



**CENTRE OF EXCELLENCE IN BIODIVERSITY AND NANTURAL
RESOURCS MANAGEMENT**



BIODIVERSITY OF MUKURA FOREST RESERVE

FINAL REPORT



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Contributors



Dr Venuste Nsengimana serves the University of Rwanda as Associate Professor of Conservation Biology and Director of the Centre of Excellence in Biodiversity and Natural Resource Management, a UNESCO Category 2 Centre under the auspices of UNESCO. He has a PhD in Agronomy and Bioengineering from the University of Liège, Gembloux-Agro BioTech, MSc in Biodiversity Conservation and Bachelor of Biology Education from the University of Rwanda. Nsengimana conducts research in Biodiversity and Sustainability with special focus on effects of land use change on insect biodiversity and participatory governance of natural resources.



Jean de Dieu Nsenganeza is a research fellow at the Centre of Excellence in Biodiversity and Natural Resource Management. He is also doing an MSc in Biodiversity Conservation and Natural Resources Management in the University of Rwanda, College of Science and Technology, School of Science, Department of Biology. His expertise is ornithology and entomology, with special emphasis on pollinating Diptera.



Pascal Sibomana is a research fellow at the Centre of Excellence in Biodiversity and Natural Resource Management. He is also doing an MSc in Biodiversity Conservation and Natural Resources Management in the University of Rwanda, College of Science and Technology, School of Science, Department of Biology. His expertise is in plant diversity, plant taxonomy and the management of Herbarium.



Mapendo Mindje is the Assistant Lecturer and Head of Department of Ecotourism and Greenspace Management based in the School of Forestry, Ecotourism and Landscape Management, College of Agriculture, Forestry and Food Sciences, University of Rwanda. He holds a Master of Science in Bio-geoscience from the University of Koblenz Rondeaux, Germany, and an MSc in Biodiversity Conservation from the University of Rwanda, College of Science and Technology, School of Science, Department of Biology. His area of research is Herpetology



Edmond Twagirayezu is a professional intern at the Centre of Excellence in Biodiversity and Natural Resource Management. He holds a BSc of Science in Zoology and Conservation, with expertise in freshwater ecology, specializing in aquatic macroinvertebrates.



Brigitte Nyirarukundo is a professional intern at the Centre of Excellence in Biodiversity and Natural Resource Management. She is also doing an MSc in Biodiversity Conservation and Natural Resources Management in the University of Rwanda, College of Science and Technology, School of Science, Department of Biology. She holds a BSc of Science in Zoology and Conservation, with expertise in Entomology.



Methode Majyambere is the Assistant Lecturer in the University of Rwanda, College of Science and Technology, School of Science, Department of Biology. He is also a PhD candidate from the University of Rwanda, College of Science and Technology, School of Science, Department of Biology. His expertise is with expertise in small mammals.



Aimé Sandrine Uwase is a research fellow at the Centre of Excellence in Biodiversity and Natural Resource Management. She is also doing an MSc in Biodiversity Conservation and Natural Resources Management in the University of Rwanda, College of Science and Technology, School of Science, Department of Biology. Researcher in Conservation Biology with expertise in plant diversity and taxonomy.



Simon Muhayimana is a research fellow at the Centre of Excellence in Biodiversity and Natural Resource Management. He is also doing an MSc in Biodiversity Conservation and Natural Resources Management in the University of Rwanda, College of Science and Technology, School of Science, Department of Biology. He has expertise in Conservation Biology with focus in entomology (Lepidoptera and Coleoptera).



David Buyoya is a research fellow at the Centre of Excellence in Biodiversity and Natural Resource Management. He is also doing an MSc in Biodiversity Conservation and Natural Resources Management in the University of Rwanda, College of Science and Technology, School of Science, Department of Biology. He has expertise in general entomology.



Venant Nzibaza holds a master's degree in Biodiversity Conservation and Natural Resource Management from the University of Rwanda and master's degree in Biogeosciences from the University of Koblenz (Formerly University of Koblenz-Landau). He has a bachelor's degree in Zoology and Biodiversity Conservation from the University of Rwanda (UR). He is a research fellow to the Centre of Excellence in Biodiversity and Natural Resource Management. His area of research is focusing on water governance in riparian zones.



Alphonse Nzarora is the Assistant Lecturer at the University of Rwanda, College of Science and Technology, School of Science, Department of Biology since April 2011. Nzarora teaches plant biology with special focus on plant diversity. He has MSc in Biodiversity and Conservation at the University of Rwanda. His interest of research is on the relationship between land use, water quality and diatom diversity in the Akagera river and its wetland system, in Rwanda, with special focus on diatom taxonomy, freshwater resources and wetlands conservation.



Ir. Dominique Mvunabandi is the Director of Sciences Technology and Innovations Unit at UNESCO Rwanda National Commission (CNRU). He has an MSc from the University of Twente Netherlands and has expertise in Zoology, Ecology, Biostatistics, Cartography, Geoinformatics (GIS), Remote Sensing, Environmental Science and Forestry

General Introduction

Mukura Forest Reserve is a vital protected area nestled in the Eastern region of Rwanda between Rutsiro and Ngororero Districts. It is celebrated for its rich biodiversity and its critical role in regional biodiversity conservation efforts. Encompassing a mosaic of dense forests, rolling hills, and vibrant ecosystems, the reserve provides a sanctuary for a variety of endemic flora and fauna while serving as a living laboratory for ecological research and sustainable management practices.

At the heart of Mukura Forest Reserve is its impressive diversity of plant life. Indigenous trees form a lofty canopy that shelters a thriving understory of shrubs, ferns, and flowering plants. This complex habitat not only supports a wide range of species—from colorful birds and elusive small mammals to countless invertebrates—but also plays a key role in regulating local water cycles and maintaining soil health. The reserve's diverse plant communities contribute significantly to the overall ecological balance, making Mukura an essential component of Rwanda's natural heritage. Beyond its ecological significance, Mukura Forest Reserve offers considerable socio-economic benefits to local communities. In recent years, initiatives to promote ecotourism have opened up opportunities for nature walks, bird-watching excursions, and environmental education programs. These activities help raise awareness about conservation challenges and foster a strong bond between residents and their natural surroundings. By providing alternative livelihoods and promoting sustainable practices, the reserve enhances community resilience and encourages local stewardship of natural resources as part of Gishwati-Mukura National Park and Biosphere reserve.

Despite the importance of Mukura, the forest has undergone disturbances mainly due to human activities such as illegal logging, agricultural expansion, and mining. These activities have led to deforestation, loss of biodiversity, and disruption of vital ecosystem services, including water regulation and carbon storage. Population pressure in surrounding areas has exacerbated the problem, as communities clear forested land for farming and firewood collection. Additionally, mining for minerals like coltan and cassiterite has caused soil erosion and water pollution, further damaging the forest's ecological integrity. In response to these challenges, conservation efforts, including reforestation and its designation as part of National Park in 2015, aim to restore the forest and protect its rich biodiversity while promoting sustainable livelihoods for local communities.

Effective conservation at Mukura is achieved through the collaborative efforts of government agencies, local communities, and international partners. The Rwanda Development Board (RDB), along with various biodiversity conservation agencies, has implemented strategies such as reforestation projects, anti-poaching measures, and scientific research initiatives to safeguard the reserve. These efforts are crucial for mitigating the impacts of climate change and human encroachment, ensuring that the forest remains a robust ecosystem for future generations.

Mukura Forest Reserve stands as a beacon of Rwanda's commitment to environmental sustainability. Its thriving ecosystems and community-centered conservation practices exemplify

how protected areas can serve both as ecological treasures and as engines of sustainable development. As challenges like climate change and habitat degradation loom large, the continued protection and careful management of Mukura are more important than ever, not only for preserving its natural beauty but also for inspiring broader efforts toward global environmental stewardship. This is mainly achieved through the identification of its biodiversity and resources.

PART I: BIODIVERSITY OF MUKURA

Biodiversity from Mukura Forest and Biosphere Reserve, Western Rwanda

Venuste Nsengimana^{1,2,}, Aimé Sandrine Uwase¹, Alphonse Nzarora^{1,2}, Brigitte Nyirarukundo¹, David Buyoya¹, Edmond Twagirayezu¹, Jean de Dieu Nsenganeza¹, Methode Majyambere^{1,2}, Pascal Sibomana¹, Simon Muhayimana¹, Dominique Mvunabandi³, Mapendo Mindje^{1,4}*

¹Centre of Excellence in Biodiversity and Natural Resource Management, College of Science and Technology, University of Rwanda

²Department of Biology, School of Science, College of Science and Technology, University of Rwanda

³Rwanda National Commission of UNESCO, Kigali, Rwanda

⁴Department of Ecotourism and Greenspace Management, School of Forestry, Ecotourism and Landscape Management, College of Agriculture, Forestry and Food Sciences, University of Rwanda

*Corresponding author contacts: venusteok@gmail.com, v.nsengimana3@ur.ac.rw

Abstract

Mukura Forest is a biodiversity hotspot within the Albertine Rift essential for biodiversity conservation, climate regulation, and provision of water resources. Despite its importance, a comprehensive biodiversity assessment was lacking. This study surveyed plants, birds, mammals, amphibians, reptiles, terrestrial arthropods, butterflies, water macroinvertebrates, and diatoms across 20 sites in December 2025. Results recorded 1,523 individuals of water macroinvertebrates and 25 diatom species, highlighting minimal anthropogenic disturbance of water in Mukura Forest. Results have also indicated a total of 4,044 arthropods including 24 butterfly species. Avian surveys documented 124 species, with 12 Albertine Rift endemics and the critically endangered Hooded Vulture. Amphibians and reptiles yielded 12 and 5 species, respectively. Identified small mammals included 12 species, with three new records for Mukura. The floristic assessment identified 255 species, with two newly recorded. These findings underscore the significance of Mukura for biodiversity and emphasize the need for further research and conservation efforts.

Keywords: Native, Albertine Rift, Bioassessment, endemic species, conservation, water quality.

Introduction

In tropical regions, natural forests provide essential ecosystem services to human beings and other living things (Aguirre-Gutiérrez et al., 2022; Williams et al., 2023). They harbor an immense diversity of plant and animal species, many of which being endemic to the regions (Pillay et al., 2022). In this regard, the Amazon, Congo, and Southeast Asian rainforests alone contain more than half of the world's terrestrial species, making them crucial for global biodiversity conservation (Seo, 2021). Additionally, tropical rainy forests play a key role in mitigating climate change effects through carbon sequestration (Dalal et al., 2008). Their dense vegetation is very well known to regulate rainfall, humidity, and temperature (Li et al., 2023; Schmidt et al., 2014). Moreover, tropical forests protect watersheds, prevent soil erosion and ensure a clean water supply for millions of people inhabiting the regions (Artaxo et al., 2022; Ehbrecht et al., 2021), meanwhile supporting their livelihoods through the provision of food and medicines (Douglas, 2017).

In the Albertine Rift, natural forests are also essential for biodiversity conservation, maintenance of ecological balance, and support human well-being (Ryan et al., 2017; Plumptre et al., 2007). This region contains some of Africa's most unique and endangered species, including primates such as critically endangered mountain gorillas, various bird species (Ayebare et al., 2018; Bober et al., 2001), and numerous endemic and vulnerable plant and animal species (Plumptre et al., 2021). Natural forests further contribute to climate resilience, helping to buffer the region against extreme weather patterns and mitigating the effects of climate change (Ayebare et al., 2018).

However, deforestation and habitat loss pose significant threats to these forests, jeopardizing biodiversity and local communities (Hartter et al., 2011). Key drivers of deforestation include agricultural expansion, illegal logging, infrastructure development, and mainly pressure emanating from consequences of the population growth (Twongyirwe et al., 2018) coupled with multiple levels of socioeconomic and political forces at local, national and global levels (Ryan et al., 2017).

In Rwanda, forests cover approximately 30% of the country's total land area, comprising both natural and planted forests (Arakwiye et al., 2021). The Albertine Rift native forests include Nyungwe, Gishwati-Mukura, and Volcanoes National Parks with a few remaining patches of remnant forests providing critical habitats for biodiversity (REMA, 2022). Nyungwe National Park is the largest and most intact rainforest that spans over 1013 km² (Mujawamariya et al., 2018) followed by the Volcanoes National Park with 163.34 km², while Gishwati-Mukura is the smallest with 32.04 km² (GoR [Government of Rwanda], 2024). Mukura Forest is part of the Gishwati-Mukura National Park also nominated as a Biosphere Reserve. While one study documented key wood species in Mukura (Fauvet et al., 1992), a recent study assessed plants, mammals, birds, amphibians, reptiles, bryophytes and butterflies in both Gishwati and Mukura (REMA [Rwanda Environment Management Authority], 2018) leaving out some key taxa. Hence, a comprehensive and extended assessment of the biodiversity of Mukura Forest lacks to understand its biodiversity.

To fill this gap, an intensive sampling of the biodiversity of Mukura was organized in December 2025 focusing on water macroinvertebrates, algae (diatoms), terrestrial arthropods, insects (butterflies), reptiles, amphibians, small mammals, birds, and plants. The purpose was to provide baseline data that may serve as references for future biodiversity studies of Mukura Forest and biosphere Reserve. Specific objective consisted of identifying the diversity and abundance of algae, plants and animals from Mukura Forest. We have hypothesized that Mukura Forest is a home to a wide range of biodiversity, some of them being endemic to Rwanda and the region.

Methodology

Description of the area of study

The study was conducted in Mukura Forest Reserve (Figure 1), a high-altitude forest in the Albertine Rift Region, Western Rwanda at an elevation ranging between 2300 and 2700 m above the sea level (Nsengimana & Dekoninck, 2021). The Forest is part of Gishwati-Mukura National Park and Biosphere Reserve (Tuyisingize et al., 2022). It covers the parts of Rutsiro district,

Mukura (Kageyo, Kagano and Mweso cells), and Rusebeya (Ruronde cells) sectors (Table 1) and the parts of Ngororero district, Ndaro (Kibanda cell) sector. Mukura Forest Reserve receives an annual rainfall of 1500 - 1600 mm with a mean annual temperature ranging between 20 and 24°C. Before 1930, the forest covered around 3000 ha, reduced to 1600 ha in 1930s due to human activities. Thanks to restoration interventions, the size of Mukura increased to 1988 ha in 1960s and later reduced to 1,618.8 ha in 2025 (Government of Rwanda [GoR], 2024). Human activities prevail around the forest include mining, cattle grazing, private production forests such as pine plantations and other surrounding agriculture activities as main threats (Muhire et al., 2021).

