IMPACTS OF ANTHROPOGENIC ACTIVITIES ON THE BIODIVERSITY STATUS OF KASYOHA-KITOMI CENTRAL FOREST RESERVE, WESTERN UGANDA

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V. Executive Summary

Different species occupy different niches in the web cycle of life. Knowing what species inhabit an ecosystem, and how many of each kind there are, is critical to understanding that ecosystem's structure and function, and predicting future changes. Tropical forest ecosystems are known for sheltering the greatest biodiversity by comparison with many other ecosystems located in the same climatic zone. The tropical Forests are essential for life on earth and about 1.6 billion people depend on them for their livelihood.

The Kasyoha-Kitomi Central Forest Reserve (KKCFR) is part of a network of protected areas (PAs) located in the Albertine Rift region. This region is known for its rare and endemic flora and fauna. The Albertine Rift Forest system is a chain of forest patches (with interconnected forest corridors) that are a major global center of diversity and endemism and are a focus of most conservation and development agencies. Unfortunately, these unique and rare species (in KKCFR) are under serious threat from anthropogenic activities. Indeed, as Plumptre et al., (2007) noted, the identified the major threats to KKCFR forest as; hunting, illegal harvesting of timber and other plant products, charcoal burning, forest encroachment and mining. Recently (in 2021), the NFA granted permission to Jena herbals U (Ltd) to harvest bark from tree species of *Warbugia ugandensis* and *Zanthoxhylum gilletii* for the manufacture of Covid-19 therapeutic drug (Covidex). The Covidex drug is now widely available in all Ugandan pharmacies. The commercialization of the bark harvest from the two trees is a precursor to negative harvest impacts on the two tree species as discussed below.

Three taxa; vegetation (trees, shrubs, lianas, vines, and herbs), terrestrial vertebrates (small mammals) and birds were used as surrogate indicator species for the assessment of the status of total biodiversity in KKCFR. Furthermore, the study used the biodiversity assessment done in 2016 as baseline to compare the changes in biodiversity currently (2022). Human activities in KKCFR of 2022 were also recorded and compared with those previously done in 2016 (baseline). After analyzing the field data collected in 2016 and 2022 using R open-source statistical software version 3.2.2, the study came out with the following results.

A total of 110 tree species were recorded in KKCFR between 2016 and 2022 study period. In 2016, Ninety-four tree species were recorded while in 2022 forty-nine tree species were recorded . Of these tree species, *Strombosia schefflera, Funtimia africana, Warbugia*

ugandensis, Xymalos monospora, Macaranga kilimadscherica and *Shirakiopsis elliptica* were the most dominant in descending order. There was no significant difference in the abundance of the tree stems (expressed per unit hectare) recorded in 2016 and 2022. However, tree species evenness (abundance) and richness (diversity) were higher in the year 2016 than 2022.

A total of 92 shrub and liana species were recorded in KKCFR between 2016 and 2022 study period. In 2016, forty seven shrub and liana species were recorded in while in 2022 forty six species of shrubs and lianas were recorded. Of these, the most dominant shrub and liana species in descending order were *Piper capense, Triumfetta brachyceros, Piper guineense, Brillantaisa citricosa, Dracaena laxissima and Alchornea hirtella.* The total stem abundance of the shrubs and lianas (expressed per unit hectare) was significantly different between 2016 and 2022. In terms of species evenness and richness (diversity), the year 2016 recorded higher values than 2022, with the implication that since 2016, KKCFR could have lost some shrub and liana species perhaps due to human activities.

A total of 57 vines and herbs species were recorded in KKCFR between 2016 and 2022 study periods. Forty-seven vine and herb species were recorded in 2016 while forty-six vine and herb species were recorded in 2022. Of these, the most dominant vine and herb species in descending order *Oplismenus hirtelleus, Panicum adenophorum, Panicum adenophorum, Pteendium aquilium, Palisota mannii, Panicium sp*., and *Asplenium sp*. The relative abundance of the vines and herbs (expressed per unit hectare) were significantly different between 2016 and 2022. Species evenness and richness of the vines and herbs was higher in 2016 than in 2022 perhaps a result of human activities in KKCFR.

A total of 9 rodent species were recorded in KKCR between 2016 and 2022 study period. In 2016, nine species of rodents were recorded while in 2022, only five species of rodents were recorded. Of these, the most dominant rodent species in descending order were *Malacomys longipes, Praomys jacksonii, Praomys jacksonii, Laphuromys sp* and *Syvisorex grantii*. The relative abundance of the rodents (expressed per unit hectare) was not significantly different between 2016 and 2022. Furthermore, the rodents’ species evenness and richness were slightly higher in 2016 than in 2021 perhaps caused by human activity impacts.

A total of 135 bird species were recorded in KKCFR in both 2016 and 2022 study time periods. In 2016, 81 bird species were recorded, while in 2022 110 bird species were detected. Three species are endemic to the mountains along the Albertine Rift - Blue-headed Sunbird *Cyanomitra alinae*, Red-faced Woodland Warbler *Phylloscopus laetus*, and the Yellow-eyed Black Flycatcher *Melaenornis ardesiacus.* The most common bird species encountered were the Tambourine Dove *Turtur tympanistria*, Yellow-whiskered Greenbul *Eurillas latirostris*, Yellow-rumped Tinkerbird *Pogoniulus bilineatus*, African Paradise-flycatcher *Terpsiphone viridis*, Common Bulbul *Pycnonotus barbatus*, Montane Oriole *Oriolus larvatus*, and Narina Trogon *Apaloderma narina*.

Due to the heterogeneous habitat created by disturbance being taken up by large numbers of successional or opportunistic species, while precluding some primary forest specialists, the species richness and density were higher in 2022 than 2016. However, the species diversity, evenness and dominance were lower in 2022 than in 2016. This could be attributed to the ongoing severe but localized human disturbances in our study area that made the birds to frequently move between different sites while feeding or breeding so that their populations were unstable and transient with a few residents. Increased forest disturbance created more forest edge, tree fall gaps and secondary forest that favour the forest generalists (F-species). Therefore, the F-species increased in number of species and density. However, the F-species are of low conservation value since they are widely distributed. The forest interior specialists (FF-species) were found to be declining. Increased forest canopy openings and vegetation density at ground level because of disturbance favour the frugivores and mixed feeders. However, the flycatchers, forage gleaners and ground feeders were adversely affected by change in the microclimate caused by forest disturbance. The understory insectivores – flycatchers, forage gleaners and ground feeders - that are highly susceptible to forest disturbance can be useful as indicators of forest disturbance impacts. KK has not been colonized by forest visitors (f-species) of non-forest and edge habitats. This probably implies that the vegetation structure and composition of the CFR has only been moderately modified.

The two harvested tree species of *Warbugia ugandensis* and *Zanthoxylum gilleti* for bark showed a population distribution with with very many seedlings and juveniles but fewer harvestable mature or adult individuals (those >11.5cm). Of the 196 tree species of *Warbugia ugandensis* sampled, only 36% had not been harvested for bark while 45% had been totally ringbarked. Furthermore, of the 67 *Zanthoxylum gilleti* tree sampled, 41% had not been harvested for bark and 33% had been ringbarked. This study shows that there is unsustainable/uncontrolled harvest of bark from the two trees in KKCFR and this is detrimental to the survival of those trees.

The most prevalent human activities recorded in KKCFR for both 2016 and 2022 in descending order were fresh human trails, firewood collection, tree bark harvest and charcoal burning. The number of human activity signs recorded in KKCFR increased from 29 in 2016 to 102 in 2022 and was statistically significant. This study also observed the active replacement of natural forest patches with eucalyptus plantation by NFA. The human activities in KKCFR have been increasing with increased demand of forest resources exacerbated by the human population growth of the surrounding local communities.

Without doubt, the human activities within the KKCFR have more than tripled and are likely to increase further as the human population increases and with the increased commercialization of forest resources (bark harvests and charcoal burning). This is a precursor to the increased loss of biodiversity in the KKCFR. Although the biodiversity loss is not yet at an alarming wide scale, the loss of some flora and fauna species since 2016 is of particular concern to conservationists. Several recommendations have been suggested by this study that include enhanced strict law enforcement in KKCFR and proactively encouraging agroforestry activities in the local communities around KKCFR by development organizations. Bark harvest from the trees of *Warbugia ugandensis* and *Zanthoxylum gilleti* should be strictly by NFA with guidelines of dos and don’ts to help sustain the bark harvest and the two tree species.

1.0 Introduction

Different species occupy different niches in the web of life. Knowing what species inhabit an ecosystem, and how many of each kind there are, is critical to understanding that ecosystem's structure and function, and predicting future changes (Pauchard et al., 2018). Recent global efforts in biodiversity accounting, such as those undertaken through the Convention on Biological Diversity (CBD) and Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), are vital if we are to track conservation progress, ensure that we can address the challenges of global change, and develop powerful and scientifically sound indicators.

Tropical forest ecosystems are known for sheltering the greatest biodiversity by comparison with many other ecosystems located in the same climatic zone. The tropical Forests are essential for life on earth and about 1.6 billion people depend on them for their livelihood (Ghazoul & Sheil, 2010; Pauchard et al., 2018). These forests also provide habitat for vast array of plants and animals, many of which are still undiscovered. Furthermore, the forests protect watersheds, supply oxygen through carbon sequestration and in some cases provide timber for products we use every day. The forests also play critical roles in mitigating climate change because they act as carbon sinks that soak up carbon dioxide and other greenhouse gases. Tropical forests are so much more than a collection of trees. There are home to 80% of terrestrial biodiversity that are ecosystems of complex web organisms, which include plants, animals, fungi and bacteria (Ghazoul & Sheil, 2010; Pauchard et al., 2018) providing an array of ecosystem services . Unfortunately, these tropical forests are being destroyed and degraded at alarming rates. Deforestation of these forests comes in many forms that include fires, clear-cutting, unsustainable logging for timber and degradation due to climate change (Ghazoul & Sheil, 2010).

The Kasyoha-Kitomi Central Forest Reserve (KKCFR) is part of a network of protected areas (PAs) located in the Albertine Rift region. This region is known for its rare and endemic flora and fauna. The Albertine Rift Forest system is a chain of forest patches (with interconnected forest corridors) that are a major global center of diversity and endemism and are a focus of most conservation and development agencies. The significant biodiversity values of the Albertine Rift Forests have been highlighted in many global and national environmental planning reports. Globally, the Albertine Rift is acknowledged as a major center of diversity and endemism for many taxa. The National Environment Action Plan of Uganda (NEAP) recognizes the global significance of these forests. Most of these forests are cross-border forests and include Bwindi, Echuya, Mgahinga, Queen Elizabeth, Rwenzoris and Virungas while others are located within the national Uganda boundaries and include Kasyoha-Kitomi, Budongo and Kalinzu forests. Responsibility for the management of these PAs is fragmented with some being managed by the Uganda Wildlife Authority (UWA), National Forest Authority (NFA) and respective district local governments.

The Kasyoha-Kitomi forest is managed by the NFA and has experienced past deforestation that has led to considerable fragmentation of forest cover, a process that continues today with grave consequences for loss of biodiversity. These are majorly anthropogenic causes from high human population density; extreme poverty and heavy dependence on forest resources by neighboring communities that exert immense pressure on the forest reserve. Indeed, (Plumptre et al., 2007) has identified the major threats to Kasyoha-Kitomi forest as; hunting for bush-meat, illegal harvesting of timber and other plant products, charcoal burning, forest encroachment (for farmland) and Mining. Some of the important fauna in Kasyoha-Kitomi include Chimpanzees, elephants, and monkeys.

2.0 Importance of the Study

Biodiversity assessment is mandatory for the implementation of any sustainable forest management policy and, as a fact, is included in the number of criteria and indicators currently in use. Recent studies have revealed a staggering statistics in global biodiversity loss: approximately 1 million plant and animal species are threatened with extinction. Since 1900, the average abundance of most land-based habitats has fallen by nearly 20% (Ghazoul & Sheil, 2010). Increased human populations and their resultant activities are the major causes of global biodiversity loss. This loss has further been exacerbated by climate change and its impacts. Although we know global biodiversity is decreasing, we don't have enough data to fully understand how biodiversity loss and the ecosystems are being affected. These data are especially critical because the first step in protecting and managing biodiversity is understanding what species exist and the effects of anthropogenic activities and other environments impacts through biodiversity surveys. During the past half century, global climate change and human disturbances have become the main drivers of ecosystem change, and have had a huge impact on ecosystems (Li et al., 2021). Human activities have shaped large scale distributions of many species, driving both range contractions and expansions. Species differ naturally in range size, with small-range species concentrated in particular geographic areas and potentially deviating ecologically from widespread species. Hence, species' responses to human activities may be influenced by their geographic range sizes, but if and how this happens are poorly understood(Xu et al., 2019).

Few biodiversity status studies have been carried out in Kasyoha-Kitomi Central Forest Reserve (KKCFR); and these include (Howard, 1991; Plumptre *et al*.,2003; Plumptre et al., 2007; Bitariho *et al* 2016). The former two studies were based on field surveys while the latter was based on published and unpublished literature sources. Plumptre *et al*. (2003) does not provide species lists but only the number of species per taxon. Bitariho *et al* 2016 on the other hand carried out comprehensive biodiversity surveys of KKCFR. There is need to understand the changes in biodiversity that could have taken place due to anthropogenic perturbations that were abundant in the 2016 biodiversity surveys. Bitariho *et al* 2016 noted a high level of human activities (charcoal burning, poaching, pitswaying poles/stake cutting etc.) in KKCFR. These activities had greatly affected the abundance and distribution of different flora and fauna in KKCFR (Bitariho *et al* 2016).

Recently (in 2021), the NFA granted permission to Jena herbals to harvest bark from tree species of *Warbugia ugandensis* and *Zanthoxhylum gilletii* for the manufacture of the therapeutic drug (Covidex) against Covid-19. The Covidex drug is now widely available in all Ugandan pharmacies. The commercialization of the Covidex drug could have negative effects on the two tree species whose bark is being used for the making Covidex. Furthermore, the anthropogenic activities are likely to have increased since 2016 and with new commercial activities (bark harvest) being introduced in KKCFR. This proposed study therefore would like to assess the impact of anthropogenic activities on the biodiversity in KKCFR. Using a baseline study of Bitariho *et al* (2016), the likely negative human impacts the KKCFR biodiversity will be assessed and determined. The study will compare the fauna and flora species richness/abundance and distribution and comparisons of biodiversity in 2016 and currently (2021).

3.0 Study Objectives

Overall, the study assessed the status of biodiversity and effects of anthropogenic activities on the biodiversity of KKCFR. The specific study objectives were to:

1. Determine and compare species richness and diversity of vegetation (trees, shrubs, liana, vines and herbs), terrestrial vertebrates (rodents) and birds of KKCFR between 2016 and 2022.
2. Assess levels and trends of illegal activities related to anthropogenic activities in KKCFR.
3. Assess the impacts of tree bark harvest on selected two tree species of *Warbugia ugandensis* and *Zanthoxhylum gilletii*) commercially harvested for making Covid-19 drug
4. Make recommendation for better management of KKCFR

4.0 Methods

4.1 Study site

Kasyoha-Kitomi Central Forest Reserve (KKCFR) covers nearly 40,000 ha of mid-altitude moist forest in the middle part of the Albertine Rift. The reserve lies in the five administrative districts of Bushenyi, Rubirizi, Ibanda, Kitagwenda and Buhweju (Figure 1). The reserve is one of Uganda's remaining medium altitude moist forests. Whereas majority of the larger trees have been exploited for timber and fuel wood, recent assessments by international conservation agencies classify the forest as one of international importance in terms of global biodiversity values and other ecosystem services. It is a critical forest for migrating large mammals and acts as a refugium during dry seasons. Nature Uganda initiated conservation interventions through CFM with surrounding communities from 2007-2010. The interventions focused on integrated empowerment of local communities with sustainable management of natural resources and livelihood improvement. For this specific study therefore, the study was carried out in the forest parts bordering six parishes of KKCR in Rubirizi district where Nature Uganda initiated the CFM. These parishes were, Butoha, Buzenga, Mwongyera, Magambo, Rwemitagu and Ndangaro (Figure 2).

