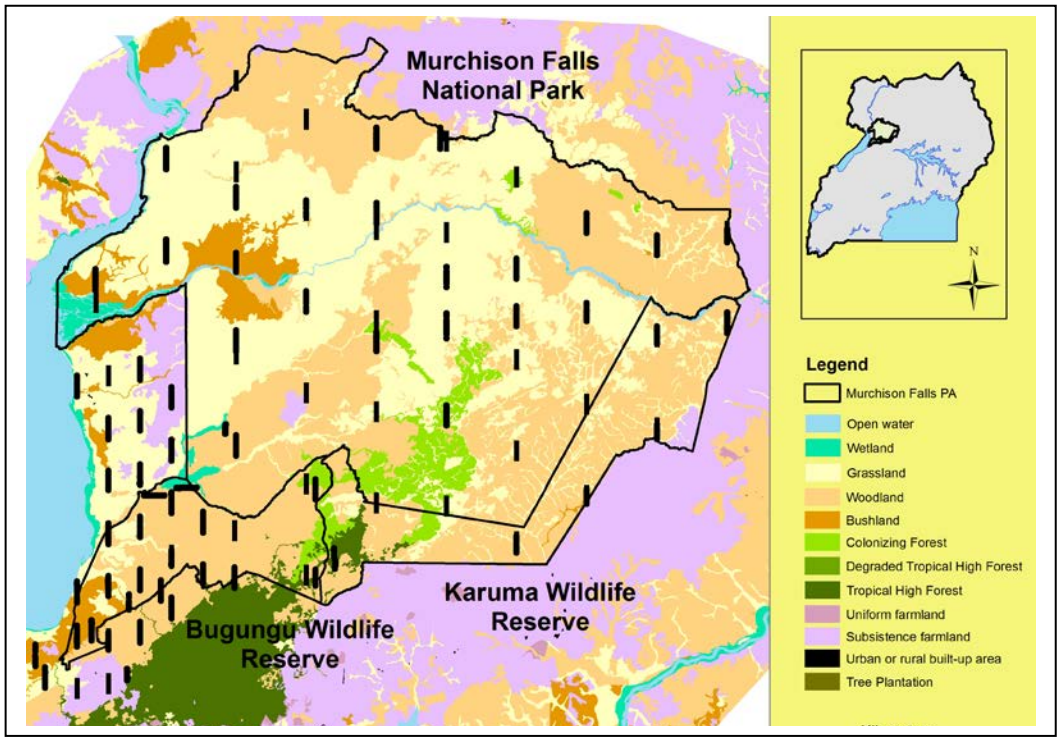

Figure 2. The design of transects surveyed across MFPA showing both transects selected in DISTANCE design and additional ones added to sample specific habitat.

Large mammal surveys

UWA undertakes regular aerial surveys of large mammals in MFPA with the last survey made with WCS in June 2014. There have also been records made over the years of sightings of large mammal species. As a result the large mammal fauna is relatively well known and didn't need to be resurveyed. However, WCS and UWA both had camera traps available and WCS placed 55 camera traps across MFPA to look at relative capture rates of different species with a particular interest in species that are rarely observed.

Small mammal surveys

Shrews/Rodents

Capturing of different mammal species requires different trapping techniques and wide variety of traps for trapping small terrestrial mammals are available. For these surveys however Sherman traps were used to capture rodents and shrews, using a bait that comprised of a mixture of peanut butter, maize flour, margarine and bananas- a usually effective bait for trapping a wide spectrum of small

terrestrial mammals. The trapping protocol used traps laid along line transects that maximized the habitat variation in each survey area. To enhance the chances of capturing animals, traps were specifically placed at locations with feeding signs, runways and against or beneath logs and areas with a good amount of low vegetation cover.

All trap locations were marked with a GPS and also marked with flagging tape so that traps could be easily relocated. For the rodents and shrews, a uniform trap effort was used for all survey areas.

Bats
Bats were sampled using mist nets, searching for roosts, and using an acoustic bat detector that can record micro-chiropteran activity. Sampling of bats was constrained by the location of sampling sites and the safety of the field team at night and as a result not every site sampled for shrews and rodents was sampled for bats also.

Amphibian and reptile surveys

In each of the main habitat types of the MFPA, reptiles and amphibians were surveyed using Visual Encounter Surveys (VES) and Pitfall Traps. These methods were used to document the presence of amphibians and reptiles and sample individuals for each species.

Visual Encounter Surveys
Visual Encounter Surveys (VES) are a well known and robust method for survey hepterofauna. VES is similar to the Timed Constrained Count (TCC) method described by Heyer et al., (1994). Visual encounter surveys are used to document presence of amphibians and reptiles and are effective in most habitats and for most species that tend to breed in lentic habitats. They generate encounter rates of species in their habitats in a unit hour.

The method comprises moving through a habitat, turning logs or stones, inspecting retreats and watching out for and recording surface-active species. The data gathered using this procedure provides information on species richness of the habitat. For amphibian fauna, the best results are achieved when the surveys take place in the evenings between 1900 and 2100 hours as this is when most amphibians are active. For reptiles, there is no particular time for sampling all reptiles because the different groups are active at different times of the day and night. For example, whereas most tortoises, skinks, agamids and some geckoes are active during the warm parts of days, other species of geckoes and snakes are nocturnal. Surveying reptiles therefore was more habitat based than temporal.

Pitfall trapping with drift fence
Pitfall traps were set up with a drift fence in selected habitats to sample any surface dwelling herpetofauna. The use of drift fences with bucket pitfall traps has been the commonest technique for studies of individual species or herpetofaunal communities and has been used with success for amphibians (Mitchell et al., 1993; Heyer et al., 1994, Handley and Varn, 1994; Msuya, 2001). The results of studies employing drift fences with pitfall traps provide valuable insights into population and community ecology, and behavioural patterns of secretive and difficult to study species (Dodd, 1991). Each drift fence comprised of 10, 20-litre plastic buckets placed at an interval of 10 m, covering a total length of 100 m. The buckets were placed in holes dug in the substrate such that their rim was level with the ground. A 100-meter long and 0.5 m high drift fence of black polythene supported vertically by wooden laths was set in an alternating manner with the buckets in the line to permit detection of directional movement of herpetofauna. The pitfall traps were inspected twice a day.

Bird Surveys

Birds were sampled using point counts at 250 m along each transect visited and the habitat of each point noted. Additional points were placed in rare habitats in the vicinity of the sample site. The latter

would include feeding sites for migratory waders, small wetlands etc. Point counts consisted of the two ornithologists arriving at a site and waiting a minute for the birds to settle down if they had been disturbed. They would then make a five minute point count noting all birds seen or heard from the point and the distance from the observer to the bird in the following distance classes: 0-10m, 10-20m, 20-50m, 50-100m, 100-200m, 200+m.

The ornithologists working with WCS can identify all the bird calls from birds that were likely to be found in MFPA and also aimed to compile a total species list for each transect in addition to the quantitative data obtained from the point counts.

Plant surveys

Plant plots were measured at 250 metres along each transect visited. Standard nested circular plots have been used at all sites in the AR. Small herbs are recorded in a circle of 2m radius; trees from 2.5-10cmDBH, lianas (>1cm diameter) and shrubs are recorded in 10m radius plots; and trees > 10cmDBH are recorded in 20m radius plots. A representative sample was taken of every species identified in the field so that checks could be made on species identifications later. A GPS reading was made for every plot and habitat, slope and canopy cover measurements were made using a standard form.

A total list of species at each transect was compiled by collecting fertile plant specimens (flower/fruit) where possible and non-fertile otherwise of all plant species detected. The specimens were pressed and dried using portable plant driers that WCS has developed for field surveys. Specimens were identified at Makerere University Herbarium. In addition, for each specimen a GPS point and field notes on habitat and characteristics were recorded.

RESULTS

Large mammals

A total of 48,824 photographs were taken by camera traps placed in the MFPA during these surveys. From these 38 large or medium sized mammal species were observed (Table 1). Few cameras were placed in Karuma WR so no data are given for here. While these species have all been recorded previously for the MFNP area it is encouraging that there are still species such as the Giant Pangolin, Ratel (Honey badger) and the Bunyoro rabbit which is only found from here to north eastern Democratic Republic of Congo.