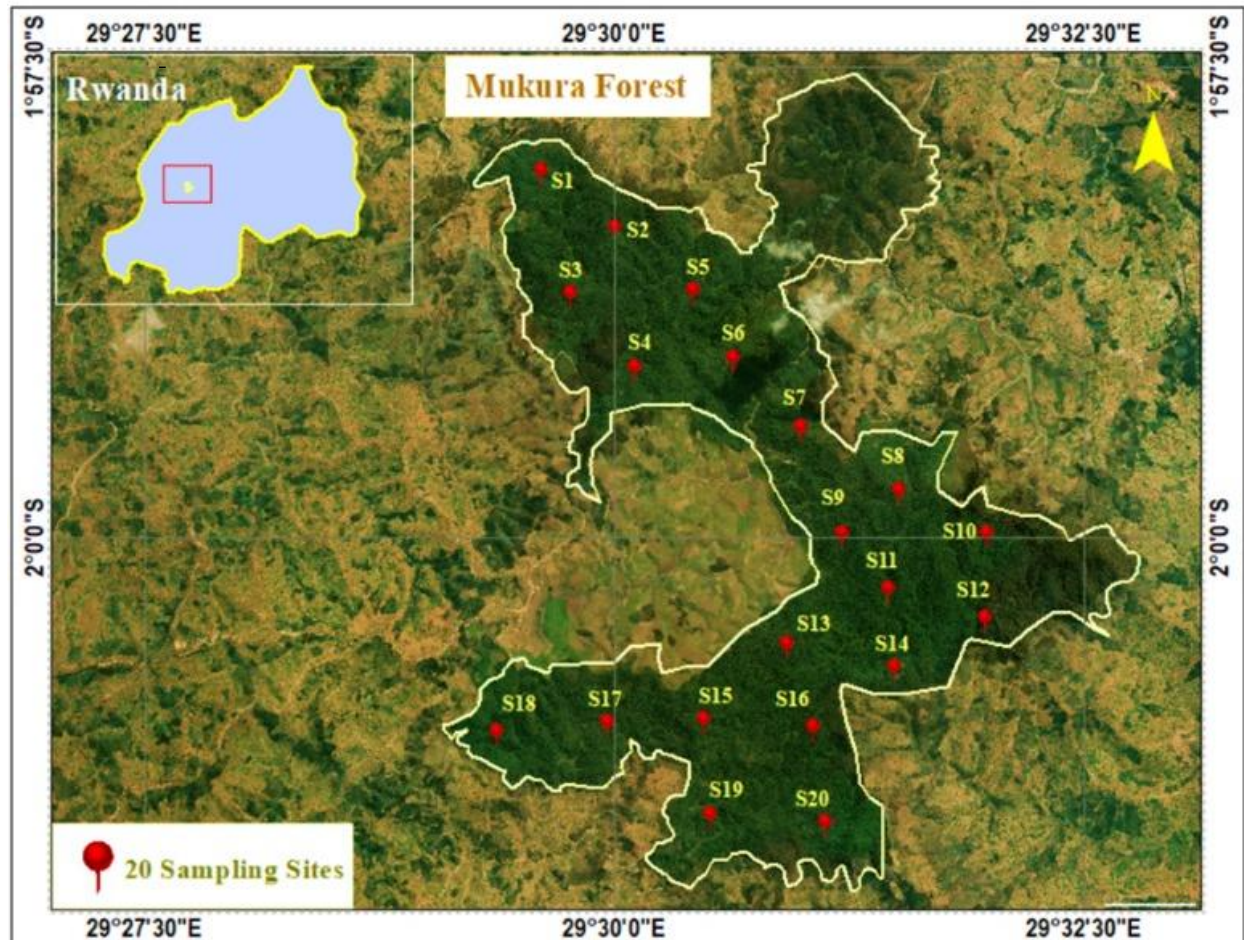


Figure 1. A map showing the location of Mukura in Rwanda and the location of sampling sites in the Mukura Forest and Biosphere Reserve.

Sampling Design

A total of 20 sampling sites were established inside Mukura (Figure 1) and data were intensively collected for 16 days in December 2025. Water macroinvertebrates were sampled using the kick-net having 500µm mesh with D-frame net. Prior to sampling, the sampling point was disturbed by turning over water and substrates to activate macroinvertebrates. The sampling was done in 2 m²

of substrates for 10 minutes. Further, hand picking was used targeting freshwater macroinvertebrates attached to substrates or stones using the forceps (Pinna et al., 2023). Samples were sorted at the sampling point, preserved in 30 ml of 80% ethanol for later identification. Further, diatom samples were collected in water by scraping on submerged substrates including on rocks and dead plants within different sampling sites located in water (Roy & Karthick, 2019). The content from different substrates was emptied into a wide-mouthed plastic storage bottle and fixed in situ by 37% formaldehyde and taken to the laboratory for the identification at species level.



Figure 2: Searching and sampling of diatoms in a River from Mukura Forest

In addition to water macroinvertebrates and diatoms, water physicochemical parameters namely Sodium Chloride [NaCl (mg l^{-1}), pH, temperature [T ($^{\circ}\text{C}$)], electrical conductivity [EC (μcm^{-1})] and redox potential (mV) were measured (Addisie, 2022) to assess effects of water quality on water macroinvertebrates and diatoms at each sampling point. Water properties were immediately measured at the field (Stewart & Atkinson, 2022) where data were recorded in field notebook.



Figure 3: Measurement of water quality and sampling of water macroinvertebrates

For terrestrial arthropods, samples were taken using combined methods at each sampling point including hand collection (McCravy, 2018) in 1m^2 subplot by actively searching from leaf-litter and other surface debris and those moving on the ground (Upton & Mantle, 2010). For small

terrestrial arthropods that cannot be hand-picked, specimens were collected using manual aspirators and forceps. Furthermore, the sweep-net method was applied within 15 minutes at each sampling point (Spafford & Lortie, 2013). In addition, pitfall traps made of plastic bottles of 6.5 cm diameter and 12 cm depth were placed in soil pit at each sampling point. Each trap was filled with 30 ml of 70% ethanol to immobilize captured arthropods. Traps were collected after 24 hours to maximize the chances of capturing the diversity of arthropods (Nsengimana et al., 2021). Specimens were kept in 30 ml of 96% ethanol for preservation and taken to the laboratory for the identification.



Figure 4: Sorting of arthropods from leaf litter and sweep nets in Mukura Forest

Within arthropods, butterflies were particularly sampled as key indicators of environmental conditions. They were sampled using sweep net and fruit-baited traps (Uwizelimana et al., 2022) by targeting adult butterflies only. For conservation purposes, the capture and release technique was applied for butterflies that could be immediately identified at the field (Arena et al., 2023). For those not able to immediately being identified, a specimen was collected in a non-stick entomological envelope (Kerr et al., 2000) and taken in the laboratory for later identification using dichotomous keys and references of specimens housed in the zoological collection of the Center of Excellence in Biodiversity and Natural Resource Management at the University of Rwanda.

Further, more sampling was done to cover avian diversity. The point count method and opportunistic observations while walking between points were used to record bird's occurrence and abundance (Ralph et al., 1995). The point-count technique involved establishing a circular point station of 50 m in diameter and conducting audio-visual recordings of birds from the center (Darras et al., 2018; Yip et al., 2017). At least one minute period was paused to allow the observed bird to settle, then recorded. Every perceived individual or heard was observed using binoculars and identified at the field using field guides (Zamora-Marín et al., 2021). When a bird could not be identified, a photo was taken using a camera and for later identification. Sampling sites were spaced by a minimum of 400 m and the sampling was done for 30 minutes at each sampling point starting from 07:00 to 12:30 PM and from 15:00 to 17:30 in the afternoon (Nalwanga et al., 2012).

Reptiles and amphibians were also sampled in different habitats including creek meadows, water dams, grasslands, wood lands, marshlands, and shrublands (Bateman & Merritt, 2020). The

inventory followed different approaches including opportunistic visual encounter survey (Mindje et al., 2020; Donnelly et al., 2005; Fatimah-Syafiq et al., 2020). An active search for specimens such as scoop netting for tadpoles and fully aquatic frogs (Ernst et al., 2020; Roelke & Smith, 2010) was done by searching under the litterfall, dead trees, rocks and shrubs (Rojas-Padilla et al., 2020). Found amphibians and lizards were caught using nets, then hand-picked for identification using morphological corroboration. Observed snakes were caught using snake tongs (De Freitas et al., 2018) and identified using a closer examination of body features such as their skin structure and the scale patterns complemented by existing identification guide (Spawls et al., 2002).



Figure 5. Major sampled habitats within the Mukura Forest (Creek Meadow, Water Dam, Shrubland, Marshland, Grassland, Woodland).

Furthermore, large and medium mammals were detected with a combination of different methods including sights, sounds, dung and tracks (Cao et al., 2024). Terrestrial small mammals were surveyed using living Sherman traps in the sampling points and they were preferred for terrestrial small mammals as they are light and can be folded flat for easy carrying in the field (Bennun et al., 2002). A total of 27 Sherman traps separated from each other by a distance of 10 m were set with a minimum of one trap at each sampling point. They were set on the ground, considering the suitable cover (Pearce & Venier, 2005) to keep the trap concealed from possible disturbances. The bait made of a mixture of peanut butter and white oats was used to attract mammals (Cardoso et al., 2020; Silva et al., 2005). Each trap was left at the site for 24 hours. Collected mammals were identified at the field and then released for the purpose of conservation. When the name was not found a photo was taken and used for later identification using the keys and collection of mammals in the Centre of Excellence in Biodiversity and Natural Resources at the University of Rwanda.

To sample plant diversity, four circular plots of 10 m radius were established at each sampling site where woody plants were identified and counted (Koricho et al., 2021). Herbaceous plants were sampled in nested 1 m² quadrants established within each plot at the sampling site (Fernández et

al., 2015; Kalkhan et al., 2007; Spicer et al., 2022). All herbaceous plants with inflorescence were identified at species level using dichotomous keys (Robbrecht, 2009; Troupin, 1985; Lebrun and Stork, 1992–1997; Fischer & Killmann, 2008; Fischer et al., 2024). When the identification could not be done immediately, a specimen was collected (Woodworth & Pyle-Eilola, 2019) and taken to the Rwanda National Herbarium located in the Centre of Excellence in Biodiversity and Natural Resource Management at the University of Rwanda for later identification in reference to the specimen in the collection. Further, photos of flowers were also used to support the identification.

Identification of Specimens

Water macroinvertebrates were identified at the family level using microscope, and identification keys (Arimoro, 2009; Harrison, 2009; Foord & Fouché, 2010; Schael, 2009). Findings were recorded in excel 365, and the sensitivity scores for each identified family was determined using their tolerance to pollution as detailed in the South Africa Scoring System (SASS5) of the families of water macroinvertebrates. A family with high tolerance to pollution was scored from 1 to 5, a family moderately tolerant to pollution was scored from 6 to 10 and a very low tolerant family to pollution (pollution sensitive family) was scored between 11 to 15 (Dickens & Graham, 2002).

To identify diatoms, mounted slides were prepared following different steps. First, 5 to 10 ml of the sample were poured into a heat-resistant beaker coded by a permanent marker to avoid mixing the samples (Alvarez-Blanco et al., 2011). Each beaker was treated by 10 ml of hydrogen peroxide to oxidize the organic matter, where the heat-resistant beaker was covered by a heat-resistant watch glass to avoid cross-contamination between the samples and left for 24 hours (Marezza et al., 2021). After, the heat-resistant beakers were transferred to the hot plate inside a fume cabinet at a temperature varying between 90 and 100°C for 2 hours. The regular follow-up was done while heating the material to prevent boiling-over or drying out. After heating, the solution was left to cool down and then started to rinse the samples with distilled water. The rinsing process was done twice with an interval of 24 hours. After the decantation of the supernatants the remaining residues were used for the preparation of permanent slides using Pasteur pipettes, mounting media (Naphrax), hot plate, microscope slides, and cover slips (Singh et al., 2006). Then mounted diatoms were identified at the species level using the recent identification key (Roy & Karthick, 2019).

Further, arthropods were sorted out under a microscope and later identified to the order and family levels using dichotomous keys (Mignon, Haubruge, and Francis 2016; Kirk-Spriggs and Sinclair 2017; Picker, Griffiths, and Weaving 2004; Delvare and Eberlenc 1989). In addition, collected butterflies were sorted out based on similarities in morphology first and then identified at the family (Mignon et al., 2016), genus and species levels using dichotomous keys in the literature (Larsen, 2023; Liseki & Vane-Wright, 2016; Woodhall, 2005). The species names of arthropods and butterflies were confirmed after consulting experts in arthropods and butterflies of Rwanda.

Furthermore birds, reptiles, amphibians and plants which were not identified at the field were identified using the reference collections in the Centre of Excellence in Biodiversity and Natural

Resources at the University of Rwanda. In any case, the reference specimen was not available, the specimen was identified to the genus and the species name was designated by the genus name followed by the acronym SP01, SP02....SPn for later identification by experts in the domain.

Data analysis

Individuals making each family of water macroinvertebrates and arthropods as well as the individual species of butterflies, reptiles, amphibians, mammals, birds and plants were recorded in an excel 365 and counted to determine their abundance and diversity and equitability. The diversity was calculated using Shannon Diversity (H'), while the evenness was calculated using the Pielou index (J'). The main purpose was to capture more information about the ecosystem health and ecosystem functioning of Mukura Forest. Furthermore, the relationships between the families of water macroinvertebrates, water parameters and species of diatoms were illustrated using the Non-metric Multidimensional Scaling (NMDS) ordination using the Bray-Curtis similarity index in Paleontological Statistics Software (PAST) 4.03 (Makumbe et al., 2022; Shrestha et al., 2021).

Results

Results have indicated a total of 1523 individuals of water macroinvertebrates classified into Annelida (one class, one order and one family) and Arthropoda (two classes: Malacostraca with one class, one order, one family and Insecta with eight orders, and 18 families). Families with low tolerance to water pollution were Chlorocyphidae (Odonata), Leptophlebiidae (Ephemeroptera), Psychomyiidae, Lepidostomatidae, Philopotamidae (Tricoptera) with the South African Scoring System 10, 9, 10, 10 and 12 respectively (**Appendix 1**). Further, results have indicated high diversity in water macroinvertebrate ($H' = 2.4$, $J' = 0.8$). Results have also indicated that water of Mukura is not highly saline [$\text{NaCl} = 11.3\text{mg/l}$], has low conductivity [$\text{EC} = 19.8\ \mu\text{S/cm}$], is slightly acidic [$\text{pH} = 4.9$] and has a moderately low redox potential [Redox potential = 107.74 mV] (**Appendix 2**). Furthermore, the results indicated 10 orders, 15 families and 25 species of diatoms (**Appendix 3**) with *Eunotia* (Order: Eunotiales, Family: Eunotiaceae) and *Frustulia crassinervia* (Order: Naviculales, Family: Amphipleuraceae) being most occurring and mainly sampled species.