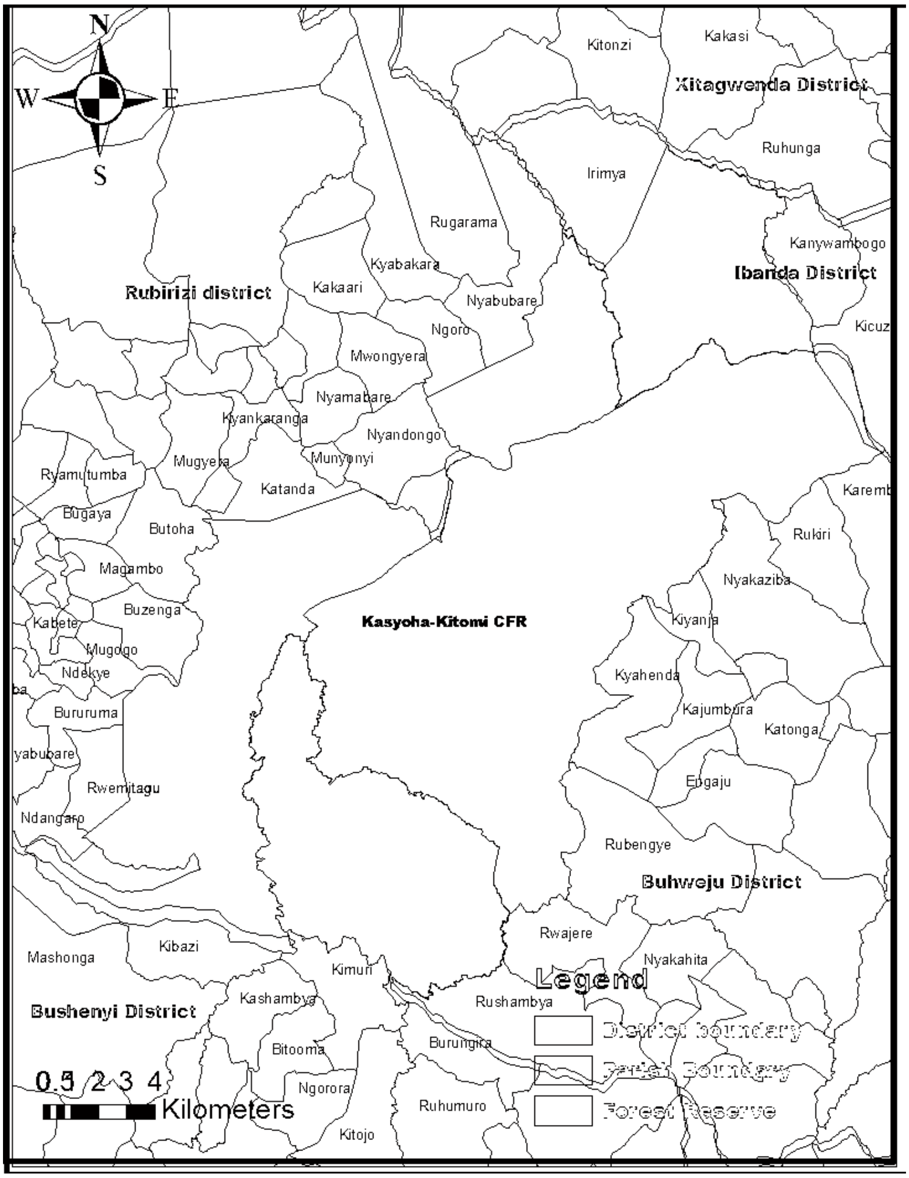


Figure 1 A map of KKCFR and surrounding administrative parishes

4.2 Biodiversity surveys

As it is impossible to survey all the possible taxa (Plumptre *et al.,* 2003), three taxa; vegetation, terrestrial vertebrates (only small mammals) and birds were used as surrogates for the total biodiversity of KKFR. Plumptre *et al.* (2003) reports that species richness of mammals, birds and plants could predict well the species richness of other taxa such as reptiles and amphibians. The species richness and diversity of mammals, birds and plants were compared for 2016 (baseline) and 2021 (current)

4.2.1 Inventory of trees, shrubs, lianas, vines, and herbs

Ecologists have devised several ways of assessing vegetation communities (Ghazoul & Sheil, 2010), (Sheil *et al*., 2003). Transects are particularly quick and allow more productive sampling in dense vegetation (Sutherland, 1996). We used belt transects (10) m wide running from the forest edge of the CFM parishes into the forest interiors to assess the KKCFR plant community (Bitariho, 2013;Hall & Bawa, 1993). The location of the first transects were determined randomly using random numbers of the eastings/northings of the KKCFR map using the ArcGIS maping software. A total of Six transects were established in the KKCFR forest and adjacent the CFM parishes (Figure 2). We then used nested quadrats to assess the different vegetation types of KKCFR. Trees (dbh ≥10cm) were enumerated in plots of 10m×10 m, shrubs and lianas in a 5×5m plots and vines, herbs and tree seedlings in a 2.5×2.5 m plots (Table 1 and Figure 3). The nested quadrats were placed at every 100 m interval along the belt transects following methods of Bitariho (2013) and (Mwima & McNeilage, 2003). The plant species were identified to species level, and diameters recorded for only trees in the sample plots.

Furthermore, for each nested quadrat, the following environmental variables were recorded: GPS position, altitude, slope position, aspect, canopy cover and any human activity signs identified at the site. We measured the diameter at breast height (DBH) of the tree species only while the rest of the plants (shrubs, vines, herbs and lianas) were recorded for abundance (numbers). The start, sample plot and end of the transect points were marked with biodegradable flagging tape and georeferenced with handheld GPS units.

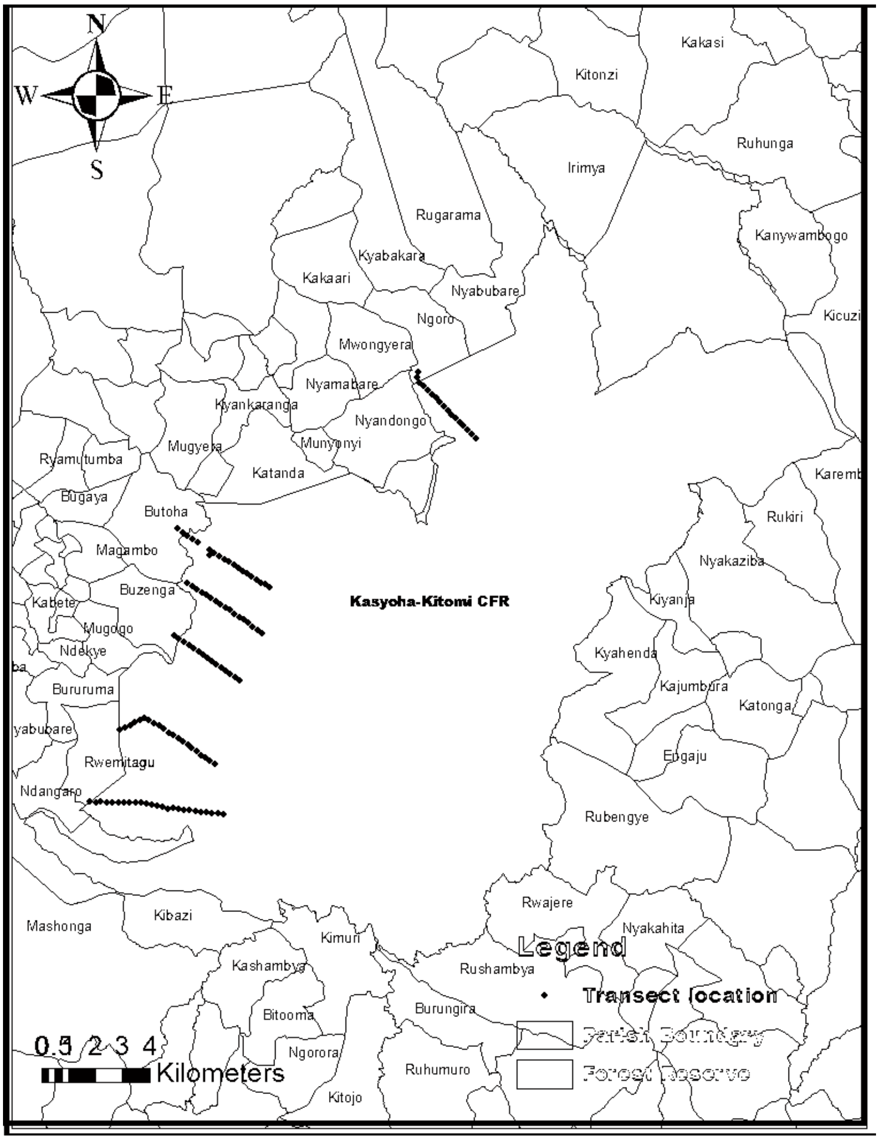
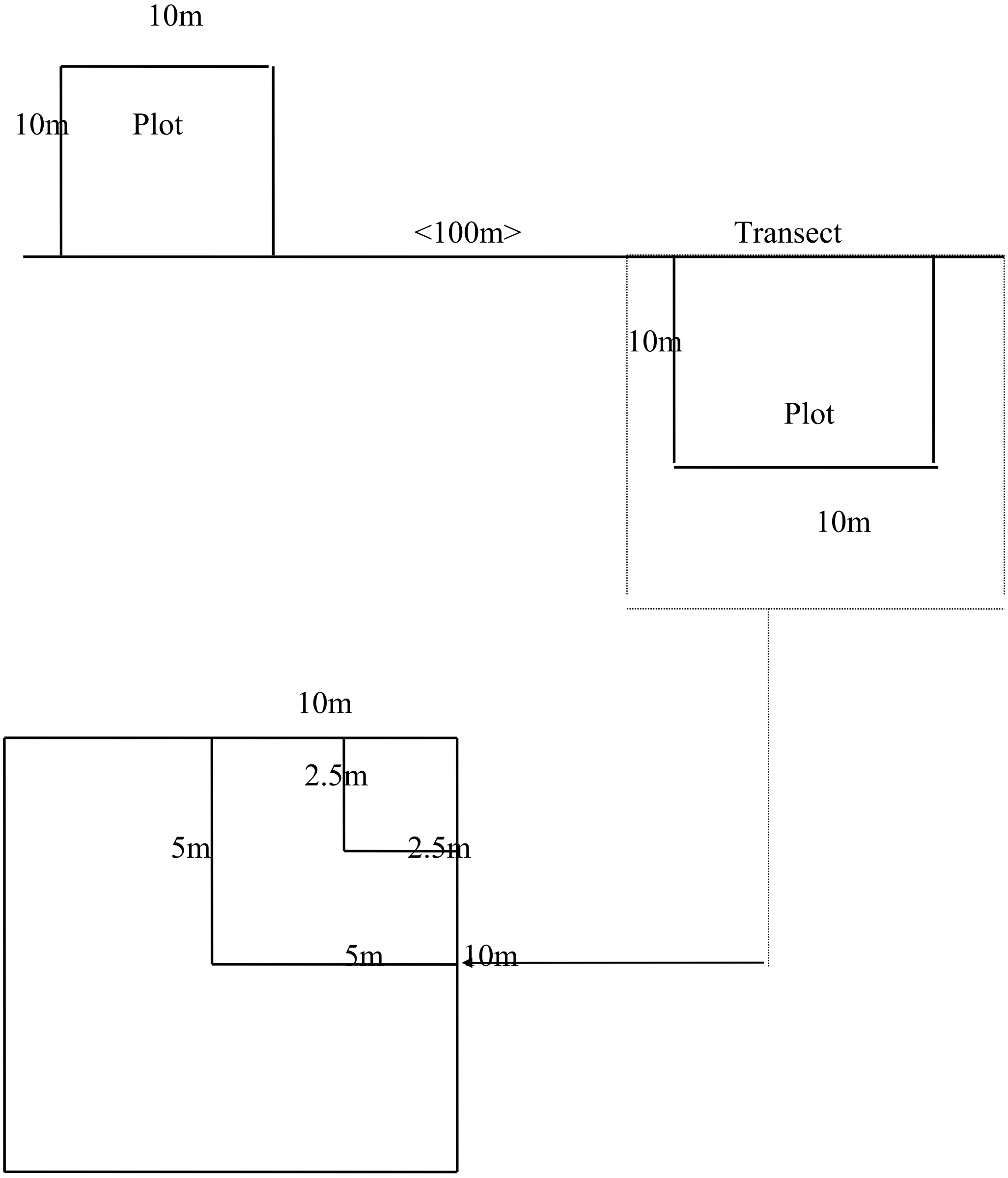


Figure 2 Transect layout for sampling in the KKCFR and adjacent CFM parishes

Table 1 Quadrat sizes for the various plant life-forms

Quadrat Size (m)	Plant Life-form
2.5 x 2.5	Vines, Invasive species Herbs/tree seedlings
5 x 5	Shrubs & Lianas
10 x 10	Tree species

Figure 3 Nested plot layout on the transects in KKCFR



4.2.2 Small mammal species diversity and distribution

Small mammals field methods aimed at obtaining qualitative rather than quantitative data, with emphasis on species richness and associations rather than on population densities. We used the six transects set up for vegetation sampling to sample the small mammals too. A specific team focusing on small mammals visited the same points as the vegetation sampling team. Trapping of rodents was done one day after the transects had been set and walked by a botanist to reduce the possible deleterious effects, any noise and movements made by the botanical team would have on trap success. Sampling was made at 600 m intervals and 40 Sherman live traps were set in two rows at 10-m interval. The traps were baited with ground nut butter and over ripened, mashed yellow bananas. The traps were set between 0800 and

0900 hours in the morning and checked between 1630 to 1830 hours in the evening, then reset and checked in the morning of the next day to ensure capture of both diurnal and nocturnal species. Each trapped animal was weighed, measured, sexed and its reproductive condition assessed. All the external attributes of the small mammals such as fur colour and texture, back colour of fore and hind foot, whisker and other physical features were recorded. The trapped samples were identified to the species level following Kingdon (2016) nomenclature.

4.2.3 Bird species richness and diversity

The point-count method was used to assess bird species diversity and richness. Counts of birds were made two days after the transects have been randomly established and walked by the vegetation team to reduce the possible deleterious effects any noise and movements made by the team would have on observations of birds. Point counts were established at 200 m intervals along the transects. On arrival at each point-count site, the team would wait for 2 min before beginning to count to allow the birds to settle down. All birds detected visually and acoustically within a fixed radius of 100 m were recorded during a period of 10 minutes. Birds in flight were not recorded. Bird sampling was conducted between 0700 and 1100 hours in the morning and again between 1600 to 1800 hours in the evening when the weather was calm and dry and the birds most active. Taxonomy and nomenclature follow Stevenson and Fanshawe (2020).

Bird species were grouped using two methods: first, we grouped the species according to their levels of forest dependence following the classification given in Bennun et al. (1996): (i) FF-species (forest specialists: true forest birds characteristic of the interior of undisturbed forest; occasionally albeit rarely occurring in non-forest habitats and secondary forest if their particular ecological requirements are met, but breeding almost invariably within undisturbed forest); (ii) F-species (forest generalists: occur fairly commonly in both undisturbed and secondary forest, forest strips, edges and gaps, but often breed within forest interior); and (iii) f-species (forest visitors: birds repeatedly recorded in the forest interior but not dependent on it, being more common in non-forest habitats, where they are likely to breed). Any species not included in the Bennun et al. (1996) list was categorized as non-forest (nf). Second, birds were grouped into five categories based on four main feeding habits viz. fly-catching (flycatcher), gleaning for insects (forage gleaner), fruit eating (frugivore) and ground feeders (ground feeder), the fifth being a combination of two or more of these (mixed feeder) (Githuru and Dejene 2008). We used information in Birds of Africa series (Vols 1 - 7) for this classification.

We assessed the effects of forest disturbance between 2016 and 2022 on the bird community of KK CFR. The following questions were asked: How did the bird community diversity change after five years of increased forest disturbance intensity? Which species categories are affected, and how?

4.3 Impact of tree bark harvests on selected two tree species

We subjectively selected areas in KKCFR authorized by NFA for harvesting the bark from two tree species of *Warbugia ugandensis* and *Zanthoxhylum gilletii*. These two tree species are commercially harvested for bark used in the making of a drug for the therapeutic treatment of Covid-19 disease. The CFM parish of Mwongyera was particularly selected for assessment of impacts of the two tree species bark harvest. We assessed the abundance and distribution of these two tree species in KKCFR and then compared them with other tree species. Furthermore, we recorded evidence of the tree species bark harvests. The following methods were used to assess the impact of bark harvest on the 2 tree species.

4.3.1 Tree species Bark harvest impact assessment

Individual stems of the two tree species of *Warbugia ugandensis* and *Zanthoxhylum gilletii* were counted in sample plots and the diameters at breast height of the trees recorded. Visual signs of bark harvest from the trees were recorded using a seven-point scale recommended by Cunningham, (2001). The seven scale bark harvest impacts are <u>0% (no harvest), <10%, 10-25%, 26-50%, 51-75%, Ringbarking</u> and <u>Total Ringbarking</u> (Cunningham, 2001). Other possible bark harvest impacts such as yellowing of leaves, fungal or insect pest attacks on the stem after bark harvest of *Warbugia ugandensis* and *Zanthoxhylum gilletii* were recorded when encountered.

4.4 Data analysis

4.4.1 Plants and small mammals' abundance, diversity, and distribution

The fauna and flora species data and environmental variables from all sites was collated in Microsoft Excel spreadsheets. The species data was first coded in an Excel spreadsheet as number of individuals for trees and present/absent for shrubs, lianas, vines, seedlings, small mammals, and birds sampled per unit hectare. The data was then imported into R software package for analysis, graphing and statistical testing (Bitariho et al., 2020). All the data was analysed using R open source statistical software version 3.2.2 (R Core Team., 2018).