Table 1. List of medium sized mammals observed in the MFPA from camera trap photos

Order	Species	MFNP	Bugungu
Primate	Black and white colobus		1
	Chimpanzee	1	
	Olive Baboon	1	1
	Patas monkey	1	
	Vervet		1
Carnivora	African Civet		1
	Large spotted genet	1	1
	Rusty-spotted genet		1
	Servaline Genet	1	1
	Banded mongoose		1
	Marsh Mongoose	1	1
	Slender mongoose		1
	White tailed mongoose		1
	Serval cat		1
	Lion	1	
	Leopard	1	
	Side striped Jackal		1
	Spotted hyena	1	1
	Ratel	1	1
Pholidota	Giant Pangolin	1	1
Artiodactyla	Buffalo	1	1
	Bush Duiker	1	1
	Bush pig	1	1
	Bushbuck	1	1
	Rothschild Giraffe	1	
	Hippopotamus	1	1
	Jackson's Hartebeest	1	
	Oribi	1	
	Reedbuck	1	
	Uganda kob	1	1
	Warthog	1	1
	Waterbuck	1	1
Proboscidae	Elephant	1	1
Lagomorpha	Bunyoro Rabbit		1
Rodentia	Cane rat		1
	Crested porcupine	1	1
Tubulidentata	Aardvark	1	1

Small mammals

A total of twenty one sites were visited where a camp was established and then surveys made in the vicinity of the camp. Of the 317 small mammals trapped/encountered, 60 small mammal species were

recorded from the three protected areas in the MFPA. These included 27 bat species, 15 shrew species, one rabbit (*Poelagus marjorita*), one galago (*Galagoides thomasi*) and 16 rodent species.

Bats

Table 2 gives the 27 bat species encountered during these surveys and the number observed or trapped in each of the three protected areas within MFPA. It can be seen from these results that MFNP is particularly rich in bat species compared with the Wildlife Reserves. One species of bat found on these surveys, *Chaerophon russatus*, was the first record for Uganda for this species.

Table 2. The number of each species of bat observed/trapped in the three protected areas in MFPA.

Family	Row Labels	Bugungu	Karuma	MFNP
Fruit Bats				
Pteropodidae	*Epomophorus labiatus*	8	1	12
	Epomops franqueti		3	1
	Hypsignathus monstrosus			1
	Micropteropus pusillus		4	1
	Rousettus angolensis			1
Insectivorous bats				
Nycteridae	*Nycteris macrotis*			1
	Nycteris thebaica	20		
Hipposideridae	*Hipposideros ruber*			9
Megadermatidae	*Lavia frons*	6		
Embalonuridae	*Taphozous mauritianus*		4	1
Vespertilionidae	*Glauconycteris argentata*			4
	Glauconycteris humeralis			1
	Glauconycteris variegata		1	
	Mimetillus moloneyi			1
	Pipistrellus capensis		1	4
	Pipistrellus guineensis			1
	Pipistrellus nanulus			1
	Pipistrellus nanus			2
	Pipistrellus rueppelli			1
	Pipistrellus somalicus			2
	Scotoecus albofuscus			2
	Scotoecus hirundo			4
	Scotophilus dinganii			4
Molosidae	*Chaerephon ansorgei*			2
	Chaerephon pumilus			1
	*Chaerophon russatus**			1
	Mops condylurus			3
	Number of species	**3**	**6**	**24**

*This is the first record of this species for Uganda

Rodents and Shrews

The 16 rodent species are listed in table 3 together with the 15 shrew species. The number of rodent species was more similar between protected areas and for shrews Bugungu and MFNP were similar in number but Karuma had few species. One rodent species, *Thamnomys venustus*, is Vulnerable on the IUCN global redlist and is also an Albertine Rift endemic species. It was found in Karuma WR.

Table 3. The number of shrew and rodent species observed in the three protected areas in MFPA.

Shrews	**Bugungu**	**Karuma**	**MFNP**
Crocidura denti			2
Crocidura dolichura	1		
Crocidura fuscomurina	1		
Crocidura gracilipes	1		2
Crocidura hildegardeae			5
Crocidura hirta	2		
Crocidura jacksoni	1		
Crocidura luna		2	1
Crocidura nanilla			1
Crocidura nigrofusca			8
Crocidura olivieri	4		4
Crocidura parvipes	3		
Crocidura roosevelti			2
Crocidura sp	6	4	11
Crocidura turba			3
Total Shrew species	**8**	**2**	**10**
Rodentia	**Bugungu**	**Karuma**	**MFNP**
Aethomys hindei	3	3	9
Aethomys kaiseri	2		4
Dendromus melanotis	1		
Dendromus mystacalis	1		1
Grammomys dolichurus		2	1
Graphiurus murinus			2
Lemniscomys barbarus	1	1	1
Lemniscomys macculus	1		
Lemniscomys striatus	4	6	11
Lophuromys aquilus		6	1
Lophuromys sikapusi	1	3	2
Mastomys natalensis	19		24
Mus mahomet	5	1	10
Mus musculoides	5	2	6
Mus triton		2	
Thamnomys venustus		1	
Total Rodent species	**11**	**10**	**12**

Sampling intensity differed between protected areas and a comparison between sites is best made with rarefaction curves (Figure 3). This shows that MFNP was richer in small mammal species compared with the two Wildlife Reserves which were similar in small mammal species richness. Mapping the

relative distribution of small mammal species richness did not show any clear pattern across MFPA (figure 4).

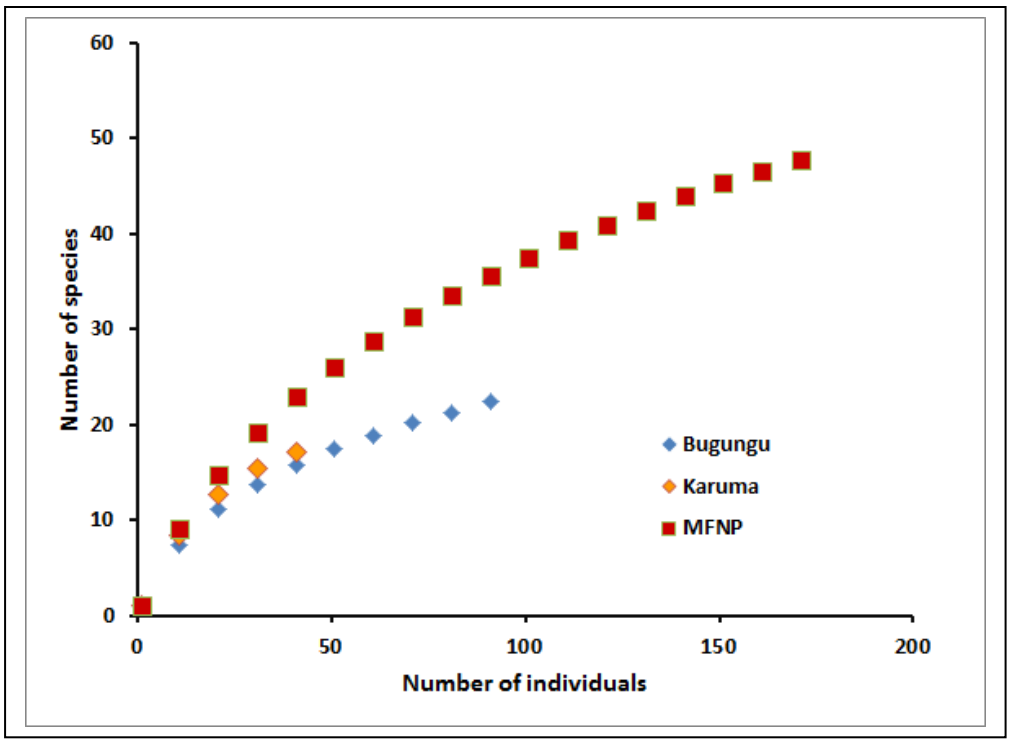

Figure 3. Rarefaction curves for the three protected areas showing the greater species richness of MFNP.