Figure 6: Some of Water macroinvertebrates indicating good water quality in Mukura



Figure 7: Example of diatoms indicating good water quality in Mukura

The NMDS (Figure 2) indicates that the diatoms cluster is more compact, overlapping with the blue cluster, suggesting that algal communities respond strongly to water conditions. Furthermore, water macroinvertebrates cluster is the most spread out, reflecting the diverse responses of different macroinvertebrate families to environmental conditions. The overlap with diatoms suggests that some macroinvertebrates and diatoms are strongly correlated with water properties. The stress is 32.08% with R^2 : Axis 1 = 22.53%, Axis 2 = 22.26%, which means that the two axes explain about 44.79% of the total variation in diatoms, macroinvertebrate and water properties.

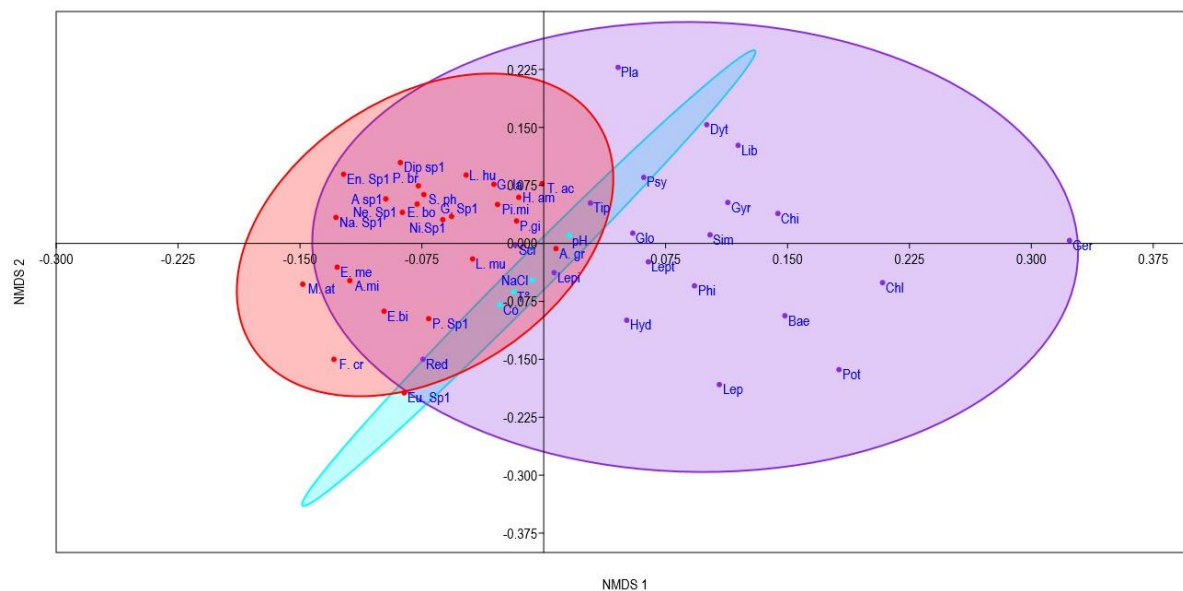


Figure 8: Non-metric Multidimensional Scaling (NMDS) plot illustrating the relationships between water properties (aqua), Algae (blue violet), and macroinvertebrate families (red)

in aquatic ecosystems of Mukura Forest Reserve. NaCl: Sodium Chloride, T°: Temperature, Co: Conductivity, Red: Redox. Macroinvertebrates: Glo: *Glossiphoniidae*, Dyt: *Dytiscidae*, Gyr: *Gyrinidae*, Sci: *Scirtidae*, Chi: *Chironomidae*, Sim: *Simulidae*, Tip: *Tipulidae* Bae: *Baetidae*, Lep: *Leptophlebiidae*, Ger: *Gerridae*, Chl: *Chlorocyphidae*, Lib: *Libellulidae*, Pla: *Platycnemidae*, Hyd: *Hydropsychidae*, Lepi: *Lepidostomatidae*, Lept: *Leptoceridae*, Phi: *Philopotamidae*, Psy: *Psychomyiidae*, Pot: *Potamonautidae*. Algae: A. sp1: *Achnanthes*, A.mi: *Achnanthidium microcephalum*, A. gr: *Aulacoseira granulata*, Dip. sp1: *Diploneis*, En. Sp1: *Encyonema*, Eu. Sp1: *Eunotia*, E.bi: *Eunotia bilunaris*, E. bo: *Eunotia botuliformis*, E. me: *Eunotia meisterioides*, F. cr: *Frustulia crassinervia*, G. Sp1: *Gomphonema*, G. la: *Gomphonema lagenula*, H. am: *Hantzschia amphioxys*, L. hu: *Lemnicola hungarica*, L. mu: *Luticola mutica*, M. at: *Mayamaea atomus*, Na. Sp1: *Navicula*, Ne. Sp1: *Neidium*, Ni.Sp1: *Nitzschia*, P. Sp1: *Pinnularia*, P. br: *Pinnularia braunii*, P.gi: *Pinnularia cfr gibba*, Pi.mi: *Pinnularia microstauron*, S. ph: *Stauroneis phoenicenteron*, T. ac: *Tryblionella acuminata*.

Results of the study have also indicated a total of 4 044 individuals of arthropods grouped into 20 orders and 79 families. The class Insecta was more abundant (N = 3,064; 75.7% with one family of Formicidae having higher abundance (N = 1450; 35.8%) compared with other families under Arachnida, Collembola and Diplopoda (**Appendix 4**). Results have also indicated that Coleoptera, Diptera and Hemiptera had a higher number of families compared to other orders. The diversity was also high ($H' = 3.0$, $J' = 0.7$). Furthermore, a total of 255 individuals of butterflies were identified. They comprise 24 species classified into Nymphalidae, Lycaenidae, Pieridae and Papilionidae with nymphalid family having more species. Generally, species diversity was high ($H' = 2.3$, $J' = 0.7$). *Bicyclus aurivillii* (Nymphalidae) was the most abundant while *Papilio jacksoni* (Papilionidae) was the least abundant compared to other identified butterflies (**Appendix 5**).



Figure 9: Species of butterflies indicating the environmental health of Mukura

There was a total of 14 orders, 46 families and 124 species of birds ($H' = 3$, $J' = 0.8$) with 12 species endemic to the Albertine Rift (Appendix 6), namely the Hooded Vulture (Order: Accipitriformes, Family: Accipitridae, Species: *Necrosyrtes monachus*), one endangered species, the Gray-Crowned crane (Order: Gruiformes, Family: Gruidae, Species: *Balearica regulorum*), one vulnerable Grauer's Swamp-warbler (Order: Passeriformes, Family: Locustelliadae, Species: *Bradypterus graueri*), one near threatened mountain Buzzard (Order: Accipitriformes, Family: Accipitridae, species: *Buteo oreophilus*). Further, there were two Afrotropical migrants Red-chested Cuckoo (Order: Cuculiformes, Family: Cuculidae, species: *Cuculus solitarius*), two palearctic migrants Willow warbler (Order: Passeriformes, Family: Phylloscopidae, Species: *Phylloscopus trochilus*), and the Western Yellow wagtail (Order: Passeriformes, Family: Motacillidae, Species: *Motacilla flava*). The most frequently species were mainly the regal sunbird (Order: Passeriformes, Family: Nectariniidae, Species: *Cinnyris regius*), the Rwenzori Turaco (Order: Musophagiformes, Family: Musophagidae, Species: *Gallirex johnstoni*) and the Ross's Turaco (Order: Musophagiformes, Family: Musophagidae, Species: *Musophaga rossae*).



Figure 10: Endemic bird species found in Mukura Forest

Findings have also identified one order of amphibians (Anura) with 7 families and 12 amphibian species (**Appendix 7**) and one order of reptiles (Squamata) with 4 families and 5 species (**Appendix 8**). Species diversity of amphibians ($H' = 1.4$, $J' = 0.9$) was lower compared to that of reptiles ($H' = 1.9$, $J' = 7.6$). The *Arthroleptis adolfifriederici* (Order: Anura, Family:

Arthroleptidae) is the most found species while *Phrynobatrachus versicolor*, *Phrynobatrachus* SP02 (Order: Anura, Family: Phrynobatrachidae) and *Sclerophrys kisoensis* (Order: Anura, Family: Bufonidae) were the least distributed species. The *Phrynobatrachus* SP02 was not identified at the species level, and it is anticipated to be a new record for Rwanda. Concerning reptiles, *Trioceros johnstoni* (Order: Squamata, Family: Chamaeleonidae) is the most distributed while *Atheris nitschei* (Order: Squamata, Family: Viperidae) is the least distributed species.



Figure 11: Mostly distributed species (*Arthroleptis adolfifriederici*) and least distributed species (*Phrynobatrachus versicolor*, *Phrynobatrachus spec.* and *Sclerophrys kisoensis*)



Figure 12: Mostly distributed (*Trioceros johnstoni*) and least distributed (*Atheris nitschei*)

In addition, 12 species of mammals distributed in 3 orders and 6 families were identified (**Appendix 9**) with the Muridae family (Order: Rodentia) having more species including the most distributed *Lophuromys woosnami*. Further, 3 species belonging to the order Rodentia family of Muridae namely *Lophuromys woosnami*, *Mus bufo* and *Praomys degraaffi* are endemic to the Albertine Rift while *Heliosciurus rufobrachium* (Order: Rodentia, Family: Sciuridae), *Hylomyscus stella* and *Mus bufo* (Order: Rodentia, family: Muridae) were new records in Mukura. The diversity of collected mammals was relatively high ($H' = 2$, $J' = 0.8$) compared to reptiles and amphibians.



Figure 13: Two species among the rodents red-legged sun squirrel *Heliosciurus rufobrachium* (on left) and the Stella wood mouse *Hylomyscus stella*.

Concerning plants, results have indicated a total of 1818 individuals distributed into 255 species distributed into 72 families and 36 orders (**Appendix 10**). Remarkably, 83 of these species are endemic to the Albertine Rift. Notably, this study recorded *Culcasia falcifolia* (Order: Alismatales, Family: Araceae) and *Monanthotaxis orophila* (Order: Magnoliales, Family: Annonaceae) as new plant species records for Mukura. The higher number of species were found under the families of *Rubiaceae* (Order: Gentianales), *Asteraceae* (Order: Asterales) and *Primulaceae* (Order: Ericales). The species diversity and equitability were high ($H' = 4.9$ and $J = 0.9$) compared to other taxa.



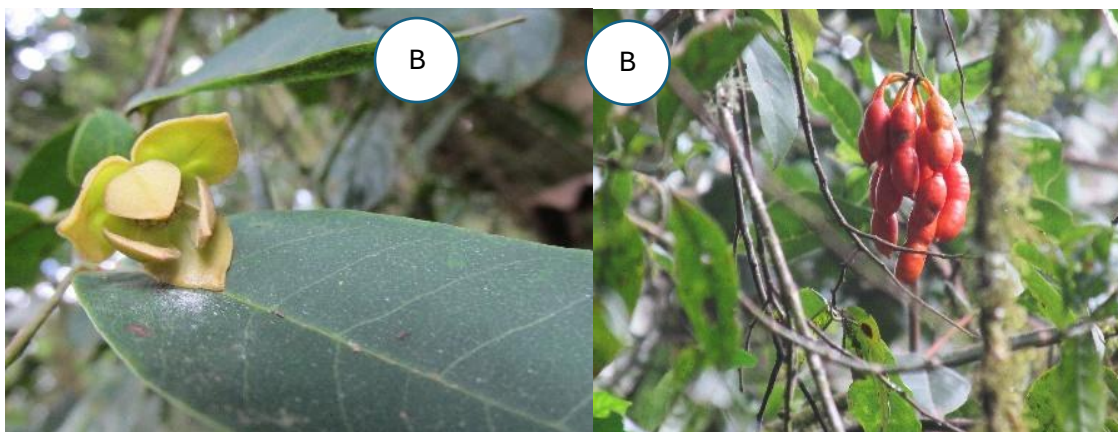


Figure 13: A-A *Culcasia falcifolia*. B-B *Monanthotaxis orophila*

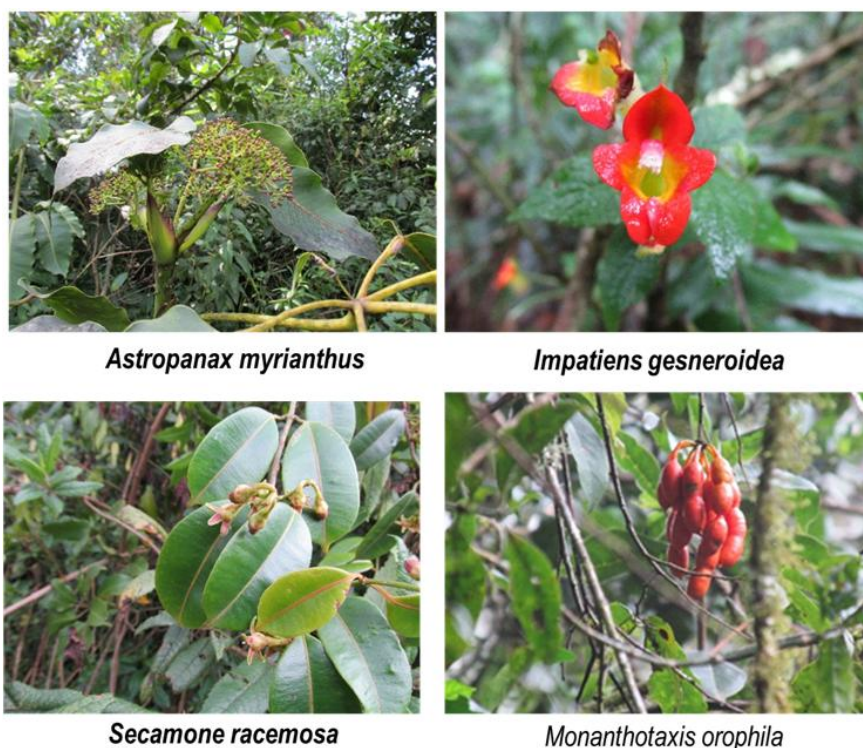


Figure 13: Key identified plant species: *Monanthotaxis orophila* (Endemic to Albertin Rift region, and listed as Near threatened on IUCN) *Astropanax myrianthus* (Native to Rwanda, and listed as Near threatened on IUCN), *Impatiens gesnerioidea* (Endemic to Albertin Rift region, and listed as vulnerable on IUCN) and *Secamone racemosa*: Endemic to Albertin Rift region, and listed as vulnerable on IUCN

Discussion

The bioassessment of Mukura highlights a diverse composition of water macroinvertebrates, diatoms, arthropods, birds, amphibians, reptiles, mammals, and plants, suggesting the importance of the ecosystem for biodiversity conservation. The presence of key bioindicators such as

Chlorocyphidae (Odonata), Leptophlebiidae (Ephemeroptera), and some Tricoptera families, which are known for their sensitivity to pollution, signifies good water quality (López-López & Sedeño-Díaz, 2015). Studies have emphasized the ecological importance of these taxa as indicators of pristine freshwater environments (O'Brien et al., 2016; Vadas et al., 2022). The recorded physicochemical parameters, including low conductivity ($EC = 19.8 \mu S/cm$) and slightly acidic pH (4.9) levels, align with findings from other tropical montane forests, where similar conditions promote high biodiversity (Larsen, 2017). The presence of *Eunotia* and *Frustulia crassinervia* further reinforces the notion of minimal anthropogenic disturbances, as these taxa are commonly associated with oligotrophic and well-oxygenated waters (Li et al., 2010; Lobo et al., 2016).