Comparisons of the total number and type of species for each taxon in KKCFR between 2016 and 2022 was made using boxplots plotted using "ggplot2" in Rstudio 2021 version 1.4.1717 software. Statistical inferences to test for differences in abundance and species diversity for each taxon over the study years (2016 and 2022) was then made using a Kruskal-Wallis Chi-Squared test in RStudio 2021 version 1.4.1717. The Shannon diversity index was used to calculate the diversity index for each taxon and compared for 2016 and 2022 (Kanieski et al., 2018). The higher the Shannon index of the two study years compared, the higher diversity of that year. Furthermore, the Shannon Equitability Index was used to calculate species evenness (relative abundance) for the different flora and fauna taxa and years (2016 and 2022). When the Shannon Equitability Index of species/years is equal to 1 then all the species have same abundance and when it tends towards 0 then the near total of flora is concentrated on only one species (Ifo et al., 2016).

The Shannon index formular used was;

$$\mathbf{H = H= -\sum(n_i/N)\ log\ (n_i/N)}$$

Where $\mathbf{n_i}$ = Importance value for each species,

N=total of importance values

The Shannon Equitability Index formular used was;

$\boldsymbol{E_H = H / ln(S)}$, where:

- ***H*****:** The Shannon Diversity Index
- ***S*****:** The total number of unique species
- ***ln:*** Natural log

This value ranges from 0 to 1 where 1 indicates complete evenness.

4.4.2 Bird species richness and diversity

Due to the low sample sizes for most species, measures of species richness, rather than abundance were analysed. Most species were single individuals, reducing the counts to presence/absence. Therefore, all the data was binary transformed to presence/absence. We then estimated the following basic community indices for each survey period (i.e., 2016 and 2022): species richness was obtained by use of Margalef's index; species density was estimated as the number of species per count-point; species diversity was assessed by Shannon diversity index; the degree of equitability in total species occurrences was measured by Simpson evenness index; and the relative importance of dominant species was evaluated using the inverse of Simpson's index (Magurran 1988). We compared the changes in bird community between the study periods in relation to overall species density, habitat categories and feeding guilds using z-tests.

Sampling effort for bird species

We analyzed the sampling effort for bird species counts using the species accumulation curve (Figure 4). The slopes of the species accumulation curves plotted for successive bird point-counts for each study period (i.e., 2016 and 2022 remained steep (Figure 4), especially for 2016, indicating that more bird species remained unrecorded. However, for 2022, the curve shape showed a steady increase and nearly reached asymptote. This implies that the 2022 survey provided a reliable representation of the bird species of the sampled area. The reason for the difference in the curve shapes is that nearly three times more points were counted in 2022 than in 2016.

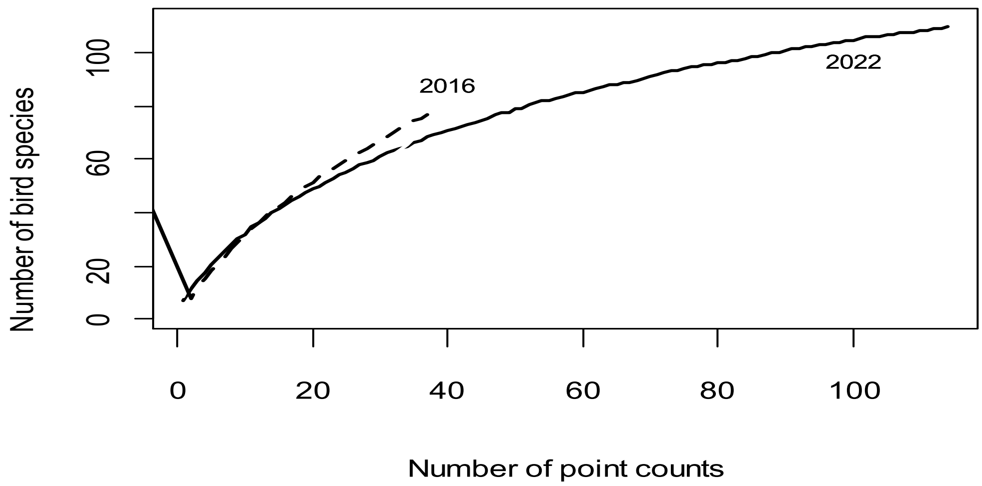


Figure 4 Species-accumulation curves for successive bird counts in 2016 and 2022

4.4.3 Tree species bark harvest data

Data of the harvested trees stem density and size class distribution was compiled into size-class histograms showing the number of individuals in different diameter size classes. The *Warbugia ugandensis* and *Zanthoxhylum gilletii* (large canopy trees) was grouped into 5.5 cm diameter class interval as recommended by Peters (1994). The size class distribution histograms provide an immediate identification of the poorly represented stages of the life history, therefore suggesting the heavily harvested individuals that require immediate attention (Hall and Bawa, 1993). Bark harvest impact assessments characteristics was presented as percentages and plotted as pie charts for visualization. These percentages were for the number of *Warbugia ugandensis* and *Zanthoxhylum gilletii* tree species with for example 0% bark harvest, 0=25% harvest, 25-50% harvest, 50-75% harvest, Ringbarked and Total ringbarked.

4.4.4 Human activities data

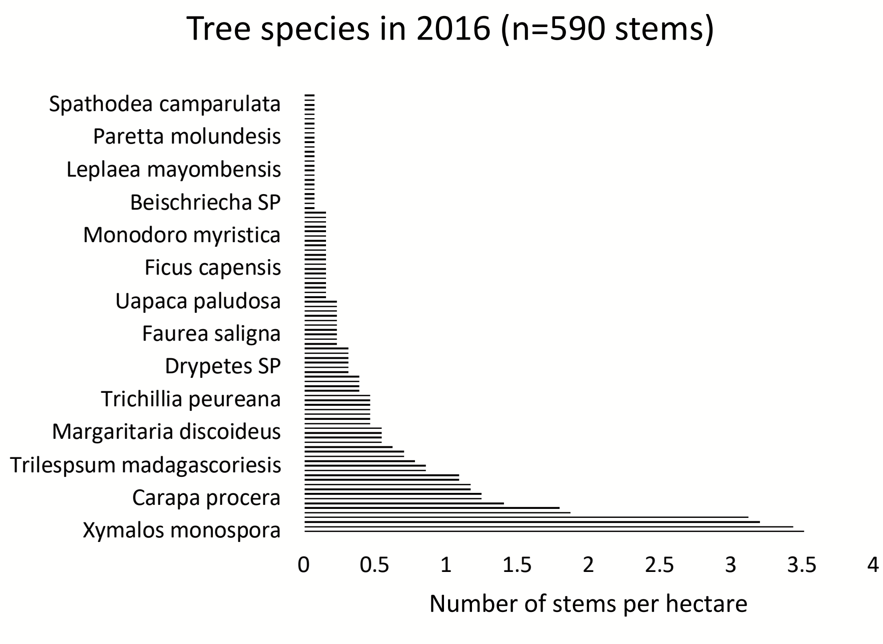
The data of the human activity encounters was first entered in Microsoft Excel and then exported (after conversion into txt file type) into RStudio 2021 version 1.4.1717 software. Comparisons of the distribution, number, and types of human activities in KKFR between 2016 and 2022 was made using boxplots plotted with "ggplot2" in Rstudio 2021 version 1.4.1717 software. Statistical inferences to test for differences in human activities between the study years (2016 and 2022) was then made using a Kruskal-Wallis Chi-Squared test in RStudio 2021 version 1.4.1717.

5.0 Results

5.1 Species richness (diversity) and evenness of trees

A total of 110 tree species were recorded in KKCFR between 2016 and 2022 study period (See appendix). This is four times more than the total number of tree species that were recorded in Echuya Central Forest (ECFR) between the same period. In 2016, Ninety-four tree species were recorded while in 2022 forty-nine tree species were recorded (Table 2). Of these tree species, *Strombosia schefflera, Funtimia africana, Warbugia ugandensis, Xymalos monospora, Macaranga kilimadscherica* and *Shirakiopsis elliptica* were the most dominant in descending order (Figure 5). The least dominant tree species in ascending order in KKCFR for both 2016 and 2022 were *Xylopia aethiopica, Trema orientalis, Spathodea camparulata, Rothmannia urcellifonus, Voacanga thoarsii, Ritchilea albersii and Prunus africana* (Figure 5). As figure 5 and table 2 show, in 2016, a total of 590 trees (46 stems per ha) were recorded while in 2022 a total of 370 tree stems (34 stems per ha) were recorded showing a reduction in the number of trees since 2016. However, statistical comparison shows that there was no significant difference in the abundance of the trees (expressed per unit hectare) recorded in 2016 and 2022 (Kruskal-Wallis Chi-square == 0.0016909, df = 1, **p-value = 0.9672).** Table

2 shows a comparison of the relative abundance of the tree species (evenness) and species richness (diversity) between 2016 and 2022. From the Table 2, species evenness and richness (diversity) for the year 2016 was slightly higher than that of 2022. The tree species evenness in 2022 is low and is concentrated mostly on three tree species that had more stems (abundance) than the rest, and these were *Strombosia scheffleri, Funtimia africana and Warbugia ugandensis* that constituted over 33% of all the tree stems sampled (Figure 5 & Table 2). For all the study years, tree species relative abundance (evenness) was similar since the evenness tended to 1 (0.61 for 2016 and 0.53 for 2022) as shown in Table 2. The implication of the tree species evenness and diversity is that the year 2016 had a higher biological diversity (in terms of trees) than 2022 perhaps as a result of increased human activities impacts in 2022.



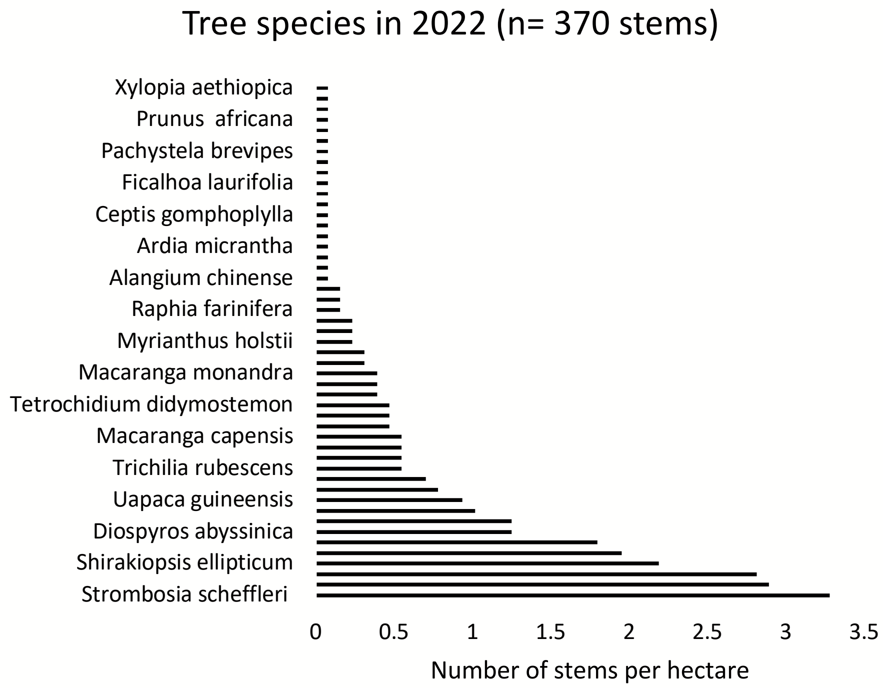


Figure 5 A comparison of tree species abundance between 2016 and 2022

Table 2 A comparison of species evenness (relative abundance) and species richness of different fauna and flora between 2016 and 2022

Species Category	Species' abundance per ha		Number of species		Species Diversity		Species Evenness	
	2016	2022	2016	2022	2016	2022	2016	2022
Trees	46	34	94	49	3.89	3.20	0.61	0.53
Shrubs & Lianas	3,969	3,316	47	46	3.12	3.05	0.48	0.45
Vines & Herbs	16,925	2,125	47	34	3.09	2.87	0.42	0.50
Rodents	167	21	9	5	1.28	1.23	0.27	0.50
Birds	0.8	5	80	113	3.93	3.87	0.76	0.55

5.2 Species richness (diversity) and evenness of shrubs and lianas

A total of 92 shrub and liana species were recorded in KKCFR for 2016 and 2022 study period (See appendix). In 2016, Forty-seven shrub and liana species were recorded in KKCFR while in 2022 forty-six species of shrubs and lianas were recorded (Table 2). Of these, the most dominant shrubs and lianas in descending order were *Piper capense,* *Triumfetta brachyceros, Piper guineense, Brillantaisa citricosa, Dracaena laxissima and Alchornea hirtella* (Figure 6). The least recorded shrubs and lianas in ascending order for KKCFR for both 2016 and 2022 were *Toddalia asiatica, Dovyalis macrocalyx, Dalberga lactea, Cyphomadra betacea* and *Acacia brevispica* (Figure 6). As shown in Figure 6 and table 2, in 2016, a total of 635 shrubs/lianas (3,969 stems per ha) were recorded while in 2022 these reduced to 370 stems (3,316 stems per ha). The total stem abundance of the shrubs and lianas (expressed per unit hectare) was significantly different between 2016 and 2022 (Kruskal-Wallis Chi-square == 3.1279, df = 1, **p-value = 0.03696**). Figure 7 shows the differences in shrub/lianas stem abundance between 2016 and 2022. From the Figure 7, it is evident that the shrubs and lianas' total stem abundance was decreased in 2022 compared to 2016. Table 2 further shows a comparison of the relative abundance of the shrub and liana species (evenness) and species richness (diversity) in 2016 and 2022. From the Table 2, the species evenness and richness in the year 2016 was higher than that of 2022. The shrub and lianas species evenness in 2022 was different since the species evenness index tended to 0 (0.45) and the shrubs and lianas evenness is concentrated on majorly three species that had more stems (abundance) than the rest. These were *Piper guineense, Piper capense and Dracaena laxissima* that constituted about 36% of all the shrubs and lianas sampled in 2021.Table 2 further shows that the shrub and lianas species diversity in KKCFR decreased in 2022 when compared to 2016. The implication is that since 2016, there has been a slight decrease in biological diversity (in terms of shrubs and lianas) in KKCFR with further implication that the KKCFR could have lost some shrubs and lianas species after 2016 perhaps as result of human activity impacts.