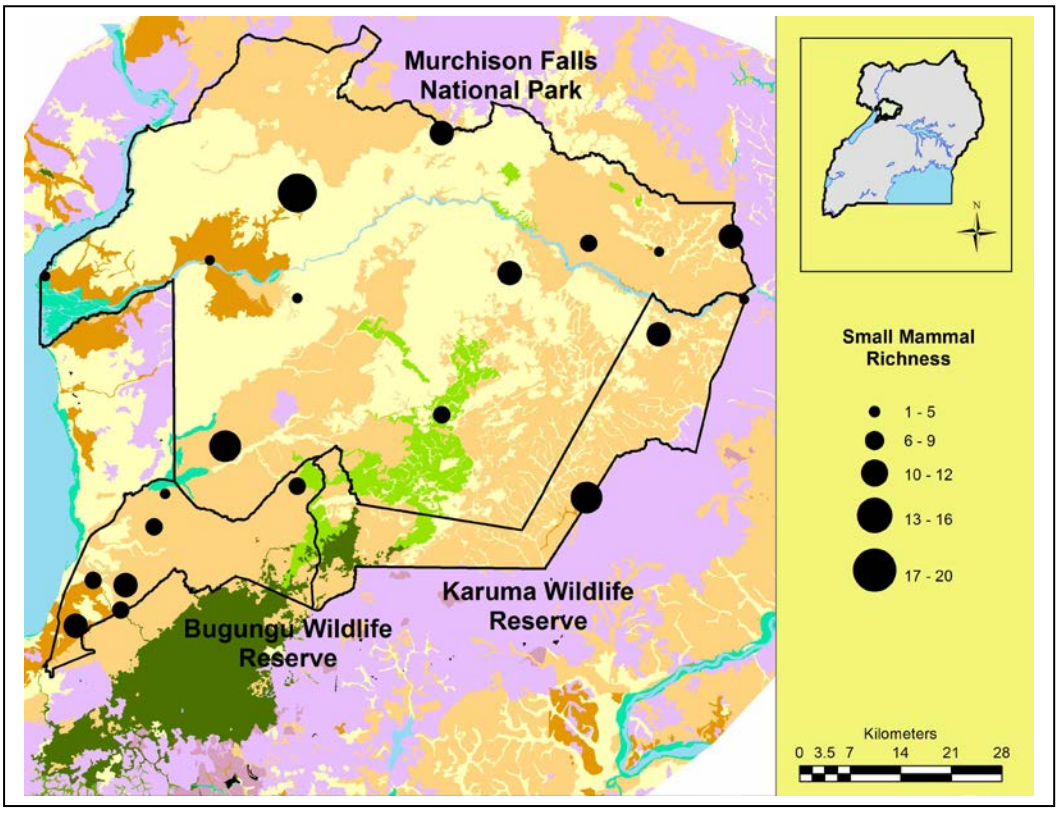

Figure 4. Map of relative species richness of small mammals across MFPA.

Species diversity was calculated for small mammals in each protected area (table 4) and shows the higher diversity in MFNP whether using the Shannon-Wiener or Alpha index.

Table 4. Shannon Wiener diversity and evenness and the Alpha diversity index calculated for the three protected areas.

Index	Bugungu Wildlife Reserve	Karuma Wildlife Reserve	Murchison Falls
Shannon H' Log Base 10.	1.134	1.177	1.469
Shannon J' (evenness)	0.833	0.938	0.874
Alpha diversity index	9.524	10.664	21.992

Birds

A total of 340 bird species were recorded in the MFPA with 133 species recorded in Karuma WR, 232 in Bugungu WR, 220 in Murchison Falls National Park and 162 in the human modified landscape north and south of Bugungu. The lower numbers of species for Karuma WR were mainly due to a lower sampling effort there compared with the other two protected areas. A total of 556 bird species are known from MFPA, adding 106 species to the list of Wilson (1995), mostly forest species from the Wildlife Reserves. Rarefaction curves, which plot the number of species observed against number of birds seen, show that the species richness is likely to be slightly higher in Bugungu WR than MFNP. The human modified landscape had many fewer species and the rarefaction curves had almost leveled off at 162 (figure 5).

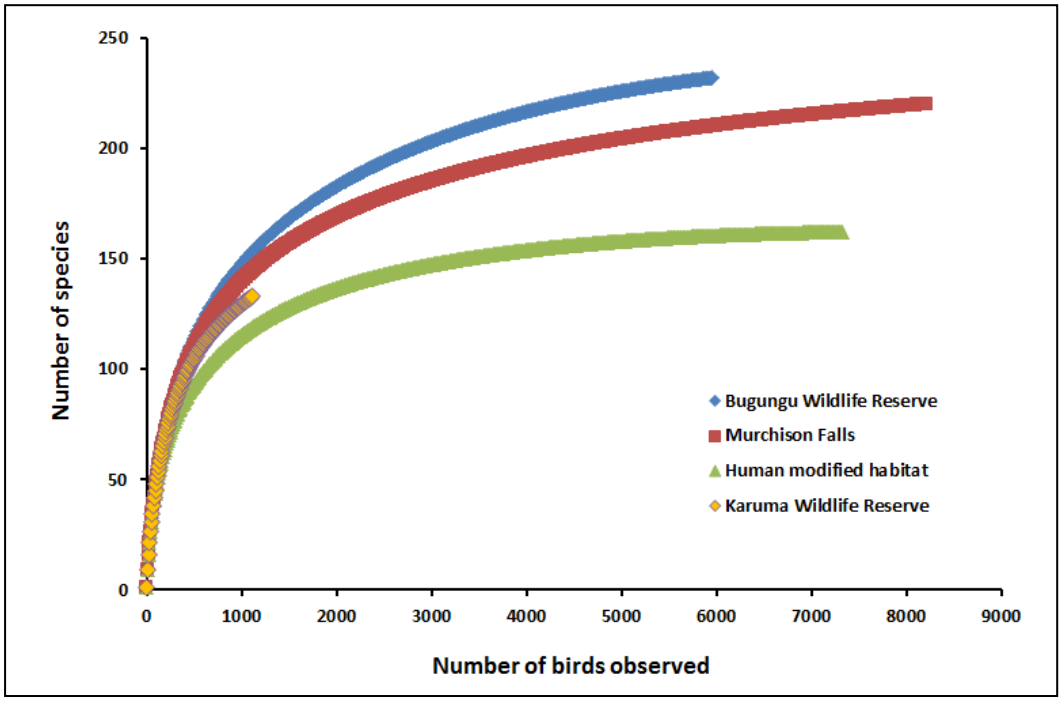

Figure 5. Rarefaction curves for the three sites plotted against the number of birds observed. Data were from point counts.

The distribution of species richness indicates that the number of species seen at each of the transects varies from 19 to 72 (figure 6). Some areas of Karuma Wildlife Reserve and northern MFNP had few species despite several point counts at each site. The richest areas were in central MFNP and also at the edge of Bugungu and MFNP where transects were also in the community land (human modified

habitat). Species that are found in human modified habitat tend to be common species but will increase species richness values of these sites.

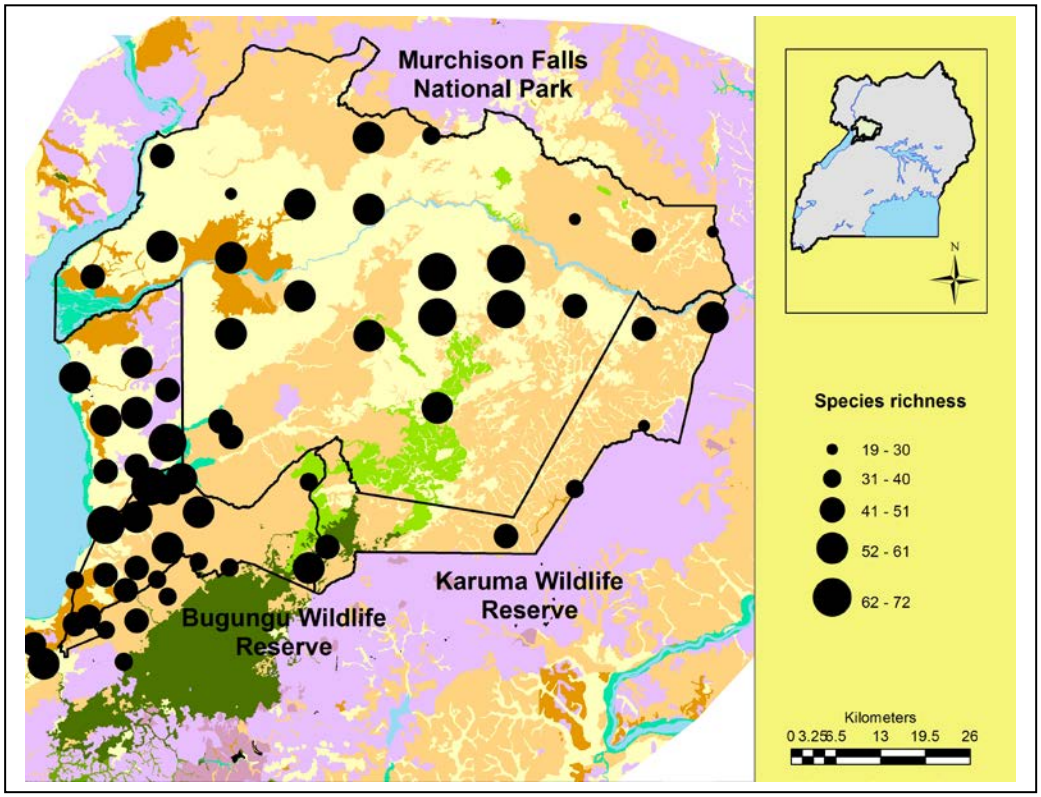

Figure 6. Relative bird species richness from point counts along each transect surveyed in the three protected areas.