The study also documented 4 044 arthropod individuals, predominantly from the class Insecta ($N = 3064$; 75.7%). The dominance of Formicidae ($N = 1450$; 35.8%) reflects their ecological role in soil aeration, decomposition, and seed dispersal, consistent with studies in other montane forests (Bàrberi et al., 2010; Langor & Spence, 2006). The high taxonomic richness in Coleoptera, Diptera, and Hemiptera mirrors findings from previous research, where these groups contribute significantly to ecosystem stability and nutrient cycling (Báldi, 2003). Additionally, the identification of 255 butterfly individuals across 24 species underscores Mukura's importance for pollinator diversity. The prevalence of *Bicyclus aurivillii* suggests the presence of suitable larval host plants, crucial for maintaining butterfly populations (Jacob Cristóbal-Perez et al., 2024).

The avian diversity was considerable, with 124 species recorded, including 12 Albertine Rift endemics and other species of conservation concern. The findings are very significant as the number of bird species identified is nearby that found in Gishwati forest, the neighboring fragment forest that counts 155 species, 20 of which being endemic to the Albertine Rift (Inman & Ntoyinkama, 2020). The presence of critically endangered Hooded Vulture (*Necrosyrtes monachus*) and the endangered, Gray-Crowned Crane (*Balearica regulorum*) highlight the significance of Mukura for bird conservation (Demmer et al., 2025; Lawer, 2024). Similar studies have reported declining populations of these species due to habitat loss and human disturbance (Daboné et al., 2024; Wamiti et al., 2021), and having them in Mukura is a call for effective biodiversity conservation planning of the forest to protect these bird species. In addition, the presence of migratory bird species such as the Red-chested Cuckoo (*Cuculus solitarius*) and the Willow Warbler (*Phylloscopus trochilus*) indicates that Mukura serves as a crucial stopover site, emphasizing the need for transboundary conservation efforts to maintain the connectivity that facilitate the migration of these species (Mattsson et al., 2022; Pascucci et al., 2019).

The diversity of the amphibian species was relatively low, with only 12 species recorded. However, the discovery of *Phrynobatrachus* SP02 as a potential new species for Rwanda is significant. Previous studies have indicated that the Eastern Afromontane region of Africa is characterized by striking levels of endemism and species richness of amphibians accompanied by significant conservation threat, a pattern typical across biodiversity hotspots (Demos et al., 2014). This might be the reason behind the small number of amphibian species. Comparatively to other protected areas in Rwanda, Mukura Forest provides important habitats for species of conservation priority

such as the Karisimbi tree frog (*Leptopelis karissimbensis*) that is globally vulnerable (V) and nationally suggested as near threatened (NT), the Golden-bellied Rocket Frog (*Ptychadena chrysogaster*) that is nationally proposed as an endangered (EN) species and the Green Puddle Frog (*Phrynobatrachus versicolor*) proposed as NT by the IUCN Red List of threatened species (Dehling & Sinsch, 2023). Besides, *Leptopelis karissimbensis* was known in Nyungwe and Volcanoes National Park but with this study, its ranges add a new habitat under the Mukura Forest.

Furthermore, the reptile survey identified five species, with *Trioceros johnstoni* being the most abundant. This finding aligns with other research showing the preference of chameleons for montane forests with high humidity (Barej et al., 2010; Ceccarelli et al., 2014). Other species were less represented probably due to the past disturbance which heavily affected the forest, and hence the habitat available is not fully suitable for them to survive and found enough food.

Mammalian diversity included 12 species, with three species (*Lophuromys woosnami*, *Mus bufo*, and *Praomys degraaffi*) being endemic to the Albertine Rift. Endemic species are of particular conservation concern as they have restricted distributions and are often highly vulnerable to habitat disturbance (Kraus et al., 2023). Additionally, the identification of *Heliosciurus rufobrachium*, *Hylomyscus stella*, and *Mus bufo* as new records for Mukura suggests that the forest harbors previously undocumented mammalian diversity, reinforcing its ecological significance. The presence of these species highlights the importance of continued biodiversity assessments to assess if there are no other species of special concern. Recent studies indicate that small mammal diversity in such ecosystems is frequently overlooked due to cryptic speciation, where morphologically similar species are genetically distinct (Nicolas et al., 2021). Advanced techniques such as DNA barcoding and phylogenetic analyses are essential for accurately identifying and conserving these cryptic species, ensuring that Mukura's mammalian biodiversity is effectively protected.

The findings of this study have highlighted that the floral diversity in Mukura Forest Reserve is remarkably high, with 1,818 individual plants identified, representing 255 species across 72 families. Such diversity is indicative of a well-preserved montane forest ecosystem, providing critical habitats for various fauna and playing a key role in ecological stability (Graham et al., 2014). The dominance of Rubiaceae, Asteraceae, and Primulaceae aligns with previous botanical studies in the Albertine Rift, where these families are often among the most species-rich due to their adaptability to tropical environments (Larson et al., 2023; Zhang et al., 2024). Notably, *Culcasia falcifolia* and *Monanthotaxis orophila* were recorded for the first time in Mukura, emphasizing the forest's role as a reservoir of botanical diversity. The discovery of these species suggests that Mukura may harbor additional undocumented flora, underscoring the need for ongoing botanical surveys and conservation initiatives to protect its unique plant life.

Conclusion and recommendations

The findings from Mukura Forest Reserve confirm its ecological importance as a biodiversity hotspot within the Albertine Rift. The high diversity of macroinvertebrates, arthropods, birds, amphibians, reptiles, mammals, and plants suggests that the forest maintains relatively pristine

environmental conditions. The presence of key bioindicators, such as sensitive aquatic macroinvertebrates and endemic bird species, further underscores the forest's good ecological integrity. However, the identification of threatened and endemic species highlights the need for ongoing conservation efforts. While Mukura remains an important refuge for various taxa, external pressures such as habitat fragmentation and climate change could threaten its long-term ecological stability. To enhance conservation efforts in Mukura Forest Reserve, we recommend continuous biodiversity monitoring, incorporating molecular techniques to accurately identify cryptic species and assess population trends. Additionally, transboundary conservation initiatives should be established to protect migratory species that rely on Mukura as a critical habitat.

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Appendix 1

Class	Order	Family	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23
Clitellata	Rhynchobdellida	Glossiphoniidae	0	3	2	0	7	9	6	2	0	9	0	0	3	3	3	4	0	4	0	1	6	0	0
Insecta	Coleoptera	Dytiscidae	0	1	0	0	0	0	0	1	0	0	2	3	0	0	0	0	0	0	1	0	0	0	7
		Gyrinidae	2	3	3	0	12	3	0	3	1	0	0	0	1	0	0	0	0	0	5	0	0	1	0
		Scirtidae	60	43	7	7	9	0	5	3	0	81	7	0	41	6	6	0	6	9	2	2	24	0	0
	Diptera	Chironomidae	0	0	0	3	4	2	0	1	0	1	2	0	0	0	1	6	0	0	11	0	0	14	0
		Simuliidae	6	1	2	0	0	4	0	3	1	0	2	2	0	0	4	0	4	11	0	0	0	0	0
		Tipulidae	2	1	1	0	0	1	1	2	1	13	1	1	0	1	1	0	3	1	5	6	3	0	0
	Ephemeroptera	Baetidae	3	12	17	5	0	0	0	0	0	0	0	3	6	0	3	4	0	0	0	0	7	0	0
		Leptophlebiidae	0	0	0	41	0	0	0	0	0	16	0	0	0	0	9	0	3	0	0	0	3	0	0
	Hemiptera	Gerridae	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Odonata	Chlorocyphidae	4	2	1	0	0	0	0	0	0	1	0	0	4	0	0	0	0	0	0	0	5	0	0
		Libellulidae	0	0	0	0	3	1	0	0	1	0	2	2	0	0	0	0	1	0	1	0	0	0	1
		Platycnemididae	0	0	0	0	0	0	2	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0
	Trichoptera	Hydropsychidae	51	1	64	7	11	13	1	0	0	95	2	1	9	12	0	0	3	0	4	0	22	0	0
		Lepidostomatidae	31	36	9	3	41	16	21	16	6	4	14	14	0	5	13	4	5	0	5	5	6	0	14
		Leptoceridae	4	2	0	3	13	1	11	3	0	2	4	2	5	14	4	1	5	16	4	0	4	0	2
		Philopotamidae	0	4	2	0	0	0	0	0	0	24	6	10	0	0	4	2	2	0	0	2	22	0	0
Psychomyiidae		3	3	3	0	0	0	0	1	0	0	9	9	0	0	0	0	3	0	2	2	0	2	0	
Malacostraca	Decapoda	Potamonautidae	0	0	0	4	0	0	0	0	0	0	0	0	0	4	0	3	0	0	0	1	0	0	

Appendix 2

Parameter	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23
NaCl	11.3	11.3	11.4	17.1	14.5	13.2	13.3	13.1	14.4	8.6	7.1	6.6	10.7	11.1	9.1	9.4	7.6	11.1	12.2	12.2	12.6	11.3	11.8
pH	4.8	4.8	4.7	5.6	4.7	4.7	4.7	4.8	4.7	4.8	5.0	4.9	4.6	4.6	5.4	4.8	5.2	4.7	5.5	5.5	4.5	5.5	5.6
Temperature	14.3	14.9	14.5	15.1	15.5	16.5	15.8	16.4	15.6	14.2	16.7	15.1	14.1	14.0	14.5	15.7	18.4	15.5	15.4	15.8	14.7	14.5	16.4

Conductivity	19.5	19.0	19.4	29.4	25.1	23.5	23.3	23.2	24.0	14.5	12.7	11.3	18.1	24.2	15.5	16.4	14.2	19.4	21.2	21.4	21.6	19.4	21.3
Redox	115.7	118.6	123.4	70.8	124.6	124.7	127.0	120.0	123.0	119.2	106.4	112.5	129.7	130.9	82.3	117.0	97.0	124.0	79.5	59.6	112.9	82.6	76.8

Appendix 3

Order	Family	Species	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22
Achnanthales	Achnanthaceae	<i>Achnanthes</i>																		3				
Achnanthales	Achnanthidiaceae	<i>Achnanthidium microcephalum</i>																			1	30		
Aulacoseirales	Aulacoseiraceae	<i>Aulacoseira granulata</i>																						
Naviculales	Diploneidaceae	<i>Diploneis</i>																				1		
Cymbellales	Cymbellaceae	<i>Encyonema</i>																		1				
Eunotiales	Eunotiaceae	<i>Eunotia</i>		58	8	55	39			451	423					290				662	32	189		
Eunotiales	Eunotiaceae	<i>Eunotia bilunaris</i>		2			1			54	36					32				71	6	22		
Eunotiales	Eunotiaceae	<i>Eunotia botuliformis</i>																				3		
Eunotiales	Eunotiaceae	<i>Eunotia meisterioides</i>																				25		
Naviculales	Amphipleuraceae	<i>Frustulia crassinervia</i>		16	29	2				281	75					274				417	2	114		
Cymbellales	Gomphonemataceae	<i>Gomphonema</i>								2											11			
Cymbellales	Gomphonemataceae	<i>Gomphonema lagenula</i>									2										2			
Bacillariales	Bacillariaceae	<i>Hantzschia amphioxys</i>														4				4	2	4		
Achnanthales	Achnanthidiaceae	<i>Lemnicola hungarica</i>									2											2		
Naviculales	Diadesmidaceae	<i>Luticola mutica</i>																		19	2	7		
Naviculales	Naviculaceae	<i>Mayamaea atomus</i>									22											50		
Naviculales	Naviculaceae	<i>Navicula</i>									4									5	46			
Naviculales	Neidiaceae	<i>Neidium</i>														4								
Bacillariales	Bacillariaceae	<i>Nitzschia</i>								2	4					13				5				
Naviculales	Pinnulariaceae	<i>Pinnularia</i>		7	12	4				32	50					53				91	1	9		
Naviculales	Pinnulariaceae	<i>Pinnularia braunii</i>																				2		
Naviculales	Pinnulariaceae	<i>Pinnularia cfr gibba</i>																		7	1	5		
Naviculales	Pinnulariaceae	<i>Pinnularia microstauron</i>								4												4		
Naviculales	Stauroneidaceae	<i>Stauroneis phoenicenteron</i>																			1			
Pennales	Bacillariaceae	<i>Tryblionella acuminata</i>								2						7				3	4	1		