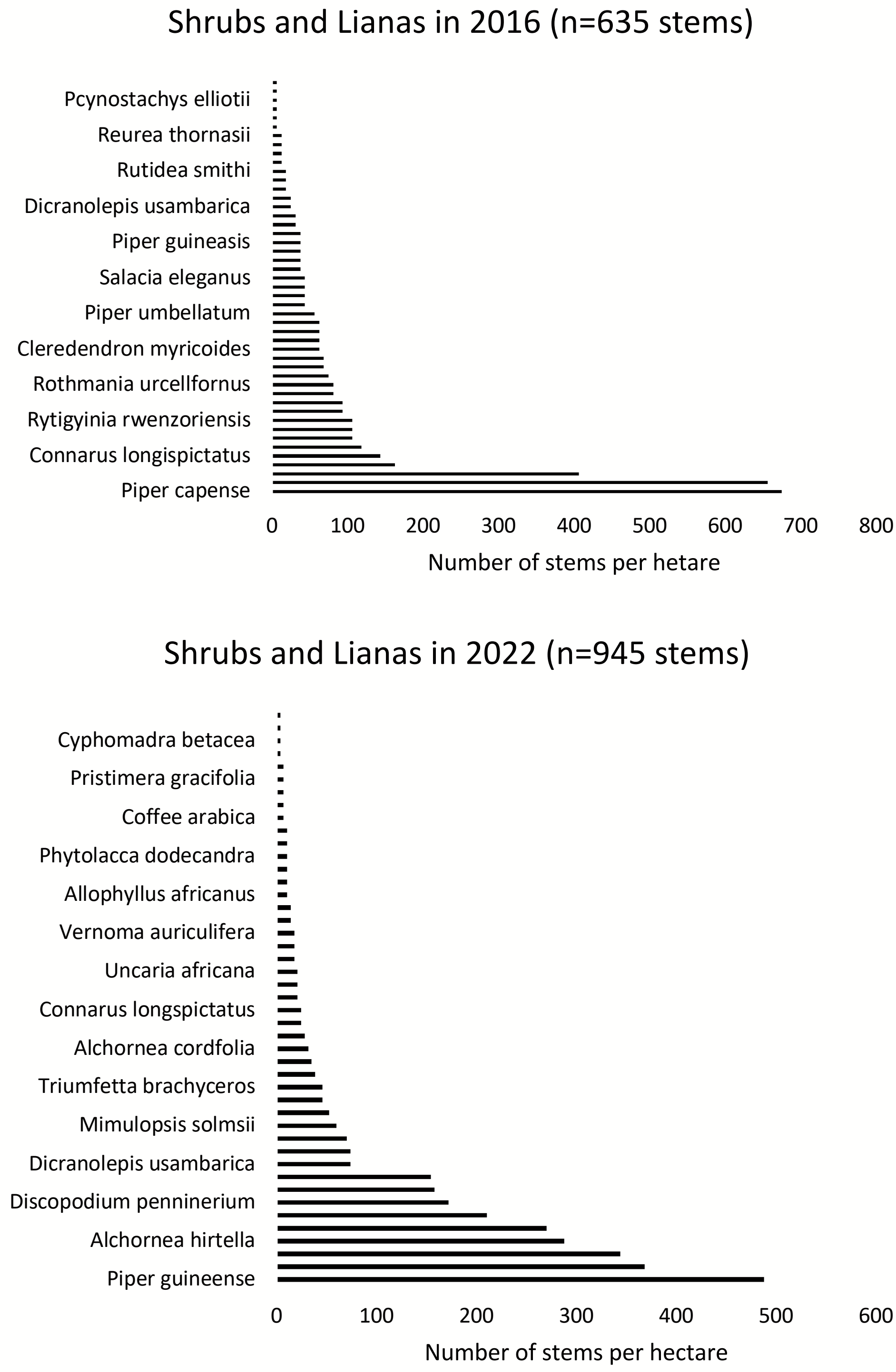


Figure 6 A comparison of shrubs and lianas' abundance between 2016 and 2022

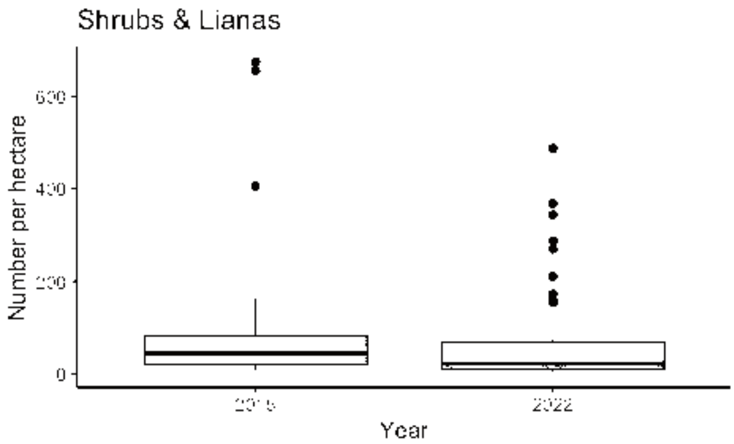
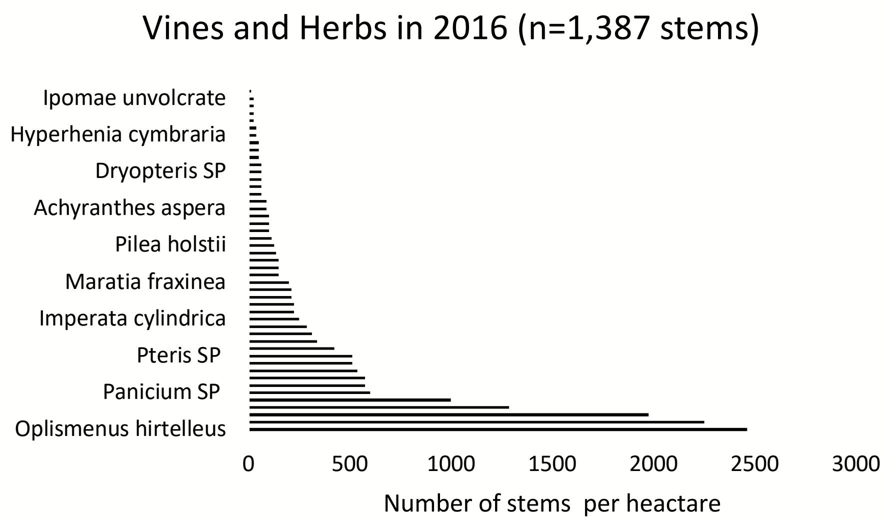


Figure 7 A boxplot showing differences in shrubs and lianas' abundance between 2016 and 2022

5.3 Species richness (diversity) and evenness of vines and herbs

A total of 57 vines and herbs species were recorded in KKCFR between 2016 and 2022 study periods (see species list in appendix). Forty-seven vine and herb species were recorded in 2016 while forty-six vine and herb species were recorded in 2022 (Table 2). Of these, the most dominant vine and herb species in descending order were *Oplismenus hirtelleus, Panicum adenophorum, Panicum adenophorum, Pteendium aquilium, Palisota mannii, Panicium sp*., and *Asplenium sp*., (Figure 8). The least vine and herb species recorded in ascending order in KKCFR for both 2016 and 2021 were *Acalypha sp., Thelypteris sp., Sida sp., Setaria plicatilis, Pasparum conjugatum, Justicia sp., Ipomea wightii, Dicrocephalum integrifolia, Crassocephelum vitellinum, Commelina sp., Aspleniun elliotii* and *Afromomum sp* (Figure 8). As shown in Figure 8 and table 2, in 2016, a total of 1,387 vines and herbs (16,925 stems per ha) were recorded that drastically reduced to 170 vines and herbs (2,125 stems per ha) in 2021. Indeed, the total stem abundance of the vines and herbs (expressed per unit hectare) was significantly different between 2016 and 2022 (Kruskal-Wallis Chi-square = 23.308, df = 1, **p-value = 0.00).** Figure 9 shows the boxplot comparing the differences in vines/herbs' stem abundance between 2016 and 2022. From the Figure 9, it is evident that vines/herbs stem abundance significantly reduced in 2022. Furthermore, table 2 shows a comparison of the relative abundance (evenness) of the vine and herb species and species richness (diversity) between 2016 and 2022. From the Table 2, the species diversity (richness) and species evenness in 2016 was slightly higher than that of 2022. In 2016, the vine and herb species showed different relative abundance since the evenness index tended to 0 (0.42) as shown in Table 2. Table 2 further shows that the vine and herb species diversity in KKCFR decreased in 2021 when compared to 2016. The implication is that since 2016, there has been a decrease in biological diversity (in terms of vines and herbs) in KKCFR with further implications that the forest could have lost a number of vines and herb species since 2016 perhaps as a result of human activity impacts.



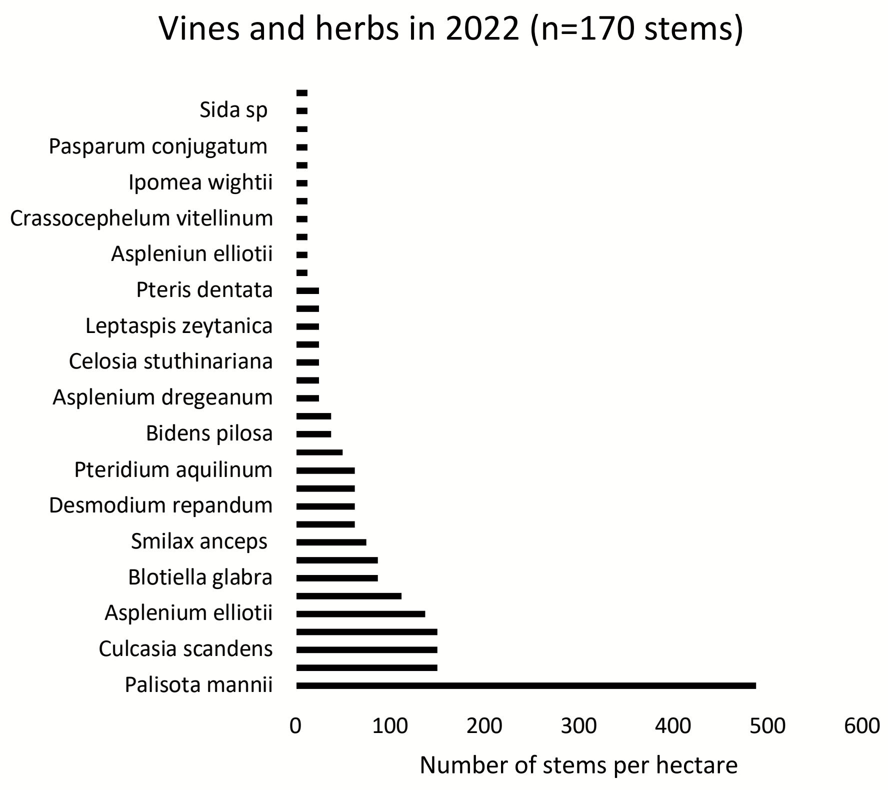


Figure 8 A comparison of vines and herbs' abundance between 2016 and 2022

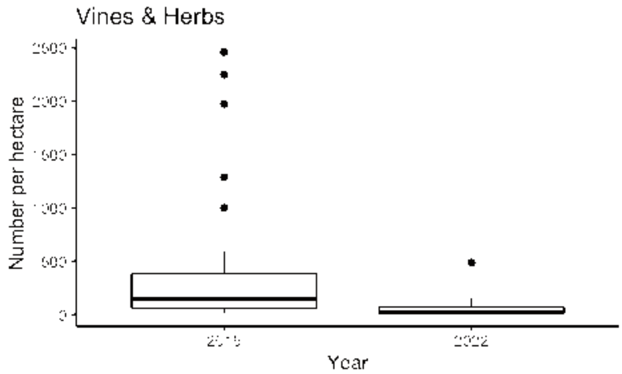
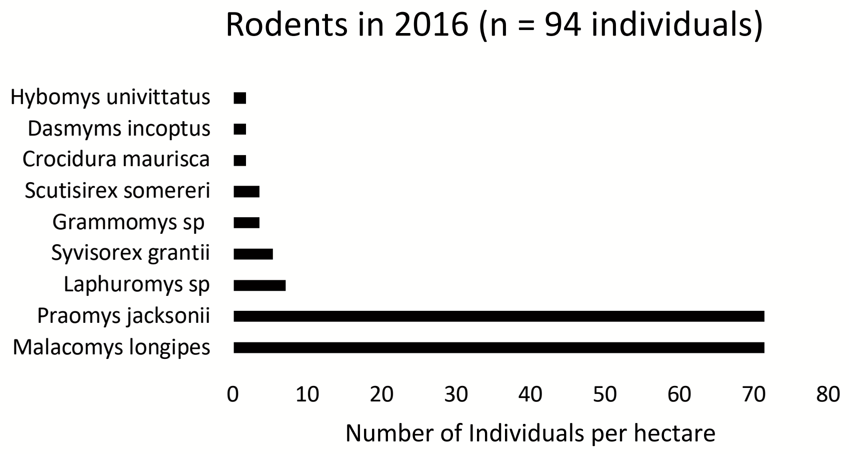


Figure 9 A boxplot showing differences in vines and herbs' abundance between 2016 and 2022

5.4 Species richness (diversity) and evenness of small mammals (rodents)

A total of 9 rodent species were recorded in KKCR between 2016 and 2022 study period (see species list in appendix). In 2016, nine species of rodents were recorded while in 2022, only five species of rodents were recorded (Table 2). Of these, the most dominant rodent species in descending order were *Malacomys longipes, Praomys jacksonii, Praomys jacksonii, Laphuromys sp* and *Syvisorex grantii* (Figure 8). The least recorded rodent species in KKCFR for both 2016 and 2022 were *Hybomys univittatus, Dasmys incomptus* and *Crocidura Maurisca* (Figure 10). In 2016, a total of 94 rodents (167 individuals per ha) were trapped/recorded while in 2022 only a total of 12 rodents (21 individuals per ha) were trapped/recorded (Figure 10). However, the abundance of the trapped/recorded rodents (expressed per unit hectare) were not significantly different between 2016 and 2022 (Kruskal-Wallis Chi-square == 0.95507, df = 1, **p-value = 0.3284).** Table 2 shows a comparison the relative abundance (evenness) of the rodents and species richness (diversity) between 2016 and 2022. From the Table 2, the species richness in the year 2016 was slightly higher than that of 2022 (1.28 and 1.23 respectively). Furthermore, the rodent species evenness in the year 2022 was higher than that of 2016 (0.50 and 0.27 respectively). The implication of this is that the rodent species diversity decreased in 2022 perhaps due to accumulation of human activity impacts in 2022.



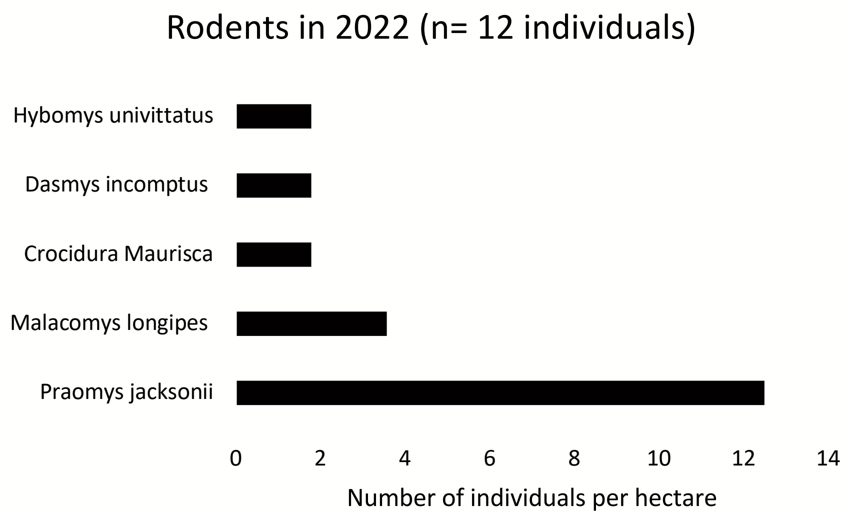


Figure 10 A comparison of rodents' abundance between 2016 and 2022

Plate 1 A *Praomys jacksonii* rodent being released after trapping and recording

5.5 Species diversity and richness of birds

A total of 135 bird species were detected, of which 81 and 110 species were recorded in 2016 and 2022, respectively. There was an overlap of 55 species (40.7% of the total bird species) between the two survey periods, with 25 bird species being detected in 2016 but not in 2022, while 54 species were encountered in 2022 but not 2016 (Appendix 10.4). The avian community structure showed particular changes between 2016 and 2022. We recorded a significant higher mean number of species occurrences per count-point in year 2022 than in year 2016 (z-test, Z=4.5, p<0.01). The species richness was also richer in 2022 than 2016 (Table 3). However, the diversity, evenness and dominance were lower in 2022 than 2016 (Table 3), indicating that the bird community in 2016 was more diverse, had a higher number of equally common species and a higher proportion of dominant species than in 2022.

Table 3 Characteristics of avian communities in 2016 and 2022

Population characteristic	**2016**	**2022**
Number of count points	40	114
Species recorded	81	110
Species richness	15.44	16.47
Species per count-point (min-max)	4.6 (1-12)	6.6 (3-17)
Diversity	3.99	3.78
Evenness	0.5	0.22
Dominance	33.2	23.1

5.5.1 Common bird species in KKCFR

In 2016, 32 bird species or 39.5% (n=81) were common (Appendix 10.4). Of these species, one single species was particularly frequent, the Yellow-whiskered Greenbul *Eurillas latirostri* contributed 11.2% (n=178) of the all the species occurrences. The same species also formed 15.5% (n=129) of the common species occurrences, two and half times as often as the second commonest species. The F-species dominated forming 37.5% of the common species, the FF-species contributed 31.2%, the f-species formed 21.9%, while the remaining 9.4% were nf-species. For the foraging guilds, the mixed feeders formed 40.6% of the common species, the flycatchers contributed 25%, forage gleaners contributed 18.8%, the frugivores formed 12.5%, while the remaining 3.1% were the ground feeders.

In 2022, 40 bird species or 36.4% (n=110) were common (Appendix 10.4). Four of the common species, Tambourine Dove *Turtur tympanistria*, Yellow-rumped Tinkerbird *Pogoniulus bilineatus.* Yellow-whiskered Greenbul *Eurillas latirostris* and African Paradise-flycatcher *Terpsiphone viridis* contributed 35.5% (n=749) of all the species occurrences and 42.2% (n=266) of the common species occurrences. The F-species dominated forming 42.5% of the common species, FF-species formed 27.5%, f-species contributed 17.5%, while the remaining 12.5% were nf-species. For the foraging guilds, the mixed feeders contributed 42.5% of the common species, the frugivores formed 25%, forage gleaners contributed 22.5%, while the remaining 10% was the flycatchers. There were no ground feeders among the common species.

Thus, between 2016 and 2022, the common species showed a slight increase in percent proportion of the number of F-species and nf-species, and a slight decline in FF-species and f-species. There was a large increase in percent proportions for the frugivores and large decrease for the flycatchers. The ground feeders were not among the common species in 2022.