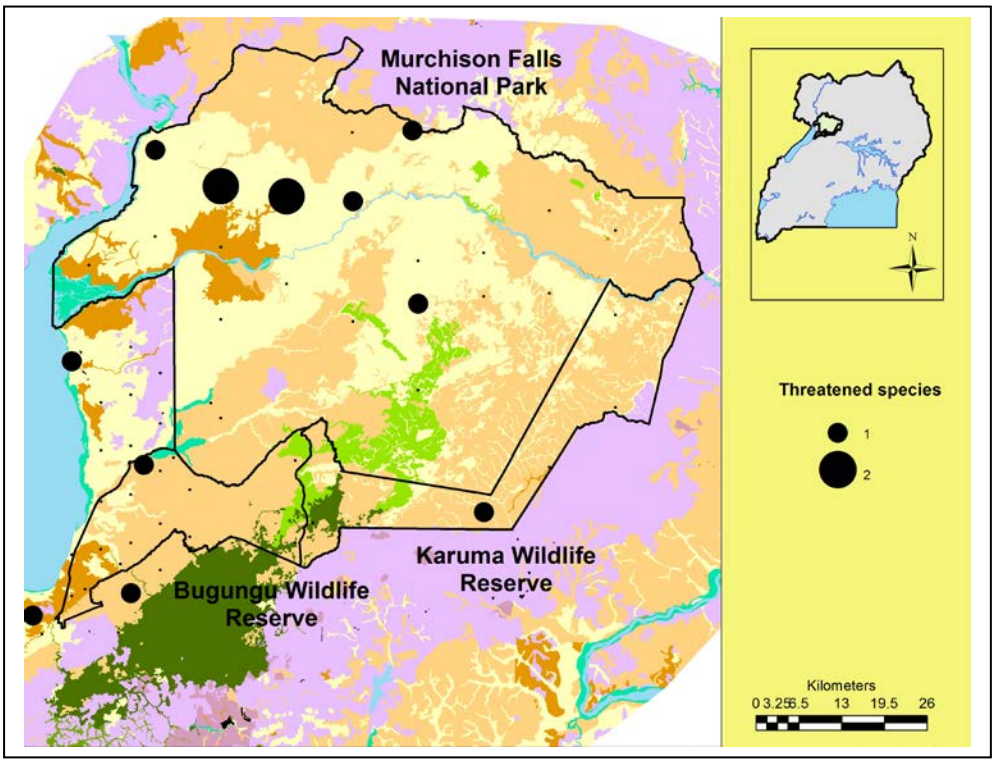

Figure 7. Locations of sightings of threatened bird species.

No bird species that are endemic to the Albertine Rift were observed in the MFPA but four threatened species were; African White-backed Vulture (*Gyps africanus*) and Ruppell's Vulture (*Gyps ruppelli*) which are Endangered and were only recorded in MFNP (at 5 point counts each) and not in the wildlife reserves, Martial Eagle which is Vulnerable was recorded at five point counts; two in MFNP and two in Bugungu WR and one in Karuma WR; and Grey-crowned Crane (*Balearica pavonina*) which is endangered and was recorded at seven point counts. Figure 7 plots the locations of these sightings and shows that only one threatened species was seen at most transects but two threatened species were seen on two transects in the heart of the park.

Diversity measurements using the Shannon Wiener Diversity measurement and the Log Series Alpha diversity measurement show that Bugungu tends to be the most diverse site (table 5). The Shannon-Wiener index is presented here because it is often used in studies and so allows comparisons to be made with other studies. However, it is known to overweight rare species and that the alpha diversity index is a better measurement of diversity (Krebs 1989).

Table 5. Shannon Wiener diversity and evenness and the Alpha diversity index calculated for the three protected areas.

Index	Bugungu Wildlife Reserve	Murchison Falls	Human modified habitat	Karuma Wildlife Reserve
Shannon H' Log Base 10.	1.85	1.77	1.74	1.74
Shannon J' (evenness)	0.78	0.76	0.79	0.82
Alpha diversity index	48.07	41.53	29.35	39.44

A cluster analysis using the Bray Curtis similarity measure showed that the bird community in human modified habitat in Buliisa District was most similar to the bird community in Bugungu Wildlife Reserve (Figure 8). Karuma Wildlife Reserve had a very different bird community, mainly because of the dense woodland that is found there, with less than 25% overlap in species composition with the other three sites. These results show that each protected area is conserving different communities of birds and despite their close juxtaposition the two wildlife reserves are important in their own right for the diversity of MFPA.

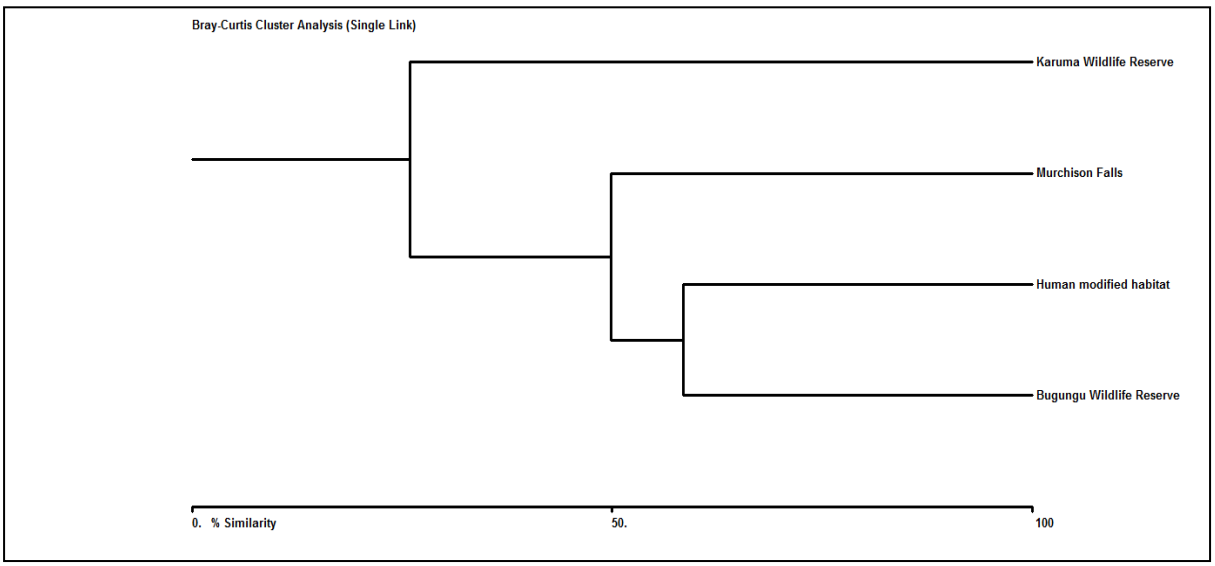

Figure 8. The percentage similarity in bird fauna between the three protected areas. Despite similar numbers of species there are big differences in species composition.

Reptiles

A total of 29 reptile species were recorded from these surveys. Eighteen species were found in Bugungu WR, six species in Karuma WR and 25 species in MFNP. None of these were endemic to the Albertine Rift or threatened species. This brings the list of reptiles for the MFPA to 51 compiling prior lists from surveys of this region and these surveys, including 44 species in MFNP, 25 in Bugungu WR and 18 in Karuma WR. No species endemic to the Albertine Rift or threatened species are known form MFPA.

Reptiles and amphibians are collected opportunistically and only one or two specimens are collected for identification purposes at any site. It is therefore not possible to plot rarefaction curves using number of individuals encountered at a site on the X-axis. Instead we plotted number of sites with number of species at a site (figure 9).