Appendix 4

No	Class	Order	Family	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	NR	WT
1	Arachnida	Araneae	Anamidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Arachnida	Araneae	Linyphiidae	3	1	3	1	5	10	1	7	1	5	0	4	2	4	5	0	7	6	12	5	0	0
3	Arachnida	Araneae	Lycosidae	3	2	4	1	2	1	5	1	5	1	0	2	1	1	0	0	0	11	4	25	3	11
4	Arachnida	Araneae	Nemesiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
5	Arachnida	Araneae	Tetragnathidae	12	1	3	1	1	2	5	0	7	3	3	10	3	3	1	4	22	7	4	12	0	11
6	Arachnida	Araneae	Thomisidae	3	0	0	1	0	0	0	0	2	0	1	4	0	0	0	1	3	0	0	2	1	0
7	Arachnida	Sarcoptiformes	Crotonidae	1	2	2	1	0	0	1	2	1	0	1	3	1	0	2	0	8	6	0	2	1	1
8	Arachnida	Sarcoptiformes	Phalangiidae	0	0	2	0	1	2	0	1	2	4	1	4	2	6	3	1	1	0	5	0	0	0
9	Arachnida	Trombidiformes	Trombidiidae	0	0	3	2	1	0	0	1	5	1	0	1	2	0	1	0	2	0	2	1	3	0
10	Chilopoda	Geophilomorpha	Mecistocephalidae	0	0	1	0	1	1	0	1	1	0	0	0	1	0	2	0	1	0	2	0	0	0
11	Collembola	Entomobryomorpha	Entomobryidae	8	8	28	7	26	6	27	8	10	2	6	23	6	15	15	2	36	14	25	7	14	9
12	Collembola	Poduromorpha	Poduridae	27	25	3	0	2	5	0	1	3	0	7	0	3	0	2	0	19	5	0	8	2	0
13	Collembola	Symphyleona	Sminthuridae	4	6	0	0	0	1	0	0	0	0	2	2	1	0	3	0	16	3	4	3	2	5
14	Crustacean	Decapoda	Cambaridae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
15	Crustacean	Isopoda	Oniscidae	0	0	4	1	12	3	2	0	7	4	0	2	8	1	6	2	0	13	11	15	0	0
16	Diplopoda	Julida	Julidae	0	0	0	0	0	0	0	0	3	0	2	0	1	0	2	0	0	3	4	0	0	0
17	Insecta	Blattodea	Blaberidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
18	Insecta	Blattodea	Blattellidae	0	0	0	0	1	0	0	0	3	1	1	2	0	3	2	0	0	1	3	6	0	0
19	Insecta	Blattodea	Blattidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	Insecta	Coleoptera	Bostrichidae	0	0	0	0	0	1	0	1	0	0	0	1	0	3	5	0	0	1	0	0	0	0
21	Insecta	Coleoptera	Carabidae	0	2	11	1	0	2	1	0	0	0	0	1	2	9	1	0	0	4	7	4	0	3
22	Insecta	Coleoptera	Chrysomelidae	2	1	2	2	3	2	1	0	2	9	3	8	4	2	0	0	3	1	5	4	3	6
23	Insecta	Coleoptera	Coccinellidae	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0
24	Insecta	Coleoptera	Curculionidae	2	0	1	1	1	0	3	2	2	1	0	1	2	3	0	2	4	10	3	2	3	1
25	Insecta	Coleoptera	Elateridae	0	0	0	0	2	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0
26	Insecta	Coleoptera	Histeridae	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
27	Insecta	Coleoptera	Lampyridae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
28	Insecta	Coleoptera	Lucanidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
29	Insecta	Coleoptera	Meloidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	Insecta	Coleoptera	Nitidulidae	0	0	1	0	3	1	1	1	0	0	1	1	3	0	0	0	0	1	0	0	0	0

31	Insecta	Coleoptera	Scarabaeidae	0	0	0	0	1	0	1	0	4	0	0	1	0	0	0	0	0	0	1	0	0	0
32	Insecta	Coleoptera	Scydamaenidae	0	1	1	2	4	1	0	0	1	0	1	0	1	0	0	0	0	1	4	3	3	0
33	Insecta	Coleoptera	Staphylinidae	0	4	14	1	10	6	7	3	3	6	3	4	6	4	7	0	1	7	2	3	2	5
34	Insecta	Coleoptera	Tenebrionidae	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	2	0	0	1	0
35	Insecta	Dermaptera	Spongiforidae	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	Insecta	Diptera	Agromyzidae	1	0	1	2	13	7	3	1	3	5	1	1	2	4	2	1	5	1	0	21	6	3
37	Insecta	Diptera	Asilidae	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
38	Insecta	Diptera	Calliphoridae	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	Insecta	Diptera	Culicidae	0	2	0	7	19	34	0	11	0	4	2	1	6	0	0	3	2	0	0	0	0	1
40	Insecta	Diptera	Dolichopodidae	5	0	2	3	1	0	0	0	4	0	0	0	0	0	3	0	1	1	0	3	0	0
41	Insecta	Diptera	Drosophilidae	4	2	0	2	7	23	1	5	9	7	11	2	6	0	9	7	3	2	0	3	1	3
42	Insecta	Diptera	Muscidae	0	1	0	4	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	Insecta	Diptera	Phoridae	0	1	0	1	1	9	1	0	1	0	4	1	0	2	4	0	5	4	8	1	0	0
44	Insecta	Diptera	Sciaridae	15	1	2	3	0	3	0	3	7	5	5	4	1	8	7	8	8	5	1	11	5	5
45	Insecta	Diptera	Sepsidae	0	0	0	0	0	5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	10
46	Insecta	Diptera	Stratiomyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
47	Insecta	Diptera	Syrphidae	0	4	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	1	0	4
48	Insecta	Diptera	Tephritidae	0	0	0	0	0	2	0	0	0	3	0	0	0	0	3	0	0	0	0	1	0	0
49	Insecta	Diptera	Tipulidae	5	13	0	5	2	9	4	2	13	1	17	1	0	13	13	0	1	5	5	4	1	0
50	Insecta	Hemiptera	Aphididae	1	1	0	0	0	0	4	0	0	0	1	1	0	6	0	0	0	0	0	0	0	2
51	Insecta	Hemiptera	Cercopidae	0	1	7	18	4	8	0	2	1	2	0	1	1	1	0	0	0	0	0	11	0	1
52	Insecta	Hemiptera	Cicadellidae	6	1	6	6	6	2	7	0	0	8	2	2	17	0	2	1	3	0	1	10	2	2
53	Insecta	Hemiptera	Cicadidae	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	1	1	0	1	0	1
55	Insecta	Hemiptera	Cixiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	10
56	Insecta	Hemiptera	Cydnidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
57	Insecta	Hemiptera	Lygaeidae	1	0	1	0	0	1	1	0	0	0	0	2	1	0	0	0	0	3	0	2	0	0
58	Insecta	Hemiptera	Membracidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
59	Insecta	Hemiptera	Miridae	1	0	1	1	8	1	4	0	1	2	0	2	5	0	1	0	1	0	0	24	2	1
60	Insecta	Hemiptera	Pentatomidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1	0	0
61	Insecta	Hemiptera	Pyrhocoridae	0	1	2	0	1	0	0	1	3	0	0	1	1	0	0	3	0	2	6	3	1	0
62	Insecta	Hemiptera	Reduviidae	0	0	1	0	0	0	4	0	1	1	0	1	1	0	0	0	1	2	2	3	0	0

63	Insecta	Hymenoptera	Apidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64	Insecta	Hymenoptera	Bethylidae	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	1	0	0	0
65	Insecta	Hymenoptera	Braconidae	2	1	1	2	2	2	2	0	1	6	4	0	1	0	2	4	5	0	0	4	0
66	Insecta	Hymenoptera	Cynipidae	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	3	0	0	0	0	
67	Insecta	Hymenoptera	Formicidae	102	77	64	20	11	0	132	46	76	59	77	40	3	44	40	101	6	40	2	249	174
68	Insecta	Hymenoptera	Ichneumonidae	0	0	0	0	0	0	0	0	2	0	0	0	1	0	1	3	0	0	0	2	
69	Insecta	Hymenoptera	Pompilidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2	
70	Insecta	Hymenoptera	Pteromalidae	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	2	
71	Insecta	Hymenoptera	Rhopalosomatidae	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	
72	Insecta	Hymenoptera	Scelionidae	1	3	1	1	0	0	1	1	0	0	0	0	3	0	3	0	1	2	0	2	
73	Insecta	Isoptera	Termitidae	2	0	0	0	0	0	1	0	0	0	9	0	4	0	0	13	9	9	0	0	
74	Insecta	Mantodea	Mantidae	0	0	0	1	0	0	1	0	0	0	0	5	1	0	0	0	0	0	3		
75	Insecta	Odonata	Lestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
76	Insecta	Orthoptera	Acrididae	0	0	1	0	11	0	13	0	1	9	2	2	1	0	2	1	1	4	3		
77	Insecta	Orthoptera	Gryllidae	3	1	4	3	2	1	8	1	1	10	3	5	3	2	0	0	0	3	2		
78	Insecta	Orthoptera	Lampyridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		
79	Insecta	Orthoptera	Tetrigidae	1	1	0	0	0	0	0	0	3	0	0	1	0	1	1	1	0	0	0		
80	Insecta	Orthoptera	Tettigoniidae	5	1	0	0	1	3	7	3	7	2	2	1	1	1	2	3	2	3	0		
81	Insecta	Thysanoptera	Phlaeothripidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0		

Appendix 5

	Family	Species	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	WT	NR
1	Lycaenidae	<i>Anthene SP01</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0
2	Lycaenidae	<i>Azanus SP01</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0
3	Lycaenidae	<i>Eicochrysops SP01</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0
4	Lycaenidae	<i>Iolaus SP01</i>	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Lycaenidae	<i>Iolaus SP02</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
6	Nymphalidae	<i>Acraea acerata</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
7	Nymphalidae	<i>Acraea asboloplintha</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
8	Nymphalidae	<i>Acraea bonasia</i>	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	2	0
9	Nymphalidae	<i>Acraea uvui</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0	5	0

10	Nymphalidae	<i>Antanartia schaeeneia</i>	0	0	1	1	0	0	0	0	1	0	0	0	1	0	0	2	0	0	0	0	0	0
11	Nymphalidae	<i>Bicyclus aurivillii</i>	3	0	2	0	2	8	3	14	8	2	5	2	0	0	13	7	15	1	4	4	2	2
12	Nymphalidae	<i>Charaxes acuminatus</i>	0	0	1	1	1	0	0	4	0	2	0	4	1	0	0	2	0	0	1	1	0	0
13	Nymphalidae	<i>Charaxes ansorgei</i>	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Nymphalidae	<i>Charaxes varanes</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0
15	Nymphalidae	<i>Eurytela dryope</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
16	Nymphalidae	<i>Hypolimnys misippus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
17	Nymphalidae	<i>Junonia oenone</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
18	Nymphalidae	<i>Junonia terea</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
19	Pieridae	<i>Mylothris ruandana</i>	0	0	0	0	0	2	1	0	0	0	0	0	0	0	5	1	0	0	0	2	0	0
20	Nymphalidae	<i>Precis octavia</i>	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
21	Papilionidae	<i>Papilio jacksoni</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
22	Pieridae	<i>Catopsilia florella</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
23	Pieridae	<i>Mylothris agathina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
24	Pieridae	<i>Mylothris croceus</i>	0	0	0	0	0	0	1	1	0	0	3	1	5	0	6	0	0	2	0	1	5	0

Appendix 6

	Order	Family	Species	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	WT
1	Passeriformes	Turdidae	<i>Turdus abyssinicus</i>								1													
2	passeriformes	Muscicapidae	<i>Muscicapa adusta</i>																		1		1	
3	Cuculiformes	Cuculidae	<i>Chrysococcyx cupreus</i>			1																		
4	Passeriformes	Oriolidae	<i>Oriolus auratus</i>							2														
5	Accipitriformes	Accipitridae	<i>Accipiter tachiro</i>									1										1		
6	Columbiformes	Columbidae	<i>Treron calvus</i>																				1	
7	Accipitriformes	Accipitridae	<i>Polyboroides typus</i>																1					
8	Passeriformes	Monarchidae	<i>Terpsiphone viridis</i>																		1		1	
9	Passeriformes	Motacillidae	<i>Motacilla aquimp</i>										1											
10	Passeriformes	Motacillidae	<i>Anthus cinnamomeus</i>										1											
11	Passeriformes	Muscicapidae	<i>Saxicola torquatus</i>						1															1
12	Strigiformes	Strigidae	<i>Strix woodfordii</i>								1													
13	Passeriformes	Hirundinidae	<i>Hirundo angolensis</i>							1														
14	Passeriformes	Muscicapidae	<i>Dessonornis archeri</i>												1									
15	Accipitriformes	Accipitridae	<i>Buteo augur</i>							2											1			

16	Passeriformes	Cisticolidae	<i>Prinia bairdii</i>		2																	
17	Cuculiformes	Cuculidae	<i>Cercococcyx montanus</i>				1															
18	Trogoniformes	Trogonidae	<i>Apaloderma vittatum</i>																		1	
19	Cuculiformes	Cuculidae	<i>Cuculus clamosus</i>				1															
20	Passeriformes	Ploceidae	<i>Ploceus melanocephalus</i>	5																		
21	Accipitriformes	Accipitridae	<i>Milvus migrans parasitus</i>														1		1	1		
22	Passeriformes	Hirundinidae	<i>Psalidoprocne pristoptera</i>						6												1	3
23	Musophagiformes	Musophagidae	<i>Tauraco schuettii</i>												1			1				
24	Passeriformes	Cisticolidae	<i>Apalis personata</i>										2				1		1	2		
25	Passeriformes	Cisticolidae	<i>Bathmocercus rufus</i>																1			
26	Passeriformes	Malaconotidae	<i>Laniarius erythrogaster</i>										1									
27	Pelecaniformes	Ardeidae	<i>Ardea melanocephala</i>					1														
28	Passeriformes	Leiotrichidae	<i>Turdoides sharpei</i>	2													2					
29	Passeriformes	Cisticolidae	<i>Apalis jacksoni</i>										1									
30	Cuculiformes	Cuculidae	<i>Centropus monachus</i>			2																
31	Columbiformes	Columbidae	<i>Turtur afer</i>														2					
32	Passeriformes	Nectariniidae	<i>Nectarinia kilimensis</i>															2	1			
33	Passeriformes	Muscicapidae	<i>Dessonornis caffer</i>							2				1								1
34	Piciformes	Picidae	<i>Dendropicops fuscescens</i>														1					
35	Passeriformes	Cisticolidae	<i>Apalis porphyrolaema</i>		1																	
36	Passeriformes	Platysteiridae	<i>Batis molitor</i>			1				2	1			3	2	3		1	3	1	1	
37	Passeriformes	Cisticolidae	<i>Cisticola chubbi</i>													1						
38	Passeriformes	Locustellidae	<i>Bradypterus cinnamomeus</i>												1							
39	Passeriformes	Meropidae	<i>Merops oreobates</i>							1												
40	Passeriformes	Nectariniidae	<i>Hedydipna collaris</i>						1													
41	Accipitriformes	Accipitridae	<i>Buteo buteo</i>																	1		
42	Falconiformes	Falconidae	<i>Falco tinnunculus</i>													1						
43	Bucerotiformes	Bucerotidae	<i>Lophoceros alboterminatus</i>		1																	
44	Passeriformes	Pycnonotidae	<i>Pycnonotus tricolor</i>	4															1			
45	Passeriformes	Malaconotidae	<i>Telophorus dohertyi</i>				1															
46	Passeriformes	Estrildidae	<i>Cryptospiza jacksoni</i>				1						2									
47	Columbiformes	Columbidae	<i>Streptopelia lugens</i>		1																	
48	Passeriformes	Pycnonotidae	<i>Arizelocichla nigriceps</i>	4	1	2		1		2	2		2	2	2	4		4	2	2		
49	Passeriformes	Muscicapidae	<i>Sheppardia aequatorialis</i>						1													
50	Coraciiformes	Meropidae	<i>Merops apiaster</i>																		2	
51	Passeriformes	Locustellidae	<i>Bradypterus lopezi</i>	2											1							
52	Passeriformes	Estrildidae	<i>Estrilda paludicola</i>																	1		