5.5.2 Rare bird species in KKCFR

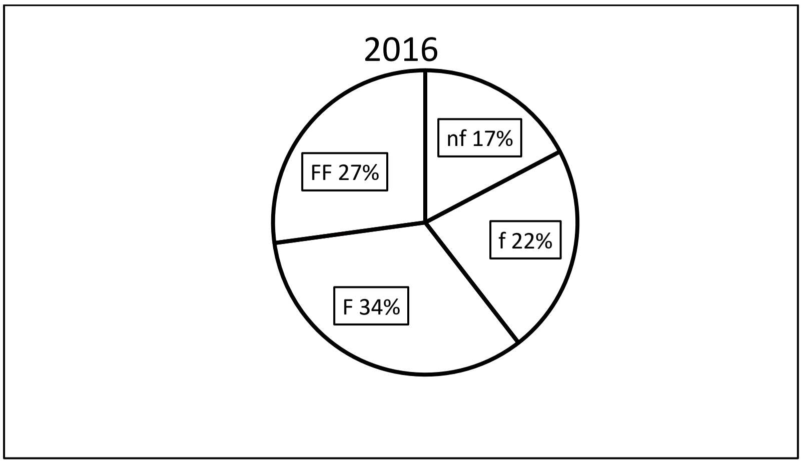
The 2016 rare bird species were regarded as those that occurred at only one count point, and the common ones were those which were detected at two or more count-points. For 2022, the the rare birds species were taken as those that occurred at one to three count points, and the common ones at four or more count points. In 2016, 49 species or 60.5% (n=81) were in the rare category (Appendix 10.4). The rare species were all encountered at one count-point. Most of the rare species were F-species (30.6%) and FF-species (24.5%). The f-species contributed 18.4%, while nf-species formed 26.5%. For the foraging guilds, the mixed feeders contributed 34.7% of the rare species, the gleaners formed 30.6%, the ground feeders formed 12.6%, the flycatchers formed 18.4%, while the frugivores contributed and raptors formed 2% each. In 2022, 70 species or 63.6% (n=110) were in the rare category (Appendix 10.4). Half of the rare species were encountered at one point-count, with the rest were detected at two to three point-counts. The f-species dominated the rare species contributing 32.8%, F-species contributed 24.3%, FF-species were 18.6%, while the remaining 24.3% were nf-species. For the feeding behavior, the mixed feeders contributed 35.7%, forage gleaners formed 22.9%, the ground feeders formed 18.6%, flycatchers formed 12.8%, while the frugivores formed 5.7% and the raptors formed 4.3%.

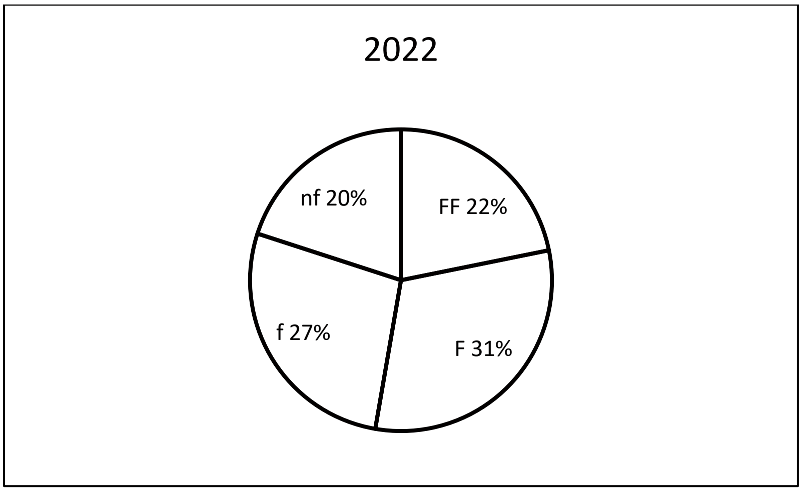
Hence, between 2016 and 2022, the rare species showed moderate percent proportion increase in f-species, and slight decline in the other forest dependent categories. There was a slight decline in forage gleaners and a slight increase in other feeding guilds.

5.5.3 Forest dependency birds in KKCFR

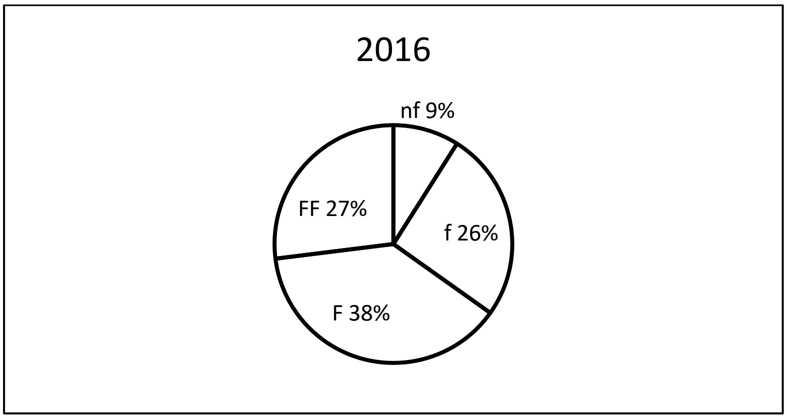
In both 2016 and 2022, the F-species were the highest in percent proportions of the number of species and frequency of species occurrences (Figure 11a and b) and had the largest increase in percent proportion (of 12%) in the frequency of species occurrence. The difference for frequency of species occurrence per count-point of F-species was significantly higher in 2022 than 2016 (z-test, Z=6.15, p<0.01). Other forest dependent categories showed no significant difference in frequency of species occurrences per count-point between the study time periods.

a) By number of species





b) By frequency of occurrence of species



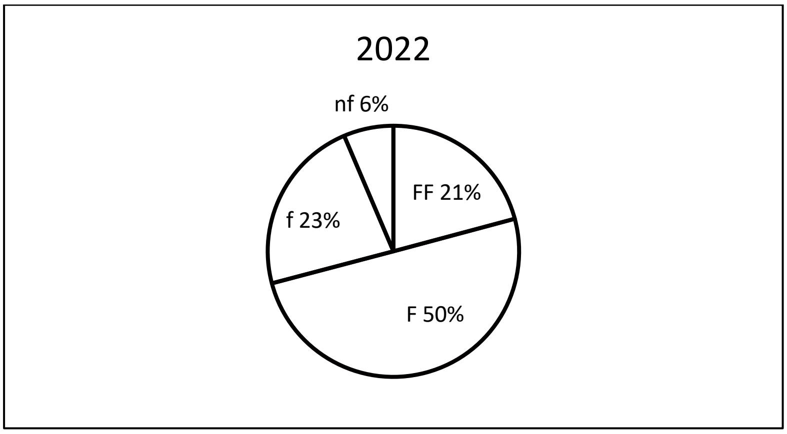


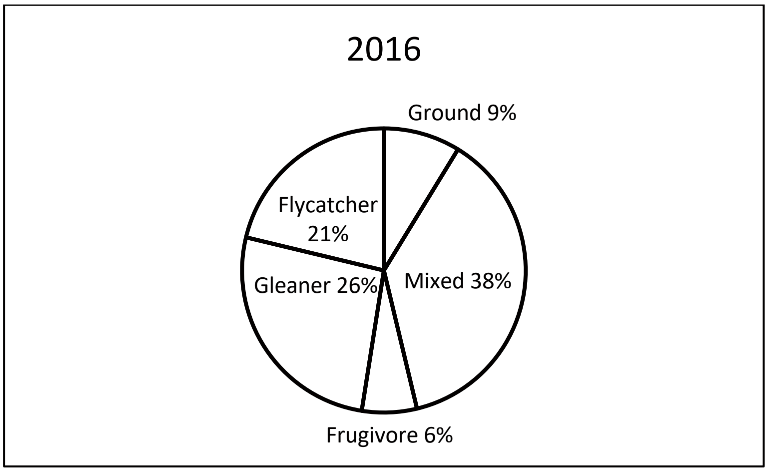
Figure 11 Proportions of birds in different forest-dependency categories in 2016 and 2022 (FF: forest interior specialists, F: forest generalists, f: forest visitors, nf: non forest species)

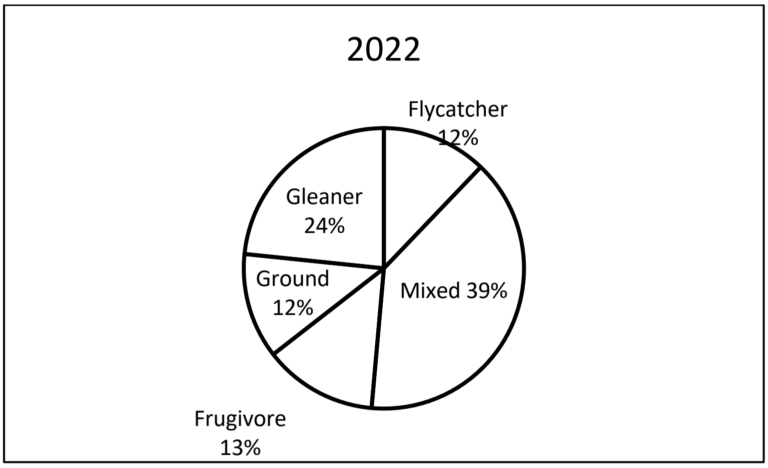
5.5.4 Feeding guilds of birds in KKCFR

The mixed feeders were dominant in both percent proportion in the number of species and frequency of species occurrences in 2016 and 2022 (Figure 12a and b). Between the study periods, the frugivores increased most in both the percent proportion in the number of species (by 7%) and frequency of species occurrences (by 13%). The flycatchers declined most in both the percent proportion in number of species (9%) and frequency of species encounters (by 7%). The forage gleaners also declined in percent proportion in number of species and frequency of species occurrences. The ground feeders were the lowest in percent proportions in the number of species and frequency of species occurrences in 2022.

A comparison of the frequency of species occurrences per count-point indicated a significant increase between 2016 and 2022 for two feeding guilds - mixed feeders (z-test, $Z=4.34$, $p<0.01$) and frugivores (z-test, $Z=8.86$, $p<0.01$). There was no significant difference in the remaining three feeding guilds – flycatchers, forage gleaners and ground feeders.

a. By number of species





b) By frequency of occurrence of species

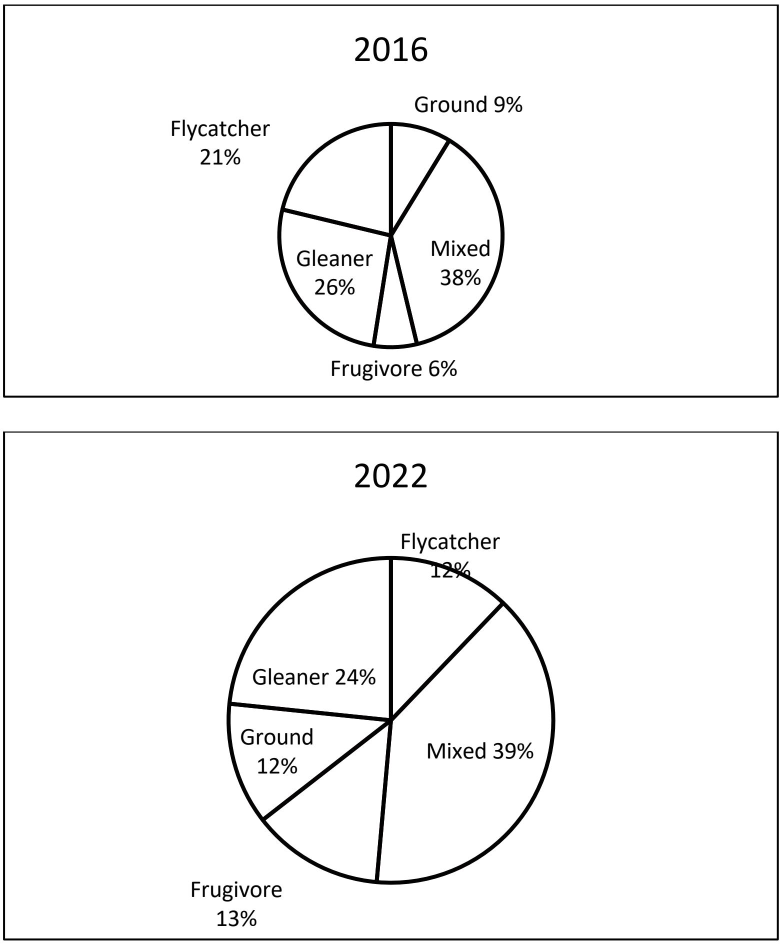
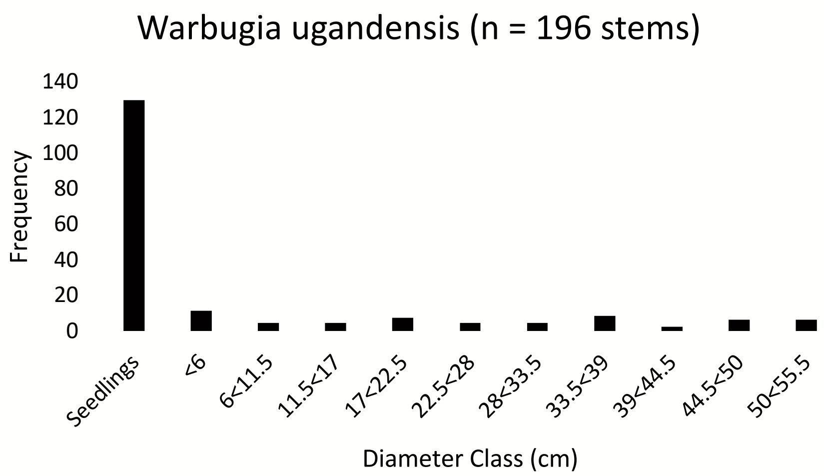


Figure 12 Proportions of birds in the different feeding guilds in 2016 and 2022

5.6 Tree species bark harvest impacts

Two tree species are being commercially harvested for bark from KKCFR. There are *Warbugia ugandensis and Zanthoxylum gilleti.* Figure 13 shows the size class (diameter) distribution of the two tree species in KKCFR. From the Figure 13, 196 *Warbugia ugandensis* trees and *67 Zanthoxylum gilleti* trees were sampled for bark harvest impact. As figure 13 shows, the two harvested tree species (*Warbugia ugandensis and Zanthoxylum gilleti*) showed a population distribution with very many seedlings and juveniles but fewer harvestable mature or adult individuals (those >11.5cm). This is an "L" type of size class distribution shown by the two harvested tree species in the zones where bark harvest is allowed. However, as mentioned previously the general picture of the two tree species shows that *Warbugia ugandensis* is one of the most dominant tree species in KKCFR unlike the *Zanthoxylum gilleti* that is least available (Figure 4). Figure 14 further shows the visual bark harvest impacts on the two tree species. From Figure 14, of the 196 tree species of *Warbugia ugandensis* sampled, only 36% had not been harvested for bark while 45% had been totally ringbarked. Furthermore, of the 67 *Zanthoxylum gilleti* tree sampled, 41% had not been harvested for bark and 33% had been ringbarked. As will be discussed later, ringbarking of trees damages and ends up killing the tree species (Cunningham, 2001).



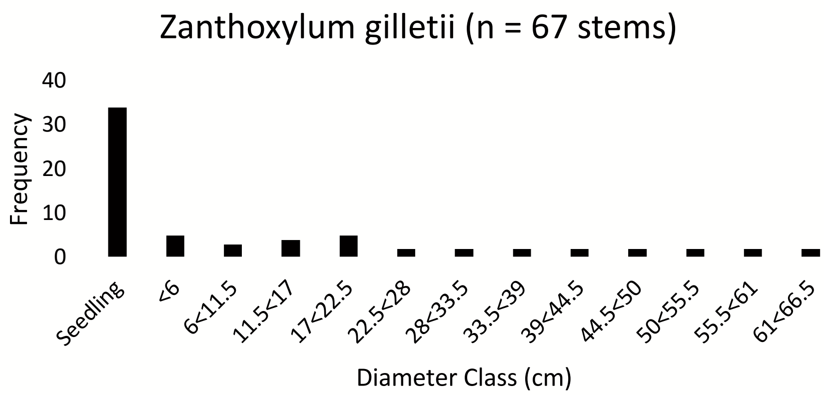


Figure 13 Size class distribution of *Warbugia ugandensis* and *Zanthoxylum gillettii*

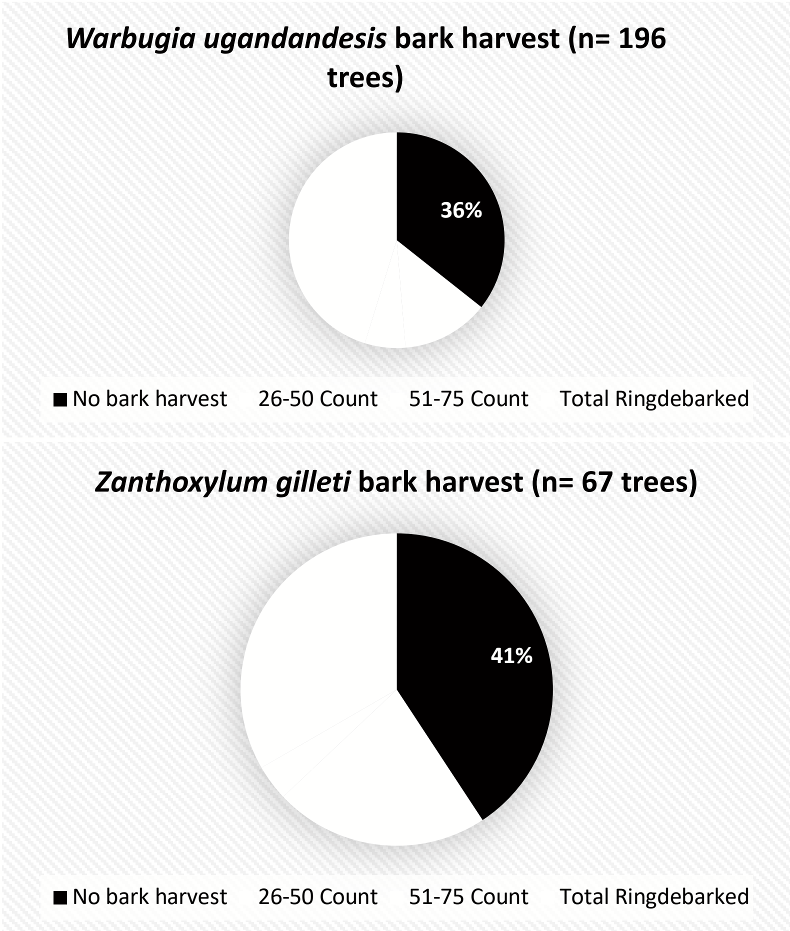


Figure 14 Percent rates of bark harvest for *Warbugia ugandensis* and *Zanthoxylum gillettii*