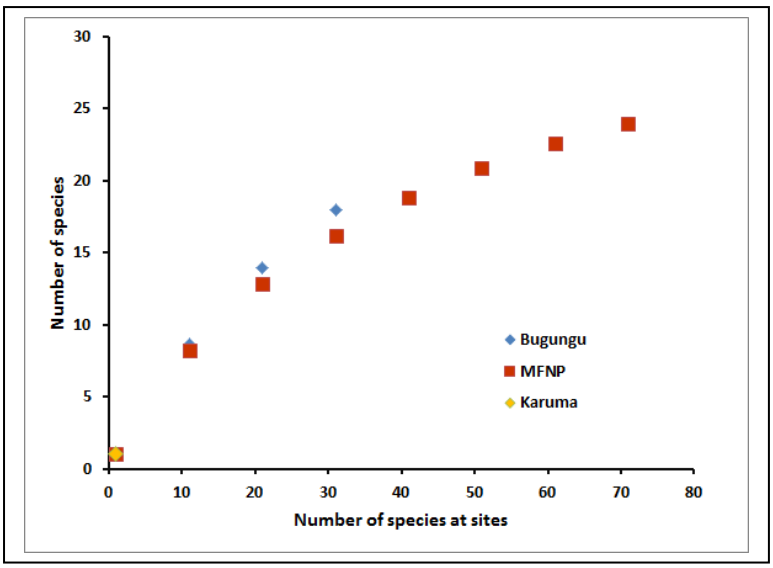

Figure 9. Rarefaction curve for the three protected areas. Karuma only has one point as few sites were sampled.

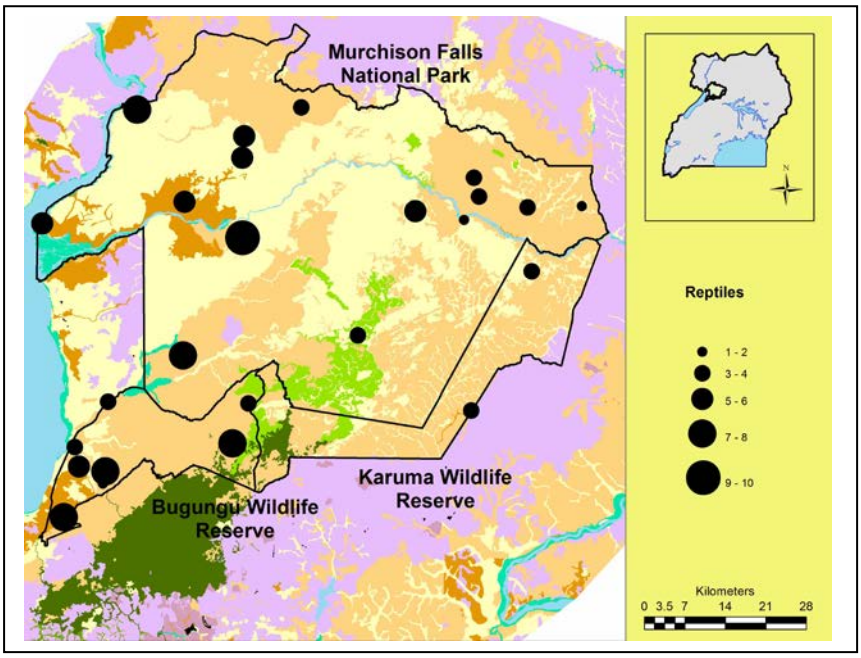

Figure 10. Relative richness of reptile species across MFPA.

Reptile species were more numerous in the western side of MFNP and in sites in Bugungu WR when compared with the eastern side of MFNP (figure 10).

The diversity of reptile species as measured by Shannon-Wiener or the alpha index differ by site (table 6). With the alpha measure the two wildlife reserves are more species rich while with the Shannon-Wiener index MFNP is slightly richer. Given the close rarefaction curves in figure 9 and the low sampling effort in Karuma WR it is likely that with more effort better measures of diversity would be obtained.

Table 6. Shannon Wiener diversity and evenness and the Alpha diversity index calculated for the three protected areas.

Index	Bugungu Wildlife Reserve	Murchison Falls	Karuma Wildlife Reserve
Shannon H' Log Base 10.	1.169	1.239	0.759
Shannon J' (evenness)	0.931	0.886	0.976
Alpha diversity index	17.926	12.481	19.941

Amphibians

A total of 45 amphibian species were found in the MFPA. Amphibians are difficult to identify to species on morphology alone and samples have been sent to the Trento Science Museum for genetic analysis to confirm preliminary species identifications. Some species however, could only be identified to genus level. A total of 36 species were found in MFNP, 30 in Bugungu WR and 13 in Karuma WR but the later was only sampled at two locations. No Albertine Rift endemic species nor threatened species were found. Of these species 23 still need to be identified to species level from Genus level.

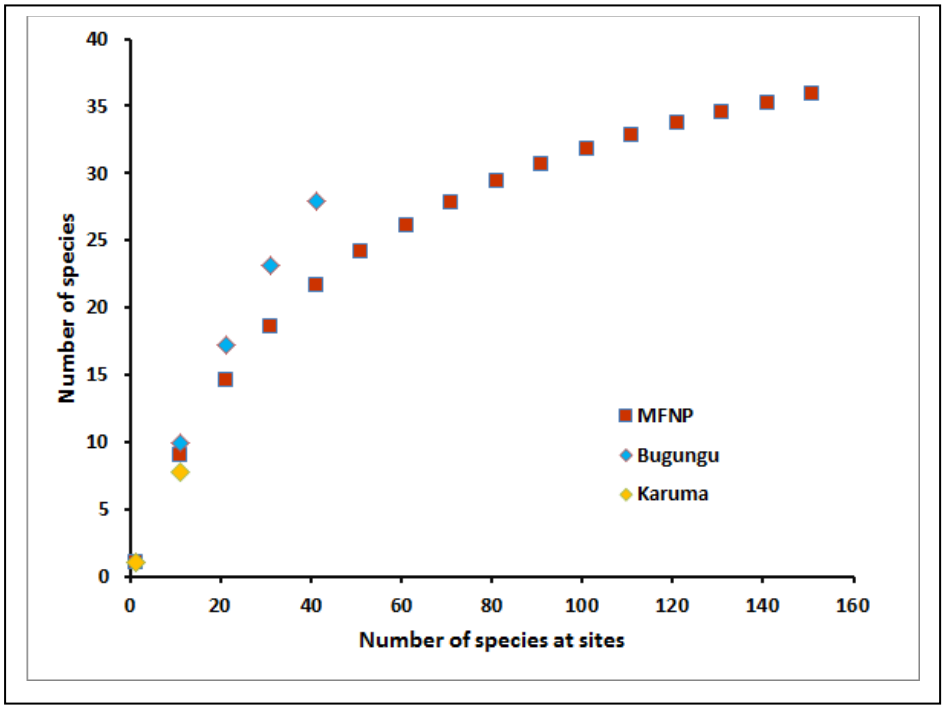

Figure 11. Rarefaction curves for the three sites plotted for the number of sites with species.

The rarefaction curves show that Bugungu WR looks to be more species rich than MFNP or Karuma WR, although the sampling of only two sites in Karuma limits what we can determine for this site. No clear pattern in richness occurs across the MFPA (figure 12) but higher richness seems to be in the wooded and forested areas.

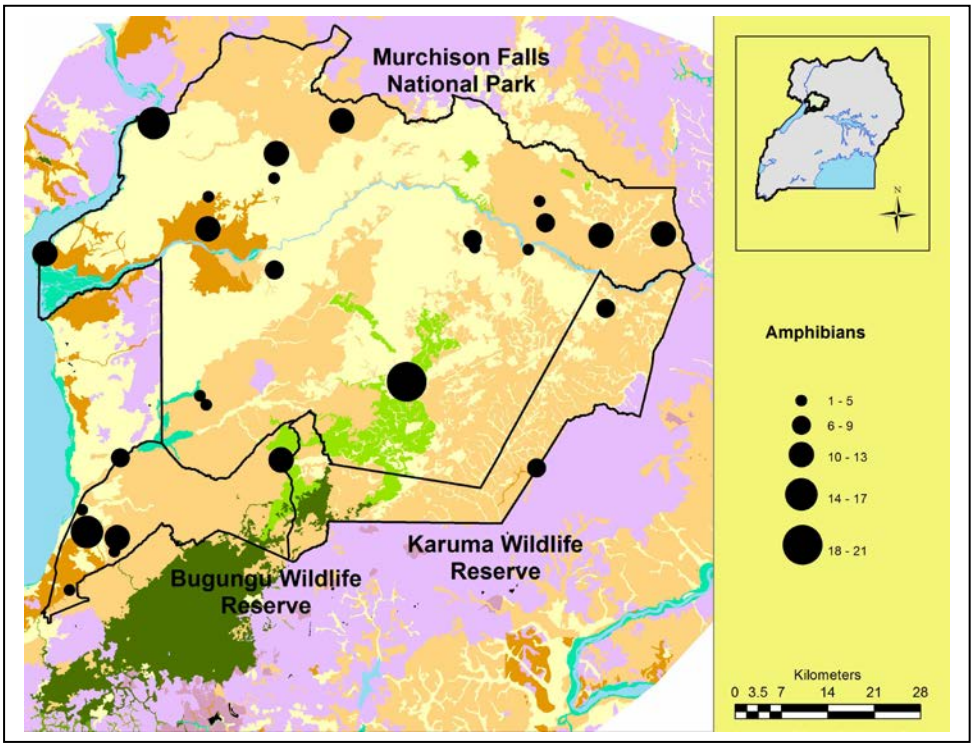

Figure 12. Relative richness of amphibian species across MFPA.