53	Passeriformes	Locustellidae	<i>Bradypterus graueri</i>																		1
54	Guiformes	Gruidae	<i>Balearica regulorum</i>							2											2
55	Musophagiformes	Musophagidae	<i>Corythaeola cristata</i>														1				
56	Passeriformes	Zosteropidae	<i>Zosterops stuhlmanni</i>	2	1														1	1	
57	Passeriformes	Cisticolidae	<i>Camaroptera brevicaudata</i>							2				1	2	2					1
58	Passeriformes	Laniidae	<i>Lanius excubitoroides</i>						2										1		
59	Passeriformes	Scopidae	<i>Scopus umbretta</i>																		1
60	Galliformes	Phasianidae	<i>Pternistis nobilis</i>														1	1			
61	Accipitriformes	Accipitridae	<i>Necrosyrtes monachus</i>															1			
62	Passeriformes	Estrildidae	<i>Estrilda kandti</i>											2							
63	Cuculiformes	Cuculidae	<i>Chrysococcyx klaas</i>								1										
64	Passeriformes	Hirundinidae	<i>Cecropis abyssinica</i>																	1	
65	Passeriformes	Locustellidae	<i>Bradypterus baboecala</i>								1								1		
66	Apodiformes	Apodidae	<i>Apus affinis</i>							1					1						
67	Accipitriformes	Accipitridae	<i>Lophaetus occipitalis</i>												1						
68	Passeriformes	Laniidae	<i>Lanius mackinnoni</i>													1				1	1
69	Passeriformes	Nectariniidae	<i>Nectarinia famosa</i>						1												
70	Accipitriformes	Accipitridae	<i>Buteo oreophilus</i>													1					
71	Passeriformes	Pellorneidae	<i>Illadopsis pyrrhoptera</i>						1												
72	Passeriformes	Malaconotidae	<i>Laniarius poensis</i>					2													
73	Passeriformes	Motacillidae	<i>Motacilla clara</i>											1							
74	Passeriformes	Motacillidae	<i>Motacilla clara</i>		2																
75	Passeriformes	Acrocephalidae	<i>Iduna similis</i>									1							1		
76	Trogoniformes	Trogonidae	<i>Apaloderma narina</i>																1		
77	Passeriformes	Nectariniidae	<i>Cinnyris reichenowi</i>																	1	
78	Passeriformes	Laniidae	<i>Lanius humeralis</i>												2						
79	Passeriformes	Passeridae	<i>Passer griseus</i>						8							1		1			
80	Passeriformes	Malaconotidae	<i>Dryoscopus gambensis</i>		1																
81	Piciformes	Picidae	<i>Chloropicus griseocephalus</i>	1			1														
82	Passeriformes	Nectariniidae	<i>Cinnyris chloropygius</i>																	1	
83	Columbiformes	Columbidae	<i>Columba arquatrix</i>								1										
84	Cuculiformes	Cuculidae	<i>Cuculus solitarius</i>													1					
85	Passeriformes	Nectariniidae	<i>Cinnyris erythrocercus</i>													1			1		
86	Columbiformes	Columbidae	<i>Streptopelia semitorquata</i>													1					
87	Passeriformes	Macrosphenidae	<i>Sylvietta whytii</i>								1				1	1					
88	Passeriformes	Phylloscopidae	<i>Phylloscopus laetus</i>												1			1			
89	Passeriformes	Hirundinidae	<i>Cecropis daurica</i>												1						

90	Passeriformes	Muscicapidae	<i>Chamaetylas poliophrys</i>															1						
91	Passeriformes	Nectariniidae	<i>Cinnyris regius</i>	7	2	1	3	1	3	5	3	1	4	4	4	3	2	4	1	3	5	2		
92	Passeriformes	Hirundinidae	<i>Ptyonoprogne fuligula</i>				1																	
93	Musophagiformes	Musophagidae	<i>Musophaga rossae</i>	2		1	2	2	1		1			2	2	3	2	3	2	2	3	1	2	1
94	Musophagiformes	Musophagidae	<i>Gallirex johnstoni</i>								1			6				1	7	11			2	
95	Passeriformes	Platysteiridae	<i>Batis diops</i>			2			1		1			1			1	3		2				
96	Passeriformes	Sylviidae	<i>Sylvia atriceps</i>	1																				
97	Caprimulgiformes	Caprimulgidae	<i>Caprimulgus ruwenzorii</i>																	1				
98	Galliformes	Phasianidae	<i>Pternistis squamatus</i>																				1	
99	Piciformes	Indicatoridae	<i>Indicator variegatus</i>				1																	
100	Passeriformes	Nectariniidae	<i>Chalcomitra senegalensis</i>																	1			3	
101	Passeriformes	Sturnidae	<i>Pholia sharpii</i>															1						
102	Passeriformes	Sturnidae	<i>Onychognathus tenuirostris</i>						2															
103	Passeriformes	Ploceidae	<i>Ploceus pelzelni</i>	5																				
104	Passeriformes	Fringillidae	<i>Crithagra striolata</i>																	1				
105	Passeriformes	Paridae	<i>Melaniparus fasciiventer</i>		1												1							
106	Passeriformes	Fringillidae	<i>Crithagra burtoni</i>	1																				
107	Passeriformes	Ploceidae	<i>Amblyospiza albifrons</i>	2																				
108	Passeriformes	Malaconotidae	<i>Laniarius aethiopicus</i>		1										1									
109	Passeriformes	Nectariniidae	<i>Cinnyris venustus</i>				1		2					1					1	1			3	
110	Passeriformes	Motacillidae	<i>Motacilla flava</i>		1																			
111	Cuculiformes	Cuculidae	<i>Centropus superciliosus</i>												1									
112	Passeriformes	Muscicapidae	<i>Cossypha heuglini</i>								1													
113	Passeriformes	Muscicapidae	<i>Cercotrichas leucophrys</i>									1		2										
114	Passeriformes	Cisticolidae	<i>Schistolais leucopogon</i>								1													
115	Passeriformes	Muscicapidae	<i>Melaenornis fischeri</i>																	2			1	
116	Coraciiformes	Phoeniculidae	<i>Phoeniculus bollei</i>		1																			
117	Passeriformes	Corvidae	<i>Corvus albicollis</i>				1																	
118	Passeriformes	Muscicapidae	<i>Pogonocichla stellata</i>														1							
119	Passeriformes	Phylloscopidae	<i>Phylloscopus trochilus</i>						2															
120	Passeriformes	Hirundinidae	<i>Hirundo smithii</i>																			1		
121	Passeriformes	Cisticolidae	<i>Apalis flavida</i>																			1		
122	Passeriformes	Fringillidae	<i>Crithagra frontalis</i>						2															
123	Piciformes	Lybiidae	<i>Pogoniulus bilineatus</i>		2																			
124	Passeriformes	Pycnonotidae	<i>Phyllastrephus flavostriatus</i>															1						
125	Passeriformes	Pycnonotidae	<i>Eurillas latirostris</i>									1				1	1	3						

Appendix 7

Order	Family	Species	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
Squamata	Viperidae	<i>Atheris nitschei</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
Squamata	Lacertidae	<i>Congolacerta vauereselli</i>	0	1	0	0	0	1	1	0	1	0	0	0	0	0	0	2	0	0	0	0
Squamata	Scincidae	<i>Leptosiphos graueri quinquedigitata</i>	0	0	0	0	0	1	1	0	6	0	0	0	0	0	0	0	0	2	0	1
Squamata	Chamaeleonidae	<i>Trioceros johnstoni</i>	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	2	1
Squamata	Chamaeleonidae	<i>Trioceros rudis</i>	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Appendix 8

Order	Family	Taxon	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
Anura	Pixycephalidae	<i>Amietia desaegeri</i>	0	0	2	0	0	1	4	0	0	0	0	0	3	3	0	0	2	1	0	0
Anura	Arthroleptidae	<i>Arthroleptis adolfifriederici</i>	12	3	4	0	10	10	0	2	0	1	5	2	10	5	0	1	6	5	6	0
Anura	Hyperoliidae	<i>Hyperolius discodactylus</i>	0	0	0	0	2	0	0	3	0	0	0	0	5	0	0	0	1	0	0	1
Anura	Hyperoliidae	<i>Hyperolius castaneus</i>	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	2	1	0
Anura	Hyperoliidae	<i>Hyperolius glandicolor</i>	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Anura	Arthroleptidae	<i>Leptopelis kivuensis</i>	0	1	0	0	4	3	5	1	4	0	1	0	0	2	0	0	0	5	1	2
Anura	Arthroleptidae	<i>Leptopelis karissimbensis</i>	0	2	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Anura	Phrynobatrachidae	<i>Phrynobatrachus versicolor</i>	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anura	Phrynobatrachidae	<i>Phrynobatrachus sp.</i>	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anura	Ptychadenidae	<i>Ptychadena chrysogaster</i>	0	1	0	0	0	1	1	0	8	1	0	0	0	4	0	0	0	13	0	0
Anura	Bufonidae	<i>Sclerophrys kisoensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Anura	Pipidae	<i>Xenopus wittei</i>	0	0	0	0	0	0	10	0	0	0	50	0	0	0	0	0	0	0	0	0

Appendix 9

Species	RD	Other	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P 20	WL
<i>Chrysochloris stuhlmanni</i>		1																					
<i>Cricetomys emini</i>		1																					
<i>Heliosciurus rufobrachium</i>		1																					
<i>Hylomyscus stella</i>		2																					
<i>Leptailurus serval</i>		3						1															
<i>Lophuromys laticeps</i>					3	1															1	1	
<i>Lophuromys woosnami</i>	2	8			2	1	4		1		1	1	1	1					1		2	1	
<i>Lupulella adusta</i>		9																					
<i>Mus bufo</i>																						1	
<i>Praomys degraaffi</i>							1	2	1								1		1				
<i>Praomys jacksoni</i>	1	2	1		1		1								1						1	3	1
<i>Unidentified</i>		6																					

Appendix 10

N0	Order	Family	Genus	Species	RD	P1	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P2	P20	P
1	Lamiales	Acanthaceae	Acanthus	<i>Acanthus polystachius</i>						3									
2	Lamiales	Acanthaceae	Brillantaisia	<i>Brillantaisia owariensis</i>						1		2		3		1		2	
3	Lamiales	Acanthaceae	Hypoestes	<i>Hypoestes forskalii</i>															
4	Lamiales	Acanthaceae	Hypoestes	<i>Hypoestes triflora</i>									2			2			
5	Lamiales	Acanthaceae	Isoglossa	<i>Isoglossa vulcanicola</i>								1							
6	Lamiales	Acanthaceae	Thunbergia	<i>Thunbergia mildbraediana</i>								2							
7	Lamiales	Acanthaceae	Justicia	<i>Justicia sp</i>				1											
8	Lamiales	Acanthaceae	Mimulopsis	<i>Mimulopsis solmsii</i>	3			1	2			1			2	5	2	1	
9	Caryophyllales	Amaranthaceae	Achyranthes	<i>Achyranthes aspera</i>	2														
10	Caryophyllales	Amaranthaceae	Sericostachys	<i>Sericostachys scandens</i>				1		2				1	2	2	1		
11	Sapindales	Anacardiaceae	Lannea	<i>Lannea schimperi</i>											2				
12	Magnoliales	Annonaceae	Monanthes	<i>Monanthes orophila</i>				2			2		2	1				2	
13	Apiales	Apiaceae	Uvaria	<i>Uvaria angolensis</i>	2														
14	Gentianales	Apocynaceae	Afrologisticum	<i>Afrologisticum runssoricum</i>								2				1			
15	Gentianales	Apocynaceae	Secamone	<i>Secamone racemosa</i>			1	3		2	1	1	1	4	1				
16	Gentianales	Apocynaceae	Tabernaemontana	<i>Tabernaemontana stapfiana</i>						2						2		2	