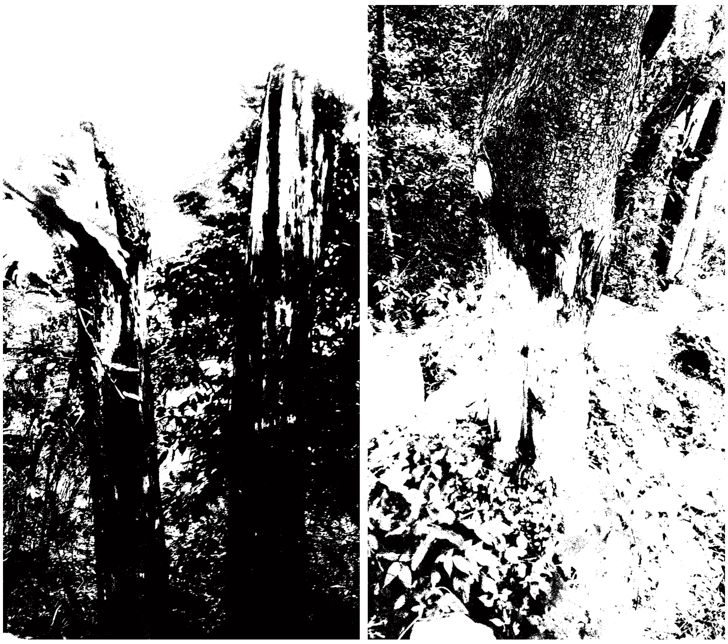


Plate 2 Evidence of total ringbarking of *Warbugia ugandensis* trees

5.6 Anthropogenic activities in KKCFR

Figure 15 shows the number and types of human activities recorded in KKCFR in 2016 and 2022. The number and type of human activities recorded in were snares, tree/pole cutting, pitsawing, fresh human trails, encroachment, pole cutting, charcoal burning, tree bark harvest and firewood collection. The most prevalent human activities recorded in KKCFR for both 2016 and 2022 in descending order were fresh human trails, firewood collection, tree bark harvest and charcoal burning (Figure 15). The least recorded human activities for both 2016 and 2022 in ascending snares and encroachment (Figure 15). The number of human activity signs recorded in KKCFR increased from 29 signs in 2016 to 102 signs in 2022 and this difference was statistically significant (Kruskal-Wallis Chi-square == 1.3834, df = 1, **p-value = 0.02395**). Furthermore, figure 16 is a boxplot showing the differences in human activities recorded in KKCFR in 2016 and 2022. The human activities in KKCFR have been increasing with increased demand of forest resources from the surrounding communities. During the field surveys we encountered about 8 sites where piles of cut tree poles had been made a waiting the charcoal burning process (see plate 4 & 5). A further human activity observed during this study is the replacement of some natural forests with plantations of Eucalyptus. In 2016, the eucalyptus plantations were not there but in 2022, some natural forest patches had been cut and replaced with eucalyptus plantations.

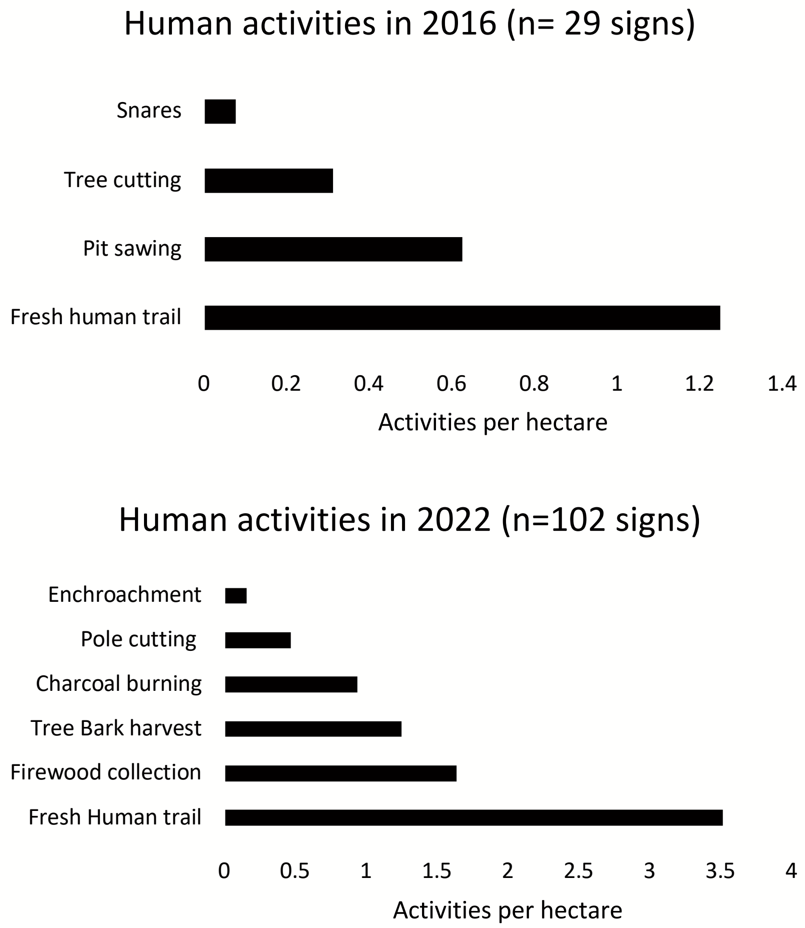


Figure 15 A comparison of types and number of human activities between 2016 and 2022

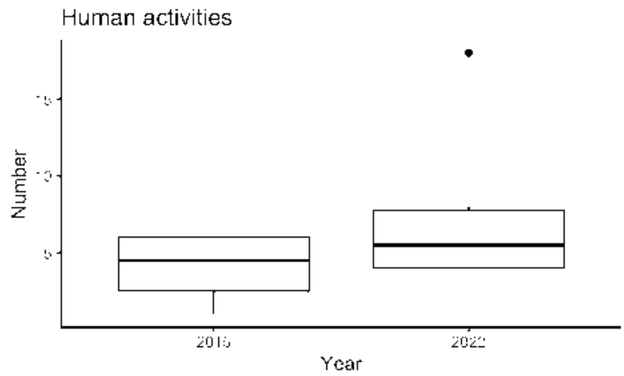


Figure 16 A boxplot showing differences in number of human activities between 2016 and 2022

Plate 3 Evidence of charcoal burning in KKCFR

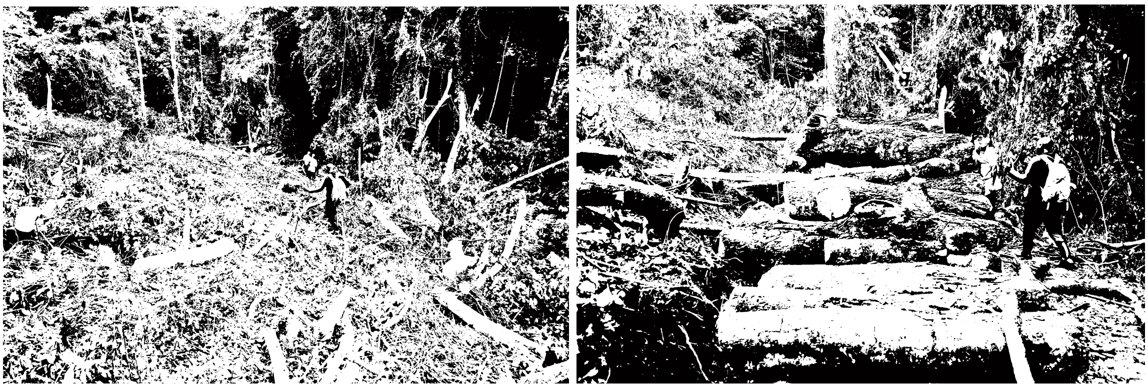


Plate 4 Evidence of Forest clearance for tree logs

Plate 5 Evidence of more piles of tree logs

6.0 Discussion

6.1. Flora and Fauna abundance and diversity in KKCFR

Our results suggest that the abundance, diversity and distributions of the different flora and fauna in KKCFR are strongly shaped by anthropogenic activities, with almost all species experiencing reduction in evenness and diversity in 2022 due to human activities. Populations and species are disappearing due to disturbances in the environment caused by human activities (Bruna & Ribeiro, 2005; Kanieski et al., 2018; Wright & Muller-Landau, 2006) Trends in species richness and evenness may reveal a good deal about present conditions of the habitat (Hayek & Buzas, 2010; Kutnar et al., 2019; Odum & Barrett, 2005). The Flora and fauna species evenness (relative abundance) is the distribution of abundances among species of concern (Ntongani & Andrew, 2013). Most natural communities contain a few species with large numbers of individuals (common or dominant species) and many species each represented by a few individuals (Hayek & Buzas, 2010; Odum & Barrett, 2005). Our study has found out that for most of the studied flora and fauna (except bird species), the species richness and evenness were low in the year 2022 than in 2016. The diversity and evenness indices of most flora and fauna in KKCFR were higher in 2016 than in 2022. This is probably an accumulation of impacts of anthropogenic disturbances in 2022.

Flora and fauna components of species diversity respond differently to various environmental conditions and most especially habitat changes (Bruna & Ribeiro, 2005). Anthropogenic activities can drive both species' range contractions and expansions and as such many species have lost substantial distribution areas due to intensifying human activities (Xu et al., 2019). Poor or highly degraded habitats such as KKCFR possess very little or diverse flora and fauna. This study has shown that KKCFR biodiversity has been declining since 2016 with the surrogate species of concern declining. However, the few species that are able to occupy certain habitats may be abundant in that habitat due to less competition with the other species for resources (Hayek & Buzas, 2010; Odum & Barrett, 2005). This study has shown that the birds were the only species that had significantly increased in numbers (abundance) in 2022. This study probably illustrates that species risk biotic homogenization as a consequence of anthropogenic activities, with narrow- ranged species becoming replaced by widespread species (Xu et al., 2019). In this case, the bird species could be considered widespread and taken advantage of the absence/reduction of the other species and therefore increasing in abundance (Hayek & Buzas, 2010; Odum & Barrett, 2005). The implication of these results is that the human activities could be having an impact on the abundance, distribution and diversity of most flora and fauna in KKCFR. Indeed, as noted by Ntongani & Andrew, (2013), it appears that human-induced disturbances and possibly other ecological factors exacerbated by humans (e.g. climate change) is contributing to the observed loss in biodiversity in KKCFR.This study, furthermore, has confirmed that the most dominant tree species in KKCFR are the secondary forest tree species of *Strombosia schefflera, Funtimia africana, Warbugia ugandensis, Xymalos monospora, Macaranga kilimadscherica etc.* These are trees that mostly dominate disturbed sites because of anthropogenic activities. These results are consistent with those of Chazdon, (2003); Ghazoul & Sheil, (2010); McGeoch et al., (2008); Olupot, (2009) who reported that secondary forest tree species densities are often high in forest regenerating areas that have previously experienced human disturbances.

6.2. Implications of forest disturbance on Bird species diversity

Plumptre et al. (2007) compiled a list of 308 bird species for KK using all the references for bird surveys and inventory work for the CFR. A number of bird species were therefore missed during our point-count surveys although many aerial feeders and overflying birds were excluded from our counts. Also, we surveyed a small portion of the reserve and spent but 14 days only for the sampling. The species accumulation curves for both survey periods (i.e., 2016 and 2022) were very steep at the beginning. This is indicative of a disturbed forest as they tend to accumulate species fairly quickly following an initial period of destabilization and loss of many species, though they do not necessarily regain species typical of a primary forest (Johns 1986). Forest disturbance between 2016 and 2022 seem to have altered the bird community with an increase in species density and richness, but with a decline in diversity, evenness and dominance. An increase in species density and richness was due to the heterogeneous habitat generated by disturbance being taken up by large numbers of successional or opportunistic species while precluding some primary forest specialists (Johns 1986; Dranzoa 1998). Many understory and canopy species are attracted to the forest floor to exploit new niches created by the reduced canopy cover and the resultant dense undergrowth. The other indices – diversity, evenness and dominance were the opposite of what has been found in other studies (e.g., Thiollay 1992 and Dranzoa 1998). This could be attributed to human disturbances (charcoal burning, pole/wood harvesting, human presence) that were taking place during field data collection for both time periods (i.e., 2016 and 2022) while in other studies, field bird surveys were done long (>10 years) after major human disturbances, especially logging, had ceased. Therefore, lack agreement in the pattern of indices with other studies could be because of the ongoing severe but localized human disturbances in our study that made the birds to frequently move between different areas while feeding or breeding (Neuschulz et al. 2013) so that their populations were unstable and transient with a few residents (Johns 1986; Dranzoa 1998). However, the use of single diversity indices to examine the whole species dataset is often discouraged as a single index masks many changes in species composition, as different subsets of species react to environmental disturbance in varying ways (Karr 1976; Johns 1986; Dranzoa 1998). Therefore, the bird assemblage of KK CFR was examined in terms of sets of species (i.e., habitat categories and feeding guilds).

6.3 Implications of forest disturbance on bird species forest dependency

The forest generalists (F-species) were the only forest-dependent group that increased significantly in species density between the study periods. This means that forest disturbance, mainly opening up of the canopy may be followed by the loss of some species, but with the appearance of previously unrecorded species from secondary or edge habitat. The F-species are well adapted to exploiting forest edges, tree fall gaps and secondary forest (Bennun et al. 1996). The forest interior specialists (FF-species) showed a slight decline in relative proportion though the decrease was not statistically significant. Dranzoa (2000) found that breeding of some forest specialists takes place in a logged forest of Kibale forest although the breeding populations remained depressed. It was observed that KK has not been colonized by forest visitors (f-species) of non-forest and edge habitats. This probably implies that the vegetation structure and composition of KK has only been moderately modified and is possibly not yet a preferred habitat for non-forest bird species.

6.4 Implications of forest disturbance on bird species *feeding guilds*

Forest disturbance between 2016 and 2022 affected the bird feeding guild structure and composition. Removal of large trees leads to more openings in the canopy cover and increased vegetation density at ground level which may make individual species vulnerable or resilient to man-induced disturbances. In this study, the 5-year forest disturbance seemed to favour the mixed feeders and frugivores. This is similar to findings in other studies in previously logged Ugandan forests of Kibale (Dranzoa 1995) and Budongo (Owiunji and Plumptre 1998). The frugivores feed on small fruits that are produced by small and early maturing trees, which are often common in early successional patches and more open habitat that contain a higher densities of flowering plants (Johns 1986). The mixed feeders are resilient to forest disturbance by being able to modify their foraging strategies in response to changes in the resource profile. For example, the frugivore-insectivore or insectivore-nectarivores are able to add or increase a proportion of fruit or nectar in their diet when faced with a shortage of insects (Johns 1986). On the other hand, the understorey birds - the flycatchers, forage gleaners and ground feeders - were found to be either very few and/or to have declined in number of species and density between the survey periods. There are a number of reasons for the low or declining in number of species or frequency of species occurrence of these feeding guilds. One of these is the inability of these understory birds to cope with the relatively harsh conditions (higher light intensity, higher ambient temperature and lower humidity) of reduced forest canopy cover (Johns 1986). The bark of some forest trees is scorched by sunlight, which kills the covering of mosses and epiphytes. This change causes a reduction in the numbers of some bark-gleaning insectivores and those that probe among moss and epiphytes for their food. Others that feed on litter arthropods may be affected by the widespread drying of the soil or presence of thick undergrowth under disturbed habitat conditions. With a high proportion of the canopy opened or damaged, the sweeping insectivores such as the swifts, swallows, and bee-eaters, which normally forage above the canopy in primary forest, forage at lower levels in the large gaps, thus outcompeting the understory flycatchers (Johns 1986; Thiollay 1992). The understory insectivores are therefore highly susceptible to forest disturbance as they tend to be replaced by more robust species, often those able to feed opportunistically on a variety of foods (Johns 1986; Owiunji and Plumptre 1998). Consequently, they can be useful as indicators of forest disturbance impacts.