Table 7. Shannon Wiener diversity and evenness and the Alpha diversity index calculated for the three protected areas.

Index	Bugungu Wildlife Reserve	Murchison Falls	Karuma Wildlife Reserve
Shannon H' Log Base 10.	1.419	1.43	0.954
Shannon J' (evenness)	0.912	0.968	1
Alpha diversity index	14.838	37.416	7.162

Both Shannon-Wiener and alpha diversity indices rank MFNP as being richer than the wildlife reserves, probably because of the fewer sampling sites. The rarefaction curves give a better comparison of sites (figure 11).

Plant species

A total of 755 plant species were identified from 455 plots surveyed across all sites with 539 species in Bugungu WR, 421 species for MFNP, 303 species in the human modified habitat and 275 species in Karuma WR. Bugungu WR is significantly richer in plant species as shown in the rarefaction curves while the other sites were all similar in species richness (figure 13).

Eight threatened plant species were recorded (all globally vulnerable) with five in Bugungu WR, three in Karuma WR, two in MFNP and one in the Human modified habitat in Buliisa (Table 8). Bugungu not only has more species of threatened plant but also had more plots with threatened species. Seven species endemic to the Albertine Rift were also found with four in Bugungu WR and only one at each of the other sites. Bugungu also had more plots with endemic species found in them (Table 9).

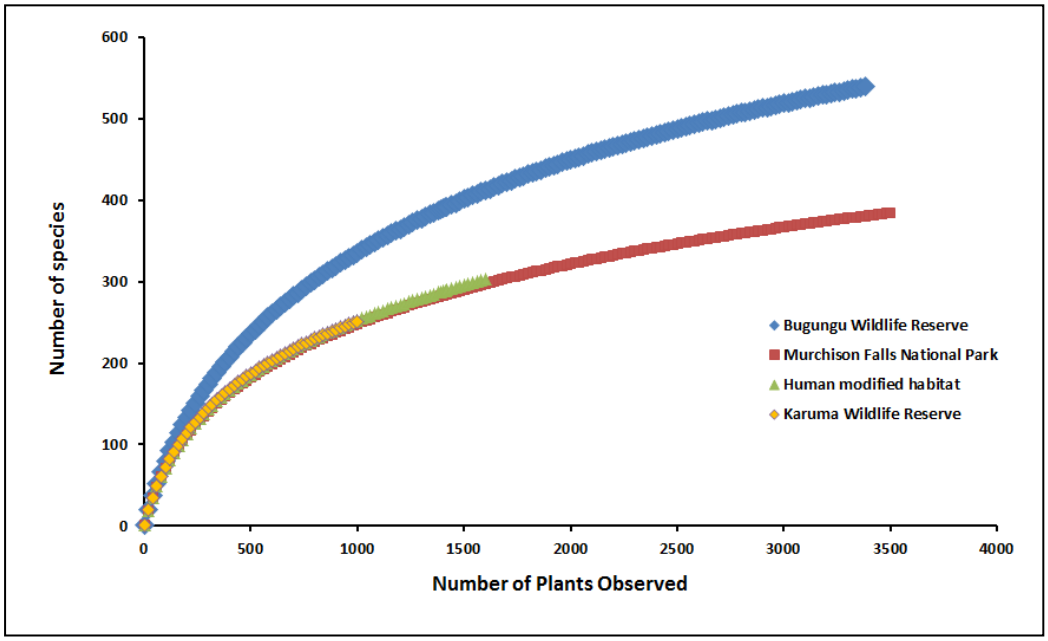

Figure 13. Rarefaction curves for plant species. Data from plots.

Table 8. The number of plots in which threatened species of plant (VU) were found in each of the three protected areas and human modified habitat.

Species	Bugungu WR	Human modified habitat	Karuma WR	Murchison Falls National Park
Afzelia africana				3
Albizia ferruginea			1	
Entandrophragma cylindricum			2	
Khaya anthotheca	4		1	
Khaya grandifoliola	3			1
Lovoa trichilioides	2			
Prunus africana	1			
Psilotrichum axilliflorum	4	1		
Number of plots with threatened species	**14**	**1**	**4**	**4**

Table 9. The number of plots in which species of plant endemic to the Albertine Rift were found in each of the three protected areas and human modified habitat.

Species	Bugungu WR	Human modified habitat	Karuma WR	Murchison Falls National Park
Coccinia mildbraedii	2			
Entada phaneroneura	12			
Isoglossa laxiflora	3			
Isoglossa vulcanicola			2	
Rytigynia bugoyensis	1			
Thunbergia mildbraediana				2
Tinospora orophila		1		
Number of plots with threatened species	**18**	**1**	**2**	**2**

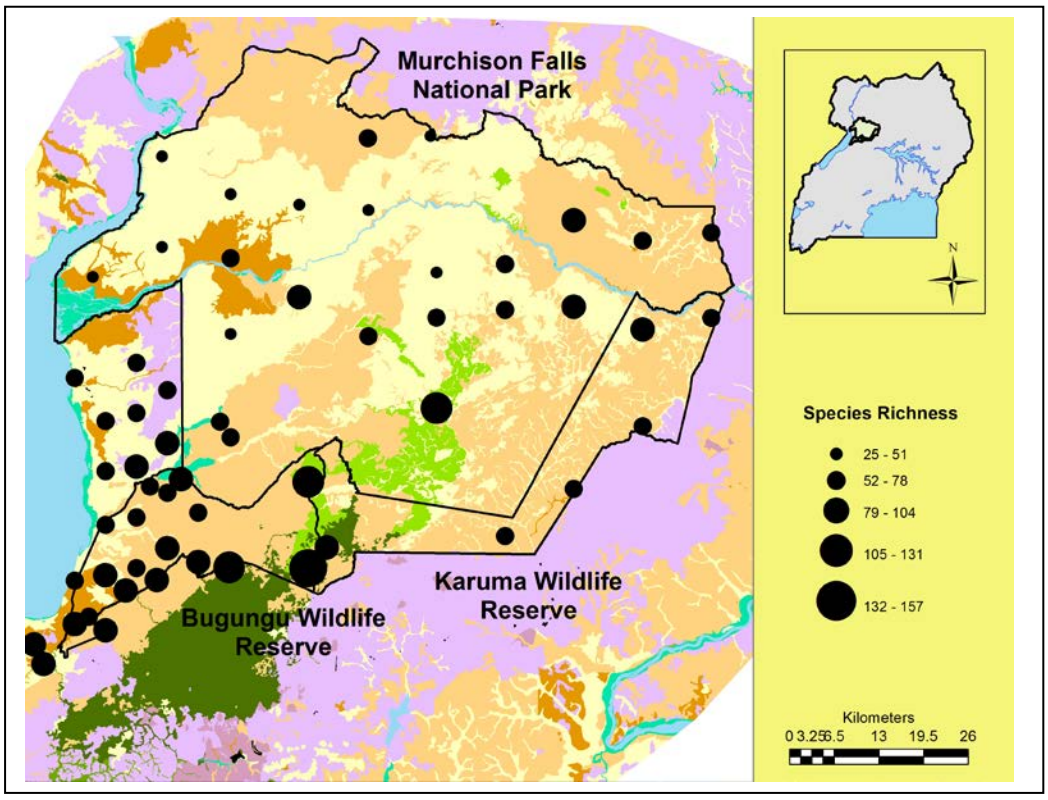

Figure 14. Plant species richness from plots along each transect.