17	Aquifoliales	Aquifoliaceae	Ilex	<i>Ilex mitis</i>								2	1		1			
18	Alismatales	Araceae	Arisaema	<i>Arisaema mildbraedii</i>												1		
19	Apiales	Araliaceae	Culcasia	<i>Culcasia falcifolia</i>									1					
20	Apiales	Araliaceae	Astropanax	<i>Astropanax goetzenii</i>	2	1	1	3		4	3	2	1	4	1	2		2
21	Apiales	Araliaceae	Astropanax	<i>Astropanax myrianthus</i>														
22	Apiales	Araliaceae	Hydrocotyle	<i>Hydrocotyle mannii</i>										2		2		
23	Apiales	Araliaceae	Polyscias	<i>Polyscias fulva</i>	1			3	1	2	1					3		1
24	Asparagales	Asparagaceae	Asparagus	<i>Asparagus asparagoides</i>					2									
25	Asparagales	Asparagaceae	Chlorophytum	<i>Chlorophytum sparsiflorum</i>					1									
26	Asparagales	Asparagaceae	Dracaena	<i>Dracaena afromontana</i>							1				2			2
27	Asparagales	Asphodelaceae	Kniphofia	<i>Kniphofia princeae</i>							1							
28	Polypodiales	Aspleniaceae	Asplenium	<i>Asplenium elliotii</i>														
29	Polypodiales	Aspleniaceae	Asplenium	<i>Asplenium friesiorum</i>	1	1	1	3			1	2	1	2	3	1	1	
30	Polypodiales	Aspleniaceae	Asplenium	<i>Asplenium gemmascens</i>						1					2	2		
31	Polypodiales	Aspleniaceae	Asplenium	<i>Asplenium linckii</i>														
32	Polypodiales	Aspleniaceae	Asplenium	<i>Asplenium mannii</i>														
33	Polypodiales	Aspleniaceae	Asplenium	<i>Asplenium mildbraedii</i>				1				1		1		1	1	
34	Polypodiales	Aspleniaceae	Asplenium	<i>Asplenium protensum</i>								1						
35	Polypodiales	Aspleniaceae	Asplenium	<i>Asplenium theciferum</i>		2										2		
36	Polypodiales	Aspleniaceae	Athyrium	<i>Athyrium newtonii</i>												2		4
37	Polypodiales	Aspleniaceae	Blechnum	<i>Blechnum tabulare</i>						1	2							
38	Polypodiales	Aspleniaceae	Thelypteris	<i>Thelypteris blastophora</i>										1				
39	Polypodiales	Aspleniaceae	Thelypteris	<i>Thelypteris confluens</i>														
40	Asterales	Asteraceae	Acmella	<i>Acmella caulirhiza</i>								4						
41	Asterales	Asteraceae	Afrocarduus	<i>Afrocarduus nyassanus</i>						2		2						
42	Asterales	Asteraceae	Ageratum	<i>Ageratum conyzoides</i>	1													
43	Asterales	Asteraceae	Baccharoides	<i>Baccharoides kirungae</i>		1		2										
44	Asterales	Asteraceae	Bidens	<i>Bidens pilosa</i>	1													
45	Asterales	Asteraceae	Bothriocline	<i>Bothriocline nyungwensis</i>	1							2				3		2
46	Asterales	Asteraceae	Bothriocline	<i>Bothriocline ruwenzoriensis</i>	2											2		
47	Asterales	Asteraceae	Bothriocline	<i>Bothriocline ugandensis</i>				2				1		1		3		
48	Asterales	Asteraceae	Crassocephalum	<i>Crassocephalum montuosum</i>	1										1			

49	Asterales	Asteraceae	Crassocephalum	<i>Crassocephalum paludum</i>														
50	Asterales	Asteraceae	Crassocephalum	<i>Crassocephalum rubens</i>	2													
51	Asterales	Asteraceae	Crassocephalum	<i>Crassocephalum vitellinum</i>														
52	Asterales	Asteraceae	Eschenbachia	<i>Eschenbachia gouanii</i>			1											
53	Asterales	Asteraceae	Galinsoga	<i>Galinsoga parviflora</i>	1													
54	Asterales	Asteraceae	Gymnanthemum	<i>Gymnanthemum auriculiferum</i>									1		2	2	1	
55	Asterales	Asteraceae	Gynura	<i>Gynura scandens</i>						1				3	1			
56	Asterales	Asteraceae	Helichrysum	<i>Helichrysum foetidum</i>														
57	Asterales	Asteraceae	Helichrysum	<i>Helichrysum globosum</i>						1						1		
58	Asterales	Asteraceae	Helichrysum	<i>Helichrysum helvolum</i>														
59	Asterales	Asteraceae	Mikania	<i>Mikania chenopodiifolia</i>										1				
60	Asterales	Asteraceae	Senecio	<i>Senecio maranguensis</i>											2		4	
61	Asterales	Asteraceae	Senecio	<i>Senecio mariettae</i>							1						1	
62	Asterales	Asteraceae	Senecio	<i>Senecio nyungwensis</i>					2	2			2			2		
63	Asterales	Asteraceae	Senecio	<i>Senecio subsessilis</i>									1					
64	Asterales	Asteraceae	Solanecio	<i>Solanecio mannii</i>											2			
65	Asterales	Asteraceae	Tagetes	<i>Tagetes minuta</i>	1													
66	Ericales	Balsaminaceae	Impatiens	<i>Impatiens burtonii</i>			1				1				1			
67	Ericales	Balsaminaceae	Impatiens	<i>Impatiens erecticornis</i>				1										
68	Ericales	Balsaminaceae	Impatiens	<i>Impatiens gesnerioidea</i>	3	3	1	2	1		1				2		2	
69	Ericales	Balsaminaceae	Impatiens	<i>Impatiens niamniamensis</i>						2	2			2	3			
70	Ericales	Balsaminaceae	Impatiens	<i>Impatiens stuhlmannii</i>			1	1	2				2			1	3	
71	Cucurbitales	Begoniaceae	Begonia	<i>Begonia meyeri-johannis</i>	2	1	1		1	1	1			2	5			1
72	Asterales	Campanulaceae	Lobelia	<i>Lobelia giberroa</i>	2					2	1		1		1			
73	Asterales	Campanulaceae	Lobelia	<i>Lobelia hartlaubii</i>							1							
74	Asterales	Campanulaceae	Lobelia	<i>Lobelia mildbraedii</i>														
75	Asterales	Campanulaceae	Lobelia	<i>Lobelia minutula</i>			3											
76	Asterales	Campanulaceae	Monopsis	<i>Monopsis stellarioides subsp. schimperiana</i>							1							
77	Caryophyllales	Caryophyllaceae	Cerastium	<i>Cerastium lanceolatum</i>		1												
78	Caryophyllales	Caryophyllaceae	Drymaria	<i>Drymaria cordata</i>			2				1				3	2		
79	Caryophyllales	Caryophyllaceae	Silene	<i>Silene kiwuensis</i>	2				2		4		4				2	
80	Celastrales	Celastraceae	Maytenus	<i>Maytenus acuminata</i>	2	2						1	1	3		1	1	

81	Celastrales	Celastraceae	Salacia	<i>Salacia erecta</i>									1					
82	Malpighiales	Chrysobalanaceae	Parinari	<i>Parinari excelsa</i>	1	1												
83	Malpighiales	Clusiaceae	Symphonia	<i>Symphonia globulifera</i>				1	1	1			1	1		1		4
84	Commelinales	Commelinaceae	Commelina	<i>Commelina africana</i>	1													
85	Commelinales	Commelinaceae	Commelina	<i>Commelina diffusa</i>	2							1			1	3	1	1
86	Commelinales	Commelinaceae	Cyanotis	<i>Cyanotis vaga</i>										2				
87	Solanales	Convolvulaceae	Dichondra	<i>Dichondra micrantha</i>												2		
88	Solanales	Convolvulaceae	Ipomoea	<i>Ipomoea involucrata</i>	2			3		1					2	1	1	1
89	Cornales	Cornaceae	Alangium	<i>Alangium chinense</i>		1			1									
90	Asterales	Crassulaceae	Crassula	<i>Crassula granvikii</i>								1						
91	Saxifragales	Crassulaceae	Kalanchoe	<i>Kalanchoe crenata</i>														
92	Cucurbitales	Cucurbitaceae	Coccinia	<i>Coccinia mildbraedii</i>					1									
93	Cucurbitales	Cucurbitaceae	Momordica	<i>Momordica foetida</i>				2							2			
94	Cucurbitales	Cucurbitaceae	Zehneria	<i>Zehneria scabra</i>					2						2			
95	Cyatheaales	Cyatheaceae	Alsophila	<i>Alsophila dregei</i>			1	2									2	
96	Cyatheaales	Cyatheaceae	Alsophila	<i>Alsophila manniana</i>			1		2	3	2	1						
97	Poales	Cyperaceae	Carex	<i>Carex bequaertii</i>								2						
98	Poales	Cyperaceae	Cyperus	<i>Cyperus brevifolius</i>							3							
99	Poales	Cyperaceae	Cyperus	<i>Cyperus denudatus</i>							2							
100	Poales	Cyperaceae	Cyperus	<i>Cyperus exaltatus</i> var. <i>exaltatus</i>						2								
101	Poales	Cyperaceae	Cyperus	<i>Cyperus lanceolatus</i>														1
102	Poales	Cyperaceae	Cyperus	<i>Cyperus mundii</i>						4								
103	Poales	Cyperaceae	Cyperus	<i>Cyperus nigricans</i>			3			2								
104	Poales	Cyperaceae	Cyperus	<i>Cyperus nitidus</i>														
105	Poales	Cyperaceae	Cyperus	<i>Cyperus platyphyllus</i>														
106	Poales	Cyperaceae	Cyperus	<i>Cyperus richardii</i>														
107	Poales	Cyperaceae	Cyperus	<i>Cyperus rotundus</i>														
108	Poales	Cyperaceae	Cyperus	<i>Cyperus sesquiflorus</i> subsp. <i>appendiculatus</i>			1	2				3						
109	Poales	Cyperaceae	Cyperus	<i>Cyperus tomaiophyllus</i>							2	2						
110	Poales	Cyperaceae	Cyperus	<i>Cyperus tomaiophyllus</i>														
111	Poales	Cyperaceae	Fimbristylis	<i>Fimbristylis quinquangularis</i>														
112	Poales	Cyperaceae	Schoenoplectiella	<i>Schoenoplectiella brachyceras</i>							1							

113	Poales	Cyperaceae	Schoenoplectus	<i>Schoenoplectus tabernaemontani</i>							2							
114	Poales	Cyperaceae	Scirpus	<i>Scirpus cyperinus</i>														
115	Polypodiales	Dennstaedtiaceae	Blotiella	<i>Blotiella bouxiniana</i>														
116	Polypodiales	Dennstaedtiaceae	Pteridium	<i>Pteridium aquilinum</i>	1			3			2	3	2	2		2		2
117	Ericales	Ericaceae	Erica	<i>Erica kingaensis</i>	2													
118	Ericales	Ericaceae	Erica	<i>Erica mannii</i>	2		3										3	
119	Malpighiales	Euphorbiaceae	Alchornea	<i>Alchornea hirtella</i>				2	2				1					
120	Malpighiales	Euphorbiaceae	Macaranga	<i>Macaranga kilimandscharica</i>	2	2	1	3	2	5	1	3	2	4	3	4	3	3
121	Malpighiales	Euphorbiaceae	Neoboutonia	<i>Neoboutonia macrocalyx</i>	2			1	1	1	1	1		3		3	1	1
122	Fabales	Fabaceae	Acacia	<i>Acacia mearnsii</i>													1	
123	Fabales	Fabaceae	Dalbergia	<i>Dalbergia lactea</i>									1					
124	Fabales	Fabaceae	Eriosema	<i>Eriosema montanum</i>														
125	Fabales	Fabaceae	Erythrina	<i>Erythrina abyssinica</i>	2											1		
126	Fabales	Fabaceae	Hylodesmum	<i>Hylodesmum repandum</i>						1		1						
127	Fabales	Fabaceae	Kotschya	<i>Kotschya africana</i>														
128	Fabales	Fabaceae	Parochetus	<i>Parochetus communis</i>								3						
129	Fabales	Fabaceae	Trifolium	<i>Trifolium usambarense</i>												1		
130	Geraniales	Francoaceae	Bersama	<i>Bersama abyssinica</i>				2	2			1		1		3	1	
131	Gentianales	Gentianaceae	Swertia	<i>Swertia brownii</i>									1	3				
132	Geraniales	Geraniaceae	Geranium	<i>Geranium aculeolatum</i>						1		1						
133	Geraniales	Geraniaceae	Geranium	<i>Geranium arabicum</i>								2		2		4		
134	Gleicheniales	Gleicheniaceae	Dicranopteris	<i>Dicranopteris linearis</i>														
135	Malpighiales	Hypericaceae	Harungana	<i>Harungana montana</i>												1		
136	Malpighiales	Hypericaceae	Hypericum	<i>Hypericum humbertii</i>						2		1		2				1
137	Malpighiales	Hypericaceae	Hypericum	<i>Hypericum scioanum</i>														
138	Asparagales	Hypoxidaceae	Hypoxis	<i>Hypoxis kilimanjarica</i>														
139	Poales	Juncaceae	Juncus	<i>Juncus oxycarpus</i>	2			2		1		1		1				1
140	Lamiales	Lamiaceae	Clerodendrum	<i>Clerodendrum fuscum</i>	1													
141	Lamiales	Lamiaceae	Clerodendrum	<i>Clerodendrum johnstonii</i>											2			1
142	Lamiales	Lamiaceae	Coleus	<i>Coleus autranii</i>					4			3		2			4	2
143	Lamiales	Lamiaceae	Coleus	<i>Coleus maculosus subsp. edulis</i>														
144	Lamiales	Lamiaceae	Coleus	<i>Coleus melleri</i>			1										1	1

145	Lamiales	Lamiaceae	Coleus	<i>Coleus meyeri</i>	3			1						2		3	3	1	
146	Lamiales	Lamiaceae	Micromeria	<i>Micromeria imbricata</i> var. <i>imbricata</i>															
147	Lamiales	Lamiaceae	Rothea	<i>Rothea bukobensis</i>															
148	Lamiales	Linderniaceae	Craterostigma	<i>Craterostigma nummulariifolium</i>			1	1		3		3		3					
149	Lamiales	Linderniaceae	Vandellia	<i>Vandellia subracemosa</i>														1	
150	Santalales	Loranthaceae	Agelanthus	<i>Agelanthus musoensis</i>										1					
151	Santalales	Loranthaceae	Englerina	<i>Englerina woodfordioides</i>	1												3		
152	Santalales	Loranthaceae	Phragmanthera	<i>Phragmanthera usuiensis</i>	2									1					
153	Santalales	Loranthaceae	Phragmanthera	<i>Phragmanthera usuiensis</i>		2													
154	Santalales	Loranthaceae	Tapinanthus	<i>Tapinanthus constrictiflorus</i>						4					2			2	
155	Gentianales	Rubiaceae	Chassalia	<i>Chassalia subochreatea</i>	1	3				1							1		
156	Lycopodiales	Lycopodiaceae	Lycopodium	<i>Lycopodium clavatum</i>			1			1				1					
157	Malvales	Malvaceae	Dombeya	<i>Dombeya torrida</i>				2	1		1	2		1	2	2	1		
158	Malvales	Malvaceae	Pavonia	<i>Pavonia urens</i>												1			
159	Malvales	Malvaceae	Triumfetta	<i>Triumfetta cordifolia</i>	1			1	1	1		1		2		1	1	2	
160	Marattiales	Marattiaceae	Eupodium	<i>Eupodium cicutifolium</i>															
161	Myrtales	Melastomataceae	Cinnabotrys	<i>Cinnabotrys oreophilus</i>			1												
162	Myrtales	Melastomataceae	Dichaetanthera	<i>Dichaetanthera corymbosa</i>										2					
163	Myrtales	Melastomataceae	Melastomastrum	<i>Melastomastrum capitatum</i>															
164	Myrtales	Melastomataceae	Tristemma	<i>Tristemma mauritianum</i>							2								
165	Sapindales	Meliaceae	Carapa	<i>Carapa grandiflora</i>				2	1	1			1	2					
166	Sapindales	Meliaceae	Lepidotrichilia	<i>Lepidotrichilia volkensii</i>														1	
167	Ranunculales	Menispermaceae	Stephania	<i>Stephania abyssinica</i>					1					3					
168	Laurales	Monimiaceae	Xymalos	<i>Xymalos monospora</i>	2	2		2		2		2	2	1		3		6	
169	Rosales	Moraceae	Ficus	<i>Ficus thonningii</i>															
170	Myrtales	Myrtaceae	Syzygium	<i>Syzygium guineense</i>	2	2	2	2		2		4	2	4	4	4	2	4	
171	Asparagales	Orchidaceae	Aerangis	<i>Aerangis</i> sp.															
172	Asparagales	Orchidaceae	Cynorkis	<i>Cynorkis anacamptoides</i>				3						5					
173	Asparagales	Orchidaceae	Cynorkis	<i>Cynorkis kassneriana</i>	1														
174	Asparagales	Orchidaceae	Eulophia	<i>Eulophia horsfallii</i>							2								
175	Asparagales	Orchidaceae	Liparis	<i>Liparis bowkeri</i>										3					
176	Asparagales	Orchidaceae	Polystachya	<i>Polystachya bifida</i>						1		1			2				

177	Asparagales	Orchidaceae	Polystachya	<i>Polystachya caloglossa</i>			1											
178	Asparagales	Orchidaceae	Satyrium	<i>Satyrium crassicaule</i>														
179	Osmundales	Osmundaceae	Osmunda	<i>Osmunda regalis</i>						1								
180	Malpighiales	Peraceae	Clutia	<i>Clutia abyssinica</i>	2												4	
181	Malpighiales	Peraceae	Clutia	<i>Clutia paxii</i>			2					1		1		1		4
182	Malpighiales	Phyllanthaceae	Bridelia	<i>Bridelia brideliifolia</i>				1						1		1		
183	Malpighiales	Phyllanthaceae	Phyllanthus	<i>Phyllanthus nummulariifolius</i>	1			2				1		2			1	
184	Malpighiales	Phyllanthaceae	Phyllanthus	<i>Phyllanthus odontadenius</i>						1						5		2
185	Caryophyllales	Phytolaccaceae	Phytolacca	<i>Phytolacca dodecandra</i>	2													
186	Piperales	Piperaceae	Peperomia	<i>Peperomia fernandopoiana</i>						2					2			
187	Piperales	Piperaceae	Piper	<i>Piper capense</i>					3									
188	Lamiales	Plantaginaceae	Plantago	<i>Plantago palmata</i>								5		2		1		
189	Lamiales	Plantaginaceae	Veronica	<i>Veronica abyssinica</i>						2		1		2			1	
190	Poales	Poaceae	Cenchrus	<i>Cenchrus clandestinus</i>														3
191	Poales	Poaceae	Digitaria	<i>Digitaria abyssinica</i>														3
192	Poales	Poaceae	Eragrostis	<i>Eragrostis olivacea</i>													2	
193	Poales	Poaceae	Isachne	<i>Isachne mauritiana</i>	2		2	2						1				3
194	Poales	Poaceae	Leersia	<i>Leersia hexandra</i>						1								
195	Poales	Poaceae	Setaria	<i>Setaria megaphylla</i>														
196	Pinales	Podocarpaceae	Afrocarpus	<i>Afrocarpus usambarensis</i>	1													
197	Fabales	Polygalaceae	Polygala	<i>Polygala ruwenzoriensis</i>													2	
198	Caryophyllales	Polygonaceae	Persicaria	<i>Persicaria longiseta</i>								1						
199	Caryophyllales	Polygonaceae	Persicaria	<i>Persicaria nepalensis</i>								2						
200	Caryophyllales	Polygonaceae	Rumex	<i>Rumex nepalensis</i> var. <i>nepalensis</i>				2		1		1						
201	Polypodiales	Polypodiaceae	Arthropteris	<i>Arthropteris anniana</i>										3				
202	Polypodiales	Polypodiaceae	Drynaria	<i>Drynaria volkensii</i>														
203	Polypodiales	Polypodiaceae	Dryopteris	<i>Dryopteris kilemensis</i>								3						
204	Polypodiales	Polypodiaceae	Dryopteris	<i>Dryopteris pentheri</i>		1		1		1		1			1			3
205	Polypodiales	Polypodiaceae	Elaphoglossum	<i>Elaphoglossum tanganjicense</i>				2										
206	Polypodiales	Polypodiaceae	Loxogramme	<i>Loxogramme abyssinica</i>														
207	Polypodiales	Polypodiaceae	Oleandra	<i>Oleandra distenta</i>		1	2				1							2
208	Polypodiales	Polypodiaceae	Polystichum	<i>Polystichum transvaalense</i>														

209	Ericales	Primulaceae	Embelia	<i>Embelia schimperi</i>	2		2	1				2	2	5	2	3	4	4	
210	Ericales	Primulaceae	Lysimachia	<i>Lysimachia angustiloba</i>						2	1								
211	Ericales	Primulaceae	Maesa	<i>Maesa lanceolata</i>	1		2	3	2		2	2		4	2	3	3	2	
212	Ericales	Primulaceae	Myrsine	<i>Myrsine melanophloeos</i>	2	3	2	3		1	4	4	2	4	1	2	4	2	
213	Ranunculales	Ranunculaceae	Clematis	<i>Clematis dolichopoda</i>								1							
214	Ranunculales	Ranunculaceae	Clematis	<i>Clematis hirsuta</i>															
215	Ranunculales	Ranunculaceae	Clematis	<i>Clematis simensis</i>		2						3					1		
216	Ranunculales	Ranunculaceae	Thalictrum	<i>Thalictrum rhynchocarpum</i>								1		1			1		
217	Rosales	Rhamnaceae	Rhamnus	<i>Rhamnus sp.</i>															
218	Malpighiales	Rhizophoraceae	Cassipourea	<i>Cassipourea ruwensorensis</i>								1		1	4				
219	Rosales	Rosaceae	Alchemilla	<i>Alchemilla ellenbeckii</i>		1											1		
220	Rosales	Rosaceae	Alchemilla	<i>Alchemilla johnstonii</i>															
221	Rosales	Rosaceae	Hagenia	<i>Hagenia abyssinica</i>						1		1				4	1	2	
222	Rosales	Rosaceae	Rubus	<i>Rubus kirungensis</i>												1			
223	Rosales	Rosaceae	Rubus	<i>Rubus runssorensis</i>	1	1		1	2	1		3		5	2	4	1	2	
224	Gentianales	Rubiaceae	Galiniera	<i>Galiniera saxifraga</i>	2		1	3	1	3		5		3	1	2	1	3	
225	Gentianales	Rubiaceae	Galium	<i>Galium chloroionanthum</i>															
226	Gentianales	Rubiaceae	Galium	<i>Galium simense</i>													1		
227	Gentianales	Rubiaceae	Keetia	<i>Keetia queinzii</i>	2			4		1		3	1	2	4	1	2	1	
228	Gentianales	Rubiaceae	Otiophora	<i>Otiophora pauciflora subsp. burtii</i>													1		
229	Gentianales	Rubiaceae	Pavetta	<i>Pavetta bagshawei</i>				1		1	2				3	1		3	
230	Gentianales	Rubiaceae	Psychotria	<i>Psychotria bugoyensis</i>	2	2	3	4	2	2	3	3		3	4	7	5	5	
231	Gentianales	Rubiaceae	Sabicea	<i>Sabicea bequaertii</i>										2					
232	Gentianales	Rubiaceae	Spermacoce	<i>Spermacoce princeae</i>				1		2						1			
233	Gentianales	Rubiaceae	Vangueria	<i>Vangueria apiculata</i>			1						1						
234	Gentianales	Rubiaceae	Virectaria	<i>Virectaria major</i>	2		1	2								1	1	1	
235	Selaginellales	Selaginellaceae	Selaginella	<i>Selaginella kraussiana</i>	1							2						2	
236	Ericales	Sladeniaceae	Ficalhoa	<i>Ficalhoa laurifolia</i>										1					
237	Solanales	Solanaceae	Solanum	<i>Solanum aculeastrum</i>	2														
238	Malvales	Thymelaeaceae	Peddiea	<i>Peddiea orophila</i>							2	2		2	4				
239	Rosales	Urticaceae	Pilea	<i>Pilea rivularis</i>								1							
240	Rosales	Urticaceae	Pilea	<i>Pilea tetraphylla</i>															

241	Rosales	Urticaceae	Scepocarpus	<i>Scepocarpus hypselodendron</i>		1		1	1	2	3	2	2		3	2	1	
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PART II CONSERVATION OF MUKURA FOREST

Exploration of local stakeholder involvement in the management of Mukura Forest Reserve, Western Rwanda

Venuste Nsengimana^{1,2}, Venant Nzibaza², Dominique Mvunabandi³, John Peter Mugume^{2,4}

¹*Department of Biology, School of Science, College of Science and Technology, University of Rwanda*

²*Centre of Excellence in Biodiversity and Natural Resource Management, University of Rwanda*

³*Rwanda National Commission of UNESCO, Kigali, Rwanda*

⁴*Center for Conflict Management, College of Arts and Social Sciences, University of Rwanda*

Abstract

Stakeholder participation is a critical component in the sustainable conservation of Mukura Forest Reserve in Eastern Rwanda. This study assesses the level of engagement of key stakeholders, including local communities, government agencies, and conservation organizations, in decision-making processes and conservation activities. Findings reveal that while governmental institutions play a leading role in policy formulation, local community involvement remains limited due to inadequate awareness, financial constraints, and competing livelihood needs. Collaborative approaches, such as community-based conservation programs and public-private partnerships, have shown potential in enhancing participation. Challenges such as conflicting interests, limited funding, and enforcement gaps hinder effective stakeholder involvement. The study recommends strengthening participatory governance structures, improving capacity-building initiatives, and fostering multi-sectoral collaboration to ensure long-term conservation success. By addressing these gaps, sustainable conservation efforts in Mukura Forest Reserve can be enhanced, ensuring biodiversity protection while benefiting local communities.

Keywords: participation, conservation, Mukura Forest Reserve, governance, community involvement, sustainability

Introduction

The lack of stakeholder participation is among main challenges to the effective management of project areas (Negacz et al., 2022). Stakeholder engagement is a prerequisite to natural resource management since it leads to a) understanding of people's concerns and their solutions b) welcoming all kinds of knowledge (c) ownership of interventions d) reduction of potential conflicts and e) proper communication and coordination of activities (Darradi et al., 2005). Unfortunately, many protected areas don't involve local community groups or local residents (Negacz et al., 2022). This lead to the lack of knowledge about benefits of protected areas or creates contradictory interests among community groups, which in turn leads to conflicts (MacKinnon et al., 2020).

Participation is a good way of resolving conflicts from divergent interests among stakeholders (Héritier, 2010). Chen et al. (2021) revealed that protected areas management is complex and cannot be achieved by a single entity. In addition, participation is a good way to promote the development of protected areas and local actors (Chen et al., 2021). Coordination and cooperation

of stakeholders such as government authorities, private businesses and local community is needed. Furthermore, in order to achieve lasting outcomes, it is good to bear in mind that even community groups involved in participation procedures are not always homogenous (Héritier, 2010). They are different because of their divergent occupations, their economic status (rich versus poor), gender and age. Participation of every category is very important for the park to realize sustainable development.

Rwanda lies in the Albertine Rift which a major biodiversity hotspot and the most important region for biodiversity conservation in Africa (Plumptre et al., 2007). However, Rwanda is the second densely populated country in Africa, with a population density of 503 inhabitants/Km² as of August 2022 (NISR, 2023). The increase of population size has been cited as a leading cause of deforestation activities. Human population growth increased demand for agricultural land and other natural resources such as wood and timber, fodder and water (Umuziranenge et al., 2021). Because of that, Mukura forest has been reduced from 4,376.18 ha in 1984 to 1,987.74 ha in 2016 ((REMA, 2018). In this context, stakeholder's participation especially the local community is needed to reverse the trend.

This research was aimed at determining stakeholders involved in the management of Mukura Forest, how they participate, motivation for their participation, challenges and suggestions for future actions. Research participants were local leaders, local cooperatives and park managers.

Methodology

Study area description

Mukura Forest is part of the Gishwati-Mukura National Park, established in 2016 as Rwanda's fourth national park and is located in the western part of Rwanda within the Albertine Rift. Situated on the ridge dividing the Congo and Nile water catchment areas, the Mukura forest's elevation ranges from 2,000 to 3,000 meters above sea level (Musabyimana, 2015). This montane rainforest is home to a rich diversity of flora, including indigenous hardwoods and bamboo and fauna (Park, 2015). Mukura Forest has enormous threats such as deforestation, biodiversity loss, soil erosion, and landslides, which are mostly caused by intensive agriculture, overgrazing, and illegal mining operations. Local populations have traditionally relied on the park's resources for survival, contributing to environmental degradation (Bizimana & Hategekimana, 2016). To address these concerns, efforts are being made to encourage sustainable land management methods and provide eco-tourism infrastructure that balances conservation and community needs. Surrounding communities are suffering significant socioeconomic issues, such as inadequate access to social infrastructure and economic possibilities. This study was conducted in 3 sectors bordering Mukura Forest, Mukura and Rusebeya sectors in Rutsiro District and Ndaro in Ngororero district.

Data collection

The focus group discussion (FGD) was conducted with 12 cooperatives working within three sectors mentioned above. Ten among them do beekeeping and the other two are merely for

environmental conservation activities and they are composed by people who historically used to do illegal activities in the Park. The FGD was conducted with each cooperative separately. Each focus group was composed by 5-9 participants. To select participants, researchers called the president of the cooperative and request him to select between 5 and 9 people who are available to participate in the research. In addition, the FGD was held with 10 village leaders in the Mukura Sector (The village is the lowest administrative entity in Rwanda).

All FGDs took place at the Cell office, sector office or RDB office, depending on the nearest convenient place for most participants. Each FGD lasted between 40 minutes and an hour. Furthermore, 20 interviews were conducted with community members individually, selected from each focus group. 1-2 people were selected from each focus group for these individual interviews. The purpose of asking these people individually was to know the activities each individual person conducts himself or herself, not because his is part of a community group. Second, researchers wanted to make sure that there no information left out because of the fear of expression within the group. Lastly, key informants interviews were conducted with six local leaders at cell and sector level and two park staff. Before any focus group or interview is conducted, researchers clearly