Finally, the avifauna of KKCFR showed modest changes between 2016 and 2022 resulting from increased and continuous human disturbances in the CFR. Much of the changes in bird composition and species density are due to changes in the structure of the vegetation as well as reduction in foraging space within a disturbed forest. There is still a high number of forest birds, but a large proportion of the bird community are the generalists (F-species) that are of low conservation significance since they are widely distributed. As a result of an increase in number of species, the species density and richness were higher in 2022 than 2016. However, the forest interior specialists (FF-species) were found to be declining. Our results also show the understory insectivores are the most adversely affected by forest disturbance. These species have a highly specialized diet or foraging behavior and are physiologically intolerant of microclimatic changes of a disturbed forest. This study considers only short-term results. However, the responses of any species to disturbance are potentially varied and difficult to predict. There is a need to generate more information on the long-term effects of disturbance on forest bird species that will help management in designing mitigation strategies to reduce the deleterious impacts of human activities on biodiversity.

6.5 Tree species bark Harvest impacts in KKCFR.

Density or the number of individuals per unit area is probably the ecological parameter of greatest interest to ethnobotanists (Peters, 1996). The first signal that a plant population is being subjected to an overly intensive level of harvest is usually manifested in the size-class distribution of that population (Hall & Bawa, 1993; Peters, 1996). One first signal that a plant population is being subjected to an overly intensive level of harvest is usually the manifestations of size-class distribution of that population (Hall & Bawa, 1993; Peters, 1996; Sampaio et al., 2008). This is indeed the case with the bark harvested tree species of the *Warbugia ugandensis and Zanthoxylum gilletii* tree species in KKCFR. The size class distribution shown by the two tree species (“L” type) is typical of heavily harvested mature individuals and with more seedling/juveniles and many sprouts and therefore need urgent monitoring/attention.

The bark harvested from the two trees of *Warbugia ugandensis and Zanthoxylum gilletii* is produced by a thin layer of cambium cells that surround the xylem tissues which transport water and nutrients to and from the roots and leaves (Cunningham, 2001). Furthermore, the bark protects the trees against fires, fungal and insect attacks. Therefore, the commercial bark harvests from the two tree species can have serious consequences on those trees. The ringbarking or girding of the trees (that was most practised in KKCFR) is where the trees’ bark is completely removed around the trunks and this leads to the death of the trees (Cunningham, 2001). It is therefore important to note that the current ringbarking harvest (at about 40% of sampled trees), coupled with bark commercialisation, is precusor to the elimination of those trees in KKCFR. The only probable consolation is that the tree *Warbugia ugandansesis* is one of the most dominant trees in KKCFR that prefers disturbed habitats.

6.6 Impact of Human activities on general biodiversity in KKCFR

Our study has shown that human activities within KKCFR have more than tripled significantly since 2016. Human population increase and demand for forest resources continue to put pressure on protected areas as highlighted by various studies. Exacerbated by the commercial demand for bark from two tree species of *Warbugia ugandensis and Zanthoxylum gilletii,* the "human foot" print in KKCFR has dramatically increased. Other human activities such as charcoal burning related to forest resource commercialization and the clearance of natural forests for eucalyptus tree plantations is a precursor for biodiversity loss in KKCFR. The observed management activity by National Forest Authority (NFA) of replacing some natural forests with eucalyptus trees is another human activity impact that is not desirable in natural forest. The anthropogenic disturbances in forest ecosystems are important drivers of ecosystem structure, function, and biodiversity changes (Kanieski et al., 2018; Kutnar et al., 2019). It is therefore obvious that the present anthropogenic disturbances in KKCFR, have had a negative impact on the biodiversity therein. According to Ghazoul & Sheil, (2010), biodiversity loss in tropical forest is mainly caused by forest clearings combined with selective logging by humans and fires. Species that are local, endemic, or that have specialized habitats are much more vulnerable to extinction when their particular habitat is degraded through anthropogenic activities (Wright & Muller-Landau, 2006).

7.0 Conclusion

Without doubt, the human activities within the KKCFR have more than tripled and are likely to increase further as the human population increases and with the increased commercialization of some of the forest resources. This is therefore a precursor to the increased loss of biodiversity in the KKCFR. Although the biodiversity loss is not yet at alarmingly at a wide scale, the loss of some flora and fauna species since 2016 is of particular concern to conservationists. Of specific concern are the endangered and endemic species such as the Albertine rift endemic birds (the Yellow- eyed Black Flycatcher, Blue-headed Sunbird, Red-faced Woodland Warbler) in KKCFR as these would likely be eliminated with increased human activities. More studies need to be carried out to assess the extent of this biodiversity loss particularly focusing on the type of species of concern (e.g., the endemic/endangered forest understory species such as rodents and birds).

8.0 Recommendations

The following are the recommendations of this study.

- The KKCFR needs urgent attention by all stakeholders to save it from the serious human activities that are threatening its existence. The human activities such as charcoal burning, tree poles cutting are being carried with impunity without any sort of control. Hundreds and hundreds of trees are being cut for charcoal making, poles and timber including other uses from KKCFR. Without urgent interventions in KKCFR, the biodiversity in KKCFR will be in peril of elimination.
- The KKCFR urgently needs strict law enforcements from the various and uncontrolled human activities currently being carried out therein. NFA needs to increase on its manpower and probably collaborate with the Uganda Wildlife Authority (UWA) to help it in halting the various charcoal making, tree poles cutting etc. activities currently being practiced in KKCFR.
- We recommend that the law enforcement efforts in KKCFR be increased and facilitated in terms of manpower and resources (financial and equipment). NFA needs to recruit more patrol staff and highly motivate them. Supervision by the NFA of these field staff also needs to be upped.
- NatureUganda needs to review and evaluate the CFM activities it currently facilitated in conjunction with NFA in KKCFR. A monitoring and evaluation program needs to be made for reviewing the impacts of the CFM. It is often assumed that the introduction of CFM where the local communities are made to appreciate the value of the forest and its benefits would halt or atleast reduce illegal activities in protected areas. This is not the case with the KKCFR CFM, rather illegal activities are increasing and being carried out with impunity. A cost benefits analysis of the KKCFR CFM is needed.
- NFA and the development organizations working around KKCFR such as NatureUganda should proactively increase efforts and implementation of tree planting or agroforestry in the parishes around KKCFR. The agroforestry should encourage communities to plant trees that would help supplement their homestead requirement for fuel wood. NFA could provide tree seedlings to the local community members for establishing tree nursery gardens for sustainable supply of tree seedlings.
- Bark harvests from the *Warbugia ugandensis* and *Zanthoxylum gilletti* needs to be controlled with strict quotas enforced by NFA. The unsustainable practice of bark harvest such as the <u>ringbarking</u> and <u>total ringbarking</u> needs to be urgently halted and strictly enforced. NFA needs to put up guidelines on the dos and don’ts for bark harvests

from the two trees. For example, ringbarking and total ringbarking must not be carried out on the trees. Removal of the bark should be carried out on one side of the tree trunk allowing the other side to maintain its bark.

- The practice by NFA where some patches of natural forests are being replaced with plantations of eucalyptus trees should be halted and if possible, the eucalyptus tree cut down to allow natural regeneration of natural forests. Active planting of indigenous trees in those cleared forest patches could also be carried out. What should be encouraged is the maintenance of natural forest patches for better biodiversity conservation in KKCFR.
- Given the short time for this survey and the limited access to a large area of the forest, we recommend that further biodiversity surveys be undertaken in KKCFR to cover other forest areas, Of particularly concern are the forest interiors and other parishes that were not covered during this survey. This would improve on the species lists we have compiled to date and get more information on the factors that influence species distribution and composition.

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10.0 Appendix

10.1 Tree species list of Kasyoha-Kitomi Central Forest Reserve

Id	*Species*	Life form
1	Agauria salicifolia	Tree
2	Aidia maicrantha	Tree
3	Alangium chinense	Tree
4	Allophylus abyssinicus	Tree
5	Antiaris toxicaria	Tree
6	Afrosersalicia cerasifera	Tree
7	Alangium chinense	Tree
8	Albizia coriaria	Tree
9	Antaris toxicaria	Tree
10	Anthocleista vogeellii	Tree
11	Antidesma lacinatum	Tree
12	Antidesma lacinatum	Tree
13	Ardia micrantha	Tree
14	Baphiopsis parviflora	Tree
15	Beischriecha SP	Tree
16	Blighia unijugata	Tree
17	Bridelia micrantha	Tree
18	Caesaria engleri	Tree
19	Canarium schweinfurthii	Tree
20	Carapa procera	Tree
21	Cassipourea sp.	Tree
22	Celtis durandii	Tree
23	Celtis gomphoplyla	Tree
24	Cordia africana	Tree
25	Croton macrostacluysus	Tree
26	Diospyros abyssinica	Tree
27	Dombeya kirkii	Tree
28	Drypetes gerradii	Tree
29	Drypetes SP	Tree
30	Drypetes ugandensis	Tree
31	Ehretia cymosa	Tree
32	Entandrophragma excelsum	Tree
33	Erythina abyssinica	Tree
34	Faurea saligna	Tree
35	Ficalhoa laurifolia	Tree
36	Ficus capensis	Tree
37	Ficus ovota	Tree
38	Funtimia africana	Tree

39	Funtumia elastica	Tree
40	Hamugana madagascariesis	Tree
41	Homoa longipes	Tree
42	Kigelia africana	Tree
43	Lepidotrichilia volkensii	Tree
44	Leplaea grewia	Tree
45	Leplaes mayombensis	Tree
46	Leptonychia mildbraedii	Tree
47	Lindacleria bukobensis	Tree
48	Lovoa swynertonii	Tree
49	Lovoa tridilloides	Tree
50	Macaranga pynertii	Tree
51	Macaranga barteri	Tree
52	Macaranga borteri	Tree
53	Macaranga capensis	Tree
54	Macaranga monandra	Tree
55	Macaranga schweinfurthii	Tree
56	Maesa lanceolata	Tree
57	Maesopsis eminii	Tree
58	Margaritaria discoideus	Tree
59	Markabania hutea	Tree
60	Maytenus sp	Tree
61	Mayterus uridata	Tree
62	Milletia dura	Tree
63	Monodoro myristica	Tree
64	Myrianthus holstii	Tree
65	Neoboutonria molleri	Tree
66	Newtonia buchananii	Tree
67	Nuxia congesta	Tree
68	Pachystela brevipes	Tree
69	Pancovia turbinata	Tree
70	Paretta molundesis	Tree
71	Parinari excelsa	Tree
72	Pauridiantha callicarpoides	Tree
73	Pcynanthus angolensis	Tree
74	Peddiea Fischeri	Tree
75	Phoenix reclinata	Tree
76	Pinus tida	Tree
77	Pittosporum spathucalyx	Tree
78	Polyscias fulva	Tree
79	Prunus africana	Tree
80	Pterigota mildbraedii	Tree

81	Raphia farinifera	Tree
82	Rawnsonia lucida	Tree
83	Ritchiea albersii	Tree
84	Rothmannia urcellifonus	Tree
85	Shirakiopsis elliptica	Tree
86	Spathodea camparulata	Tree
87	Strombosia scheffleri	Tree
88	Strombosiopsis tetrandra	Tree
89	Syensepalum cerasiferum	Tree
90	Syzgium guineense	Tree
91	Tarbernaemontana odoratissima	Tree
92	Tarbernamontana holstii	Tree
93	Tarena parettoides	Tree
94	Tetrochidium didymostemon	Tree
95	Trema orientalis	Tree
96	Trichilia prieureana	Tree
97	Trichilia rubescens	Tree
98	Trichillia dregeana	Tree
99	Trichillia SP	Tree
100	Trichoscypha submontana	Tree
101	Trichosypha ulugurunsis	Tree
102	Trilepsium madagascanesis	Tree
103	Uapaca guineensis	Tree
104	Uapaca paludosa	Tree
105	Voacanga thoarsii	Tree
106	Warbugia ugandensis	Tree
107	Xylopia aethiopica	Tree
108	Xylopia eminii	Tree
109	Xymalos monospora	Tree
110	Zanthoxylum gilletii	Tree

10.2 Shrub and Liana species list of Kasyoha-Kitomi Central Forest Reserve

Id	Species	Lifeform
1	Acanthus pubescens	Shrub
2	Aegelea pentagyna	Shrub
3	Afromonum SP	Shrub
4	Alchornea hirtella	Shrub
9	Brillantaisa citricosa	Shrub
11	Cleredendron myricoides	Shrub
12	Clerodendrom SP	Shrub
13	Clerodendron johnistoni	Shrub
14	Clerodendrun formicarum	Shrub
15	Connarus longispictatus	Shrub
16	Dicranolepis usambarica	Shrub
18	Doryalis macrolyx	Shrub
19	Dracaena laxissima	Shrub
20	Erica arborea	Shrub
21	Ficus asperifolia	Shrub
22	Keetia queinzii	Shrub
23	Lasianthus kilimadscherica	Shrub
24	Leea guineasa	Shrub
25	Leonotis neptifolia	Shrub
26	Lobelia Sp	Shrub
27	Marantochloa purpureum	Liana
28	Monanthotaxis ferruguinea	Liana
29	Ocimuni gratissimum	Liana
30	Paulinia pinnata	Liana
31	Pcynostachys elliotii	Shrub
32	Phyllanthus ovalifolies	Liana
33	Piper capense	Liana
34	Piper guineasis	Liana
35	Piper umbellatum	Shrub
36	Reurea thornasii	Shrub
37	Rothmania urcellfornus	Shrub
38	Rutidea orientalis	Liana
39	Rutidea smithi	Liana
40	Rytigyinia kigeziensis	Shrub
41	Rytigyinia rwenzoriensis	Shrub
42	Salacia cerasifera	Liana
43	Salacia eleganus	Liana
44	Salacia leptoclada	Liana
45	Schafflera barteri	Liana
46	Tephrosia vogelii	Shrub

47	Todalia asiatica	Liana
48	Triumfetta brachyceros	Shrub
49	Turrea vogelloides	Shrub
50	Urera cameroonensis	Liana
51	Uvaria SP	Liana
52	Vangueria apiculata	Shrub
53	Vernonia lasiopus	Shrub
54	Acacia brevispica	Liana
55	Acanthus pubescens	Shrub
56	Afromomum sp	Shrub
57	Alchornea cordfolia	Shrub
58	Alchornea hirtella	Shrub
59	Allophyllus africanus	Shrub
60	Brillantarisia citricosa	Shrub
61	Clerodendrum	Shrub
62	Coffee arabica	Shrub
63	Combretum linearifolia	Shrub
64	Connarus longspictatus	Shrub
65	Cyphomadra betacea	Shrub
66	Dalberga lactea	Shrub
67	Datura swaveolens	Shrub
68	Dicranolepis usambarica	Shrub
69	Discopodium penninerium	Shrub
70	Dovyalis macrocalyx	Shrub
71	Flabelleria paniculata	Liana
72	Fluggea virosa	Shrub
73	Gouania longispilata	Liana
74	Hibscus sp	Shrub
75	Illigera petaphylla	Liana
76	Keetia gueinzii	Liana
77	Lantana camara	Shrub
78	Lasiathus kilimadscharica	Shrub
79	Iodes usambarensis	Shrub
80	Marantochroa purpurea	Shrub
81	Mimulopsis solmsii	Liana
82	Monanthotaxis littoralis	Liana
83	Paulinia pinnata	Liana
84	Phytolacca dodecandra	Liana
85	Piper capense	Shrub
86	Piper guineense	Liana
87	Piper unbellutum	Shrub
88	Pristimera gracifolia	Liana

90	Rourea thomsonii	Shrub
91	Rubus sp.	Liana
92	Salacia elegans	Liana
93	Scheffleri barferi	Liana
94	Sericostachyts scandens	Liana
95	Toddalia asiatica	Liana
96	Triumfetta brachyceros	Shrub
97	Uncaria africana	Liana
98	Urera cameroonensis	Liana
99	Vernoma auriculifera	Shrub

10.3 Vine and Herbs species list of Kasyoha-Kitomi Central Forest Reserve

Id	Species	Life form
1	Acalypha SP	Herb
2	Achyranthes aspera	Herb
3	Afromomum angustifolia	Herb
4	Afromomum SP	Herb
5	Annisopappus africanus	Herb
6	Asplenium aethiopium	Herb
7	Asplenium dregeanum	Herb
8	Asplenium elliotii	Herb
9	Asplenium sp	Herb
10	Bidens pilosa	Herb
11	Blotiella crenata	Herb
12	Blotiella glabra	Herb
13	Cardiospermum grandiflorum	Herb
14	Celosia stulhmaniana	Vine
15	Chasalia cristata	Herb
16	Cissus peliolata	Herb
17	Commelina SP	Herb
18	Crassocephelum montuosum	Herb
19	Crassocephelum vitellinum	Herb
20	Culcasia gracilifolia	Vine
21	Culcasia scandens	Vine
22	Desmodium repandum	Herb
23	Desmoduin adenscens	Herb
24	Dicrocephalum integrifolia	Herb
25	Didymochlaena trancetula	Herb
26	Didymochlaena tricatula	Herb
27	Dioscorea odoratissima	Vine
28	Dioscorea Sp	Vine
29	Dryopetes sp	Herb
30	Dryopteris Kilemensis	Herb
31	Elatostemma monticola	Herb
32	Hyparrhenia sp.	Herb
33	Hyperhenia cymbraria	Herb
34	Impatiens SP	Herb
35	Imperata cylindrica	Herb
36	Ipomae unvolcrate	Vine
37	Ipomea wightii	Vine
38	Justicia SP	Herb

39	Leptaspis zeylanica	Herb
40	Maratia fraxinea	Herb
41	Olyra latifolia	Herb
42	Oplismanus hirtellus	Herb
43	Palisota mannii	Herb
44	Panicium SP	Herb
45	Panicum adenophorum	Herb
46	Pasparum conjugatum	Herb
47	Pilea holstii	Herb
48	Pteridium aquilinum	Herb
49	Pteris dentata	Herb
50	Pteris SP	Herb
51	Setaria plicatilis	Herb
52	Sida sp	Herb
53	Smilax anceps	Vine
54	Solanum terminale	Vine
55	Stephenia abyssinica	Vine
56	Thelypteris sp	Herb
57	Vanila imperialalis	Vine

10.3 Rodents species list for Kasyoha-Kitomi Central Forest Reserve

Id	Species	Status
1	*Crocidura Maurisca*	Of least concern
2	*Dasmys incomptus*	Of least concern
3	Grammomys sp	Of least concern
4	*Hybomys univittatus*	Of least concern
5	*Laphuromys flavopunctatus*	Of least concern
6	*Malacomys longipes*	Of least concern
7	*Praomys jacksonii*	Of Least concern
8	*Scutisorex somereni*	Of least concern
9	*Sylvisorex grantii*	Of least concern

10.4 Bird species list for Kasyoha-Kitomi Central Forest Reserve

Taxonomy and nomenclature follow Stevenson and Fanshawe (2020); Forest dependency categories follow Bennun et al. (1996); feeding guilds after Birds of Africa (1982-2004); and conservation status follow Birdlife International (2022) and Stattersfield et al. (1998). Frequency of occurrence for each species and study period are shown.