Figure 14 shows the species richness of plants for each transect surveyed across the MFPA. It is clear the highest species richness is found on transects close to the Budongo Forest and in colonising forest (compare figure 14 with Figure 1). Grassland areas in MFNP have a very low species richness which is why the park ranks so much lower than Bugungu WR in terms of total species richness because grassland cover is much greater in the park.

Figures 15 and 16 plot the number of threatened plants and plants endemic to the Albertine Rift respectively. These figures show how important Bugungu WR is for endemic plant species which were found in forest and along the escarpment above Lake Albert. Threatened plant species appear to

be closely associated with forested or dense bushland areas and hence were more common in the forests in Bugungu WR.

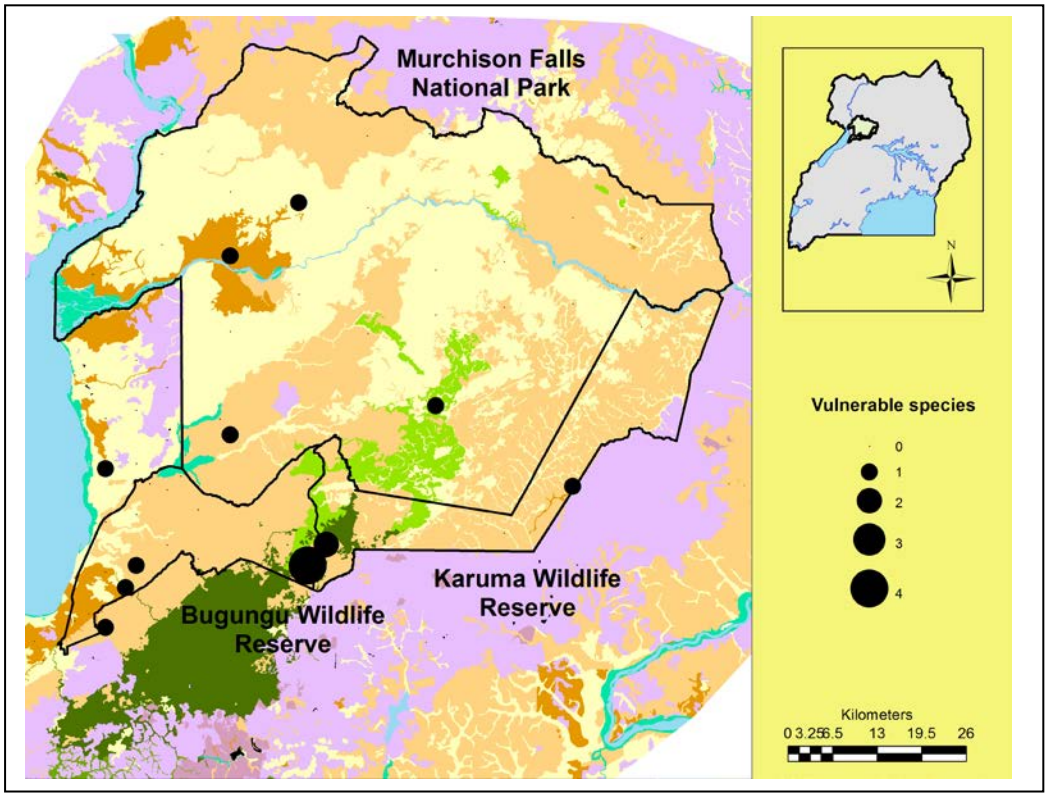

Figure 15. Richness of plant species that are VU under IUCN global redlisting

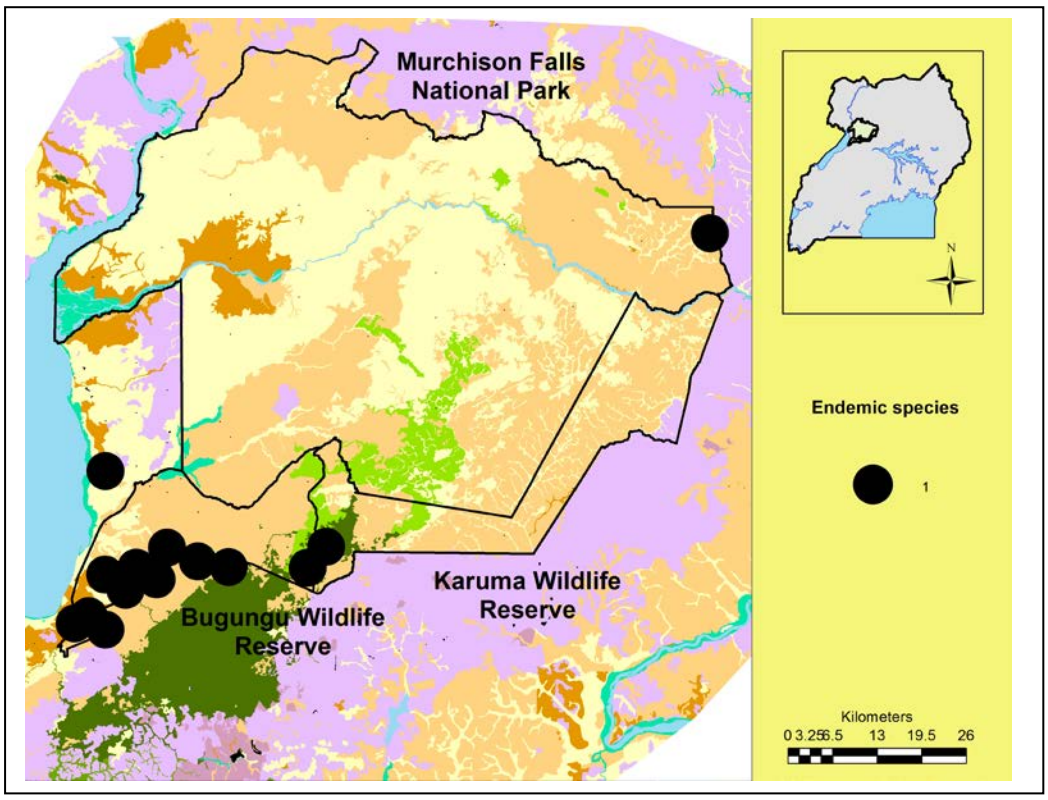

Figure 16. Number of Albertine Rift endemic plant species found on each transect

Diversity measurements using the Shannon Wiener Diversity measurement and the Log Series Alpha diversity measurement show that Bugungu WR tends to be the most diverse site although the Shannon Wiener evenness index indicates that Karuma WR is more even in its composition of species (table 10). The alpha diversity index ranks the human modified habitat as far less diverse than the Shannon Wiener index. The Shannon-Wiener index is presented here because it is often used in studies and so allows comparisons to be made with other studies. However, it is known to overweight species that are rarely encountered and that the alpha diversity index is a better measurement of diversity (Krebs 1989).

Table 10. Shannon Wiener diversity and evenness and the Alpha diversity index calculated for the three protected areas.

Index	Bugungu Wildlife Reserve	Murchison Falls	Human modified habitat	Karuma Wildlife Reserve
Shannon H' Log Base 10.	1.85	1.77	1.74	1.74
Shannon J' (evenness)	0.78	0.76	0.79	0.82
Alpha diversity index	48.07	41.53	29.35	39.44

A comparison of the similarity between communities using a Bray-Curtis clustering showed that Bugungu WR and MFNP were the most similar in species composition with 47% overlap but that Karuma WR was the most dissimilar with less than 30% overlap with any of the other sites (figure 17).