KEY: **Habitat category:** FF – Forest interior specialists; F - Forest generalist; f – forest visitors; nf – non-forest. **Conservation status:** LC – Least Concern; ARE – Endemic to the mountains along the Albertine Rift

Species	**Habitat category**	**Feeding guild**	**Conservation status**	**Frequency of species occurrence**	
				2016	**2022**
THRESKIORNITHIDAE Ibises and spoonbills					
Hadada ibis *Bostrychia hagedash*	nf	Ground feeder	LC	-	3
ACCIPITRIDAE Hawks, vultures, buzzards and eagles					
Little Sparrowhawk *Accipter minullus*	f	Raptor	LC	-	2
African Harrier-Hawk *Polyboroides typus*	f	Mixed feeder	LC	-	1
Augur Buzzard *Buteo augur*	nf	Raptor	LC	-	1
Long-crested Eagle *Lophaetus occipitalis*	f	Raptor	LC	-	2
NUMIDIDAE Guineafowl					
Crested Guineafowl *Guttera pucherani*	nf	Ground feeder	LC	-	2
PHASIANIDAE Quails and francolins					
Scaly Spurfowl *Pternistis squamatus*	F	Ground feeder	LC	1	3
COLUMBIDAE Pigeons and doves					
African Green-Pigeon *Treron calvus*	F	Frugivore	LC	2	4
African Olive Pigeon *Columba arquatrix*	FF	Frugivore	LC	-	9

Tambourine Dove *Turtur tympanistria*	F	Frugivore	LC	7	78
Mourning Collared Dove *Streptopelia decipiens*	nf	Frugivore	LC	-	2
Ring-necked Dove *Streptopelia capicola*	f	Frugivore	LC	-	2
Red-eyed Dove *Streptopelia semitorquata*	f	Frugivore	LC	-	1
PSITTACIDAE Parrots and lovebirds					
Red-headed Lovebird *Agapornis pullarius*	f	Ground feeder	LC	1	-
MUSOPHAGIDAE Turacos and go-away-birds					
Ross's Turaco *Musophaga rossae*	F	Frugivore	LC	1	9
Black-billed Turaco *Tauraco schuettii*	FF	Frugivore	LC	2	21
Great Blue Turaco *Corythaeola cristata*	F	Frugivore	LC	-	7
Eastern Plantain-eater *Crinifer zonurus*	nf	Frugivore	LC	-	6
CUCULIDAE Cuckoos, coucals and yellowbirds					
Barred Long-tailed Cuckoo *Cercococcyx montanus*	FF	Gleaner	LC	-	12
Red-chested Cuckoo *Cuculus solitarius*	F	Gleaner	LC	-	12
African Emerald Cuckoo *Chrysococcyx cupreus*	F	Gleaner	LC	-	2
Chattering Yellowbill *Ceuthmochares aereus*	F	Gleaner	LC	1	2
Blue-headed Coucal *Centropus monachus*	nf	Gleaner	LC	2	4
White-browed Coucal *Centropus superciliosus*	nf	Gleaner	LC	-	1
STRIGIDAE Typical Owls					
Spotted Eagle-Owl *Bubo africanus*	nf	Raptor	LC	1	-
COLIIDAE Mousebirds					
Speckled Mousebird *Colius striatus*	nf	Frugivore	LC	2	6
Narina Trogon *Apaloderma narina*	F	Gleaner	LC	8	35
ALCEDINIDAE Kingfishers					
Pied Kingfisher *Ceryle rudis*	nf	Ground feeder	LC	-	1

African Pygmy Kingfisher *Ispidina picta*	f	Ground feeder	LC	1	1
Malachite Kingfisher *Corythornis cristatus*	nf	Ground feeder	LC	1	-
MEROPIDAE Bee-eaters					
Cinnamon-chested Bee-eater *Merops oreobates*	F	Flycatcher	LC	2	3
Black Bee-eater *Merops gularis*	FF	Flycatcher	LC	1	-
CORACIIDAE Rollers					
Blue-throated Roller *Eurystomus gularis*	FF	Ground feeder	LC	-	3
BUCEROTIDAE Hornbills and ground-hornbills					
Crowned Hornbill *Lophoceros alboterminatus*	f	Mixed feeder	LC	-	4
Black-and-white-casqued Hornbill *Bycanistes subcylindricus*	F	Mixed feeder	LC	1	13
White-thighed Hornbill *Bycanistes albotibialis*	FF	Mixed feeder	LC	-	1
LYBIIDAE African barbets and tinkerbirds					
Yellow-rumped Tinkerbird *Pogoniulus bilineatus*	F	Mixed feeder	LC	2	68
Speckled Tinkerbird *Pogoniulus scolopaceus*	F	Mixed feeder	LC	-	3
Grey-headed Barbet *Gymnobucco cinereiceps*	F	Mixed feeder	LC	-	7
Double-toothed Barbet *Pogonornis bidentatus*	f	Mixed feeder	LC	1	1
Eastern Yellow-billed Barbet *Trachylaemus purpuratus*	F	Mixed feeder	LC	1	7
Yellow-spotted Barbet *Buccanodon duchaillui*	FF	Mixed feeder	LC	1	-
INDICATORIDAE Honeyguides					
Least Honeyguide *Indicator exilis*	FF	Flycatcher	LC	1	-
Lesser Honeyguide *Indicator minor*	f	Flycatcher	LC	1	-
Scaly-throated Honeyguide *Indicator variegatus*	f	Flycatcher	LC	1	-
PICIDAE Woodpeckers, wrynecks and piculets					
Cardinal Woodpecker *Dendropicos fuscescens*	f	Gleaner	LC	6	5

Bearded Woodpecker *Dendropicos namaquus*	f	Gleaner	LC	-	2
African Grey Woodpecker *Dendropicos goertae*	nf	Gleaner	LC	1	-
Fine-banded Woodpecker *Campethera taeniolaema*	FF	Gleaner	LC	1	-
HIRUNDINIDAE Swallows and martins					
White-headed Saw-wing *Psalidoprocne albiceps*	f	Flycatcher	LC	-	1
MOTACILLIDAE Wagtails, pipits and longclaws					
African Pied Wagtail *Motacilla aguimp*	nf	Ground feeder	LC	-	1
Yellow-throated Longclaw *Macronyx croceus*	nf	Ground feeder	LC	1	-
CAMPEPHAGIDAE Cuckooshrikes					
Black Cuckooshrike *Campephaga flava*	f	Gleaner	LC	-	2
NICATORIDAE Nicators					
Western Nicator *Nicator chloris*	F	Mixed feeder	LC	1	1
PYCNONOTIDAE Bulbuls and greenbuls					
Yellow-whiskered Greenbul *Eurillas latirostris*	F	Mixed feeder	LC	20	64
Common Bulbul *Pycnonotus barbatus*	f	Mixed feeder	LC	7	31
Slender-billed Greenbul *Stelgidillas gracilirostris*	FF	Mixed feeder	LC	1	2
Little Greenbul *Eurillas virens*	F	Mixed feeder	LC	1	8
Eastern Mountain Greenbul *Arizelocichla nigriceps*	FF	Mixed feeder	LC	6	11
Red-tailed Bristlebill *Bleda syndactylus*	FF	Mixed feeder	LC	2	3
Red-tailed Greenbul *Criniger calurus*	FF	Mixed feeder	LC	2	10
Pale-throated Greenbul *Atimastillas flavigula*	nf	Mixed feeder	LC	-	2
Icterine Greenbul *Phyllastrephus icterinus*	FF	Mixed feeder	LC	1	-
Spotted Greenbul *Ixonotus guttatus*	FF	Mixed feeder	LC	2	-
MUSCICAPIDAE Old World robins					
White-starred Robin *Pogonocichla stellata*	F	Ground feeder	LC	1	5

Brown-chested Alethe *Chamaetylas poliocephala*	FF	Ground feeder	LC	4	1
Snowy-crowned Robin-Chat *Cossypha niveicapilla*	F	Ground feeder	LC	-	1
White-browed Robin-Chat *Cossypha heuglini*	f	Ground feeder	LC	-	2
Red-capped Robin-Chat *Cossypha natalensis*	F	Ground feeder	LC	3	-
TURDIDAE Thrushes					
Abyssinian Thrush *Turdus abyssinicus*	F	Ground feeder	LC	3	9
White-tailed Ant-Thrush *Neocossyphus poensis*	FF	Ground feeder	LC	-	3
MUSCICAPIDAE Old World chats					
African Stonechat *Saxicola torquatus*	nf	Flycatcher	LC	-	2
White-browed Scrub-Robin *Cercotrichas leucophrys*	f	Ground feeder	LC	1	-
MODULATRICIDAE Spot-throat and allies					
Red-tailed Ant-Thrush *Neocossyphus rufus*	FF	Ground feeder	LC	1	-
PHYLLOSCOPIDAE Leaf warblers					
Red-faced Woodland-Warbler *Phylloscopus laetus*	FF	Gleaner	LC ARE	-	1
MACROSPHENIDAE Crombecs and allies					
White-browed Crombec *Sylvietta leucophrys*	FF	Gleaner	LC	1	1
Green Crombec *Sylvietta virens*	F	Gleaner	LC	1	-
CISTICOLIDAE Cisticolas and allies					
Black-faced Rufous Warbler *Bathmocercus rufus*	FF	Gleaner	LC	-	4
Croaking Cisticola *Cisticola natalensis*	nf	Gleaner	LC	1	1
Grey-capped Warbler *Eminia lepida*	f	Gleaner	LC	1	1
White-chinned Prinia *Schistolais leucopogon*	F	Gleaner	LC	1	1
Tawny-flanked Prinia *Prinia subflava*	f	Gleaner	LC	1	1
Grey-backed Camaroptera *Camaroptera brachyura*	f	Gleaner	LC	6	23
Banded Prinia *Prinia bairdii*	F	Gleaner	LC	1	-

Black-throated Apalis *Apalis jacksoni*	FF	Gleaner	LC	1	-
MUSCICAPIDAE Old World flycatchers					
Yellow-eyed Black Flycatcher *Melaenornis ardesiacus*	F	Flycatcher	LC ARE	-	1
African Dusky Flycatcher *Muscicapa adusta*	F	Flycatcher	LC	1	4
Ashy Flycatcher *Muscicapa caerulescens*	F	Flycatcher	LC	1	1
VANGIDAE Shrike-flycatchers					
Black-and-white Shrike-flycatcher *Bias musicus*	f	Flycatcher	LC	1	2
PLATYSTEIRIDAE Batises and wattle-eyes					
Brown-throated Wattle-eye *Platysteira cyanea*	f	Flycatcher	LC	2	4
MONARCHIDAE Monarch-flycatchers					
African Paradise-flycatcher *Terpsiphone viridis*	f	Flycatcher	LC	3	56
STENOSTIRIDAE Fairly-flycatchers and allies					
White-tailed Blue-flycatcher *Elminia albicauda*	F	Flycatchers	LC	2	2
PELLORNEIDAE Ground babblers					
African Hill-Babbler *Pseudoalcippe abyssinica*	FF	Ground feeder	LC	1	3
Scaly-breasted Illadopsis *Illadopsis albipectus*	FF	Ground feeder	LC	2	2
Mountain Illadopsis *Illadopsis pyrrhoptera*	FF	Ground feeder	LC	6	10
PARIDAE Tits					
Dusky Tit *Melaniparus funereus*	FF	Gleaner	LC	3	1
REMIZIDAE Penduline-tits					
African Yellow White-eye *Zosterops senegalensis*	f	Gleaner	LC	2	9
NECTARINIIDAE Sunbirds					
Bronze Sunbird *Nectarinia kilimensis*	f	Mixed feeder	LC	2	1
Blue-headed Sunbird *Cyanomitra alinae*	FF	Mixed feeder	LC ARE	1	3
Green-headed Sunbird *Cyanomitra verticalis*	F	Mixed feeder	LC	-	3

Olive-bellied Sunbird *Cinnyris chloropygius*	F	Mixed feeder	LC	3	6
Scarlet-chested Sunbird *Chalcomitra senegalensis*	nf	Mixed feeder	LC	1	4
Green-throated Sunbird *Chalcomitra rubescens*	F	Mixed feeder	LC	-	1
Olive Sunbird *Cyanomitra olivacea*	FF	Mixed feeder	LC	-	11
Collared Sunbird *Hedydipna collaris*	F	Mixed feeder	LC	1	3
LANIIDAE Shrikes					
Common Fiscal *Lanius collaris*	nf	Flycatcher	LC	2	-
MALACONOTIDAE Bushshrikes and allies					
Tropical Boubou *Laniarius major*	f	Gleaner	LC	-	2
Northern Puffback *Dryoscopus gambensis*	F	Gleaner	LC	1	4
Black-crowned Tchagra *Tchagra senegalus*	nf	Gleaner	LC	1	2
Black-headed Gonolek *Laniarius erythrogaster*	nf	Gleaner	LC	1	-
Doherty's Bushshrike Telophorus dohertyi	nf	Gleaner	LC	1	-
Luhder's Bushshrike *Laniarius luehderi*	F	Flycatcher	LC	5	-
ORIOLIDAE Orioles					
Montane Oriole *Oriolus percivali*	FF	Mixed feeder	LC	7	33
Eastern Black-headed Oriole *Oriolus larvatus*	f	Mixed feeder	LC	-	2
STURNIDAE Starlings					
Waller's Starling *Onychognathus walleri*	FF	Frugivore	LC	-	4
Great Blue-eared Starling *Lamprotornis chalybaeus*	nf	Frugivore	LC	-	5
Violet-backed Starling *Cinnyricinclus leucogaster*	f	Frugivore	LC	-	1
PASSERIDAE Old World sparrows					
Northern Grey-headed Sparrow *Passer griseus*	nf	Gleaner	LC	-	1
PLOCEIDAE Weavers and allies					
Lesser Masked Weaver *Ploceus intermedius*	nf	Mixed feeder	LC	-	1

Village Weaver *Ploceus cucullatus*	nf	Mixed feeder	LC	1	1
Baglafetcht Weaver *Ploceus baglafecht*	f	Mixed feeder	LC	-	2
Brown-capped Weaver *Ploceus insignis*	FF	Mixed feeder	LC	-	3
Red-headed Malimbe *Malimbus rubricollis*	FF	Mixed feeder	LC	1	4
Yellow Bishop *Euplectes capensis*	nf	Mixed feeder	LC	1	1
Black-necked Weaver *Ploceus nigricollis*	f	Mixed feeder	LC	1	-
ESTRILDIDAE Waxbills and allies					
Grey-headed Nigrita *Nigrita canicapillus*	F	Ground feeder	LC	2	1
White-breasted Nigrita *Nigrita fusconotus*	F	Ground feeder	LC	-	2
Black-bellied Seedcracker *Pyrenestes ostrinus*	F	Ground feeder	LC	-	1
Red-billed Firefinch *Lagonosticta senegala*	nf	Ground feeder	LC	-	1
Black-and-white Mannikin *Spermestes bicolor*	f	Ground feeder	LC	-	3
Red-headed Bluebill *Spermophaga ruficapilla*	nf	Mixed feeder	LC	1	-
FRINGILLIDAE Canaries, seedeaters and allies					
Brimstone Canary *Crithagra sulphurata*	nf	Ground feeder	LC	-	1
African Citril *Crithagra citrinelloides*	f	Ground feeder	LC	-	3
Streaky Seedeater *Crithagra striolata*	f	Ground feeder	LC	-	1
EMBERIZIDAE Buntings					
Golden-breasted Bunting *Emberiza flaviventris*	nf	Gleaner	LC	-	1