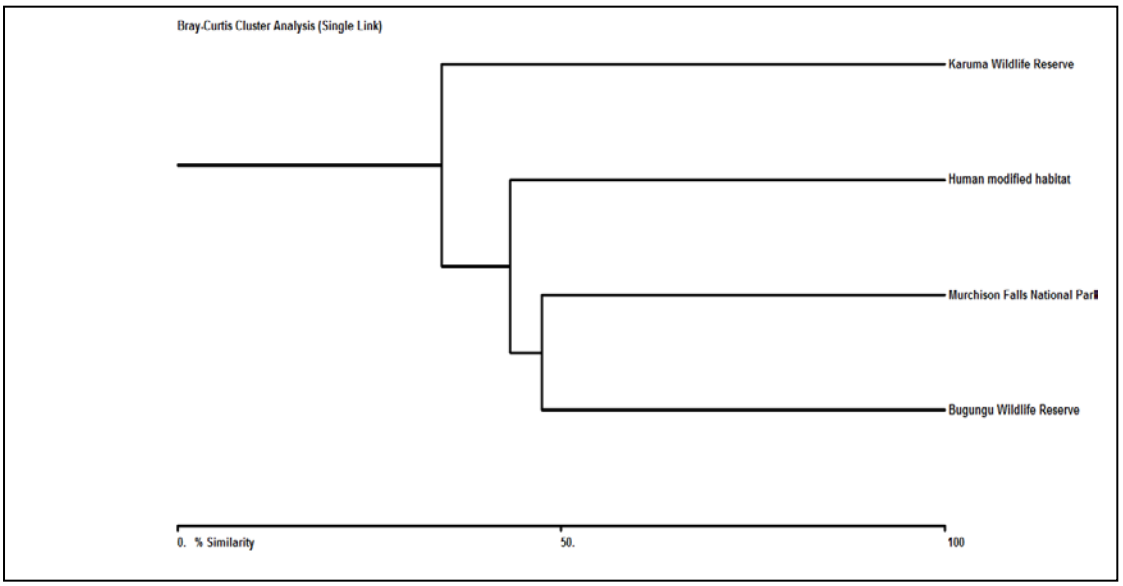

Figure 17. The percentage similarity in plant community between the three protected areas and human modified habitat.

CONSERVATION IMPLICATIONS

Biodiversity and species of Conservation Concern in MFPA

Combining the species described form the surveys above with previously published species lists for the park brings the numbers of species to many more than previously published (Table 11). Wilson (1995) published 76 mammal species for Murchison Falls National Park which has increased to 144 for MFPA with these surveys as well as other surveys that have been made in the park and wildlife reserves. This increase is mostly due to the intensive surveys of small mammals, particularly the shrews and bats. Similarly plant species have increased from 450 (J. Kalema in grey literature) to 755 with some specimens remaining to be identified. Bird numbers increased form 450 (Wilson 1995) to 555 with this survey as well as the Frontier surveys of Bugungu WR (Allen 1997). Plant species of conservation concern are listed in Tables 8 and 9 and threatened vertebrates are listed in table 12.

Table 11. The number of species for each taxon and number of restricted range species (Albertine Rift Endemic) and threatened species known from MFPA.

Taxon	Number of species	Albertine Endemics	Number threatened
Mammals	144		1 EN; 4 VU
Birds	556		4 EN; 7VU
Reptiles	51		
Amphibians	51		2 DD
Plants	755	7	8VU

Table 12. Threatened vertebrates from MFPA

Mammals	Birds	Amphibians
Chimpanzee (EN)	African White-backed Vulture (EN)	*Bufo vitattus* (DD)
Rothschild giraffe (EN)	Ruppell's Vulture (EN)	*Ptychadena chrystyi* (DD)
Lion (VU)	Hooded Vulture (EN)	
Hippopotamus (VU)	Egyptian Vulture (EN)	
Elephant (VU)	Shoebill (VU)	
Thamnomys venustus (VU)	Secretary Bird (VU)	
	Lappet-faced Vulture (VU)	
	White-headed Vulture (VU)	
	Martial Eagle(VU)	
	Lesser Kestrel (VU)	
	Black-crowned Crane (VU)	

Conservation of MFPA

The results of the surveys greatly increased the conservation value of this landscape, increasing species richness and identifying more species of global conservation concern. It also highlighted the biological value of Bugungu Wildlife Reserve which in the case of birds, amphibians and plants was richer in species than Murchison Falls National Park (see rarefaction curves). It was also the site where many of the endemic and threatened plants occurred. This is probably because Bugungu is very diverse in habitats and also includes Tropical High Forest with its overlap with the Budongo Forest Reserve.

Combining the species richness maps for all five taxa across MFPA is possible by calculating the ranking of each survey site (transect) in relation to other sites in terms of the number of species encountered for each taxon separately. The mean ranking is then calculated across the five taxa to provide an average value of species richness across the taxa (figure 18). This shows the importance of Bugungu WR graphically as well as the central areas of MFNP. There are rumours currently that politicians are lobbying for the degazettment of parts of Bugungu to provide land for people in the Buliisa District. In-migration of people looking for work in the Oil Industry as well as the collapse of the fisheries on Lake Albert is leading to limited livelihood options and the desire for land for cultivation. We would argue that these results show the biological importance of Bugungu WR for conservation.

Interestingly the species richness of sites outside the protected areas was also relatively high (mainly bird and plant species). Some of these sites were remaining wetlands and patches of natural habitat surrounded by farmland, but in other cases species richness could be high for bird species but they tended to be species that were very common and not of conservation value.

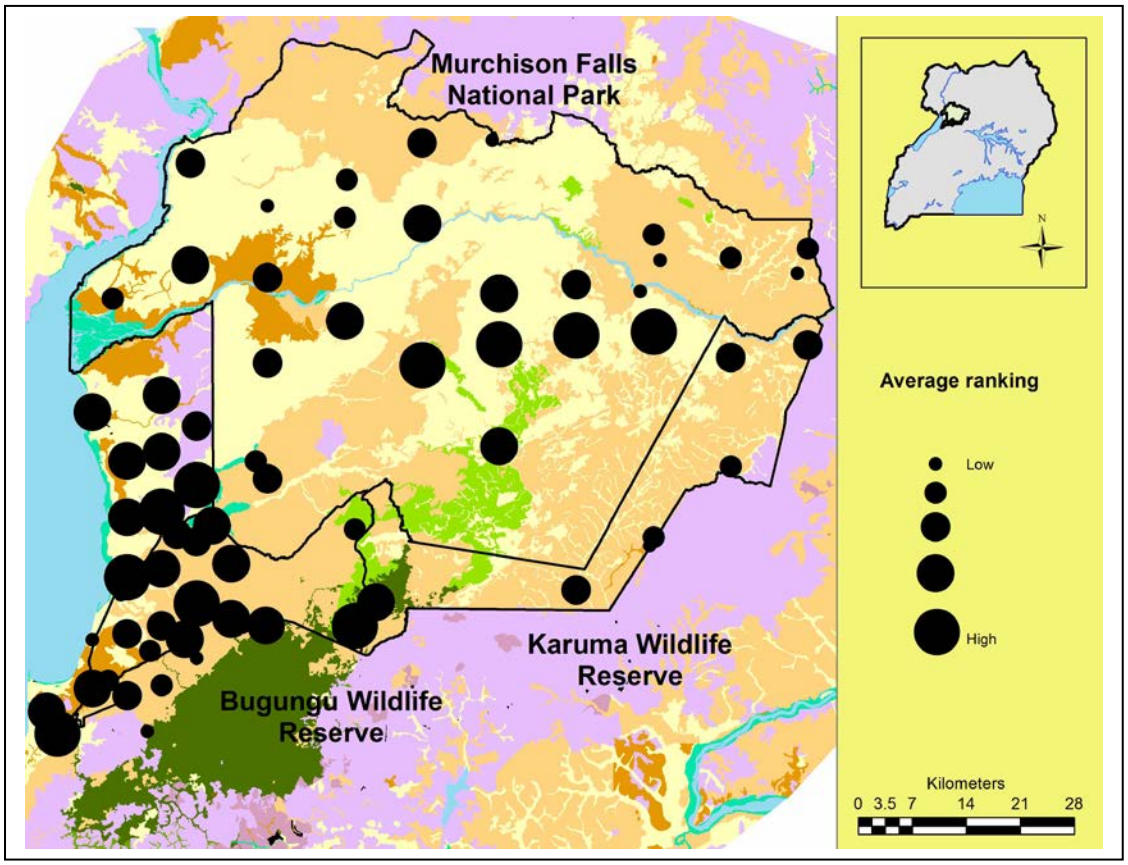

Figure 18. Average ranking across taxa, highlighting the areas of high overall biodiversity.

The development of Oil production in this region is of concern for the biodiversity that we report here. While we believe the oil companies and Government are making the correct approaches, working to minimize the impacts of the oil industry on this landscape these results make it even more imperative that great care is taken to ensure that none of the biodiversity is lost as a result of these activities. Careful planning of pipeline routes and roads should be made to avoid passing through the protected areas and where possible they should pass along the border of the protected areas and should be fenced. This would also reduce crop raiding conflict between the local people and Uganda Wildlife Authority and thereby encourage a win-win situation. However exact routing and fence locations and the manner of construction must still allow for migration of species between the MFPA and other important biodiversity sites, particularly to Budongo Forest, along the escarpment edges and forest corridors.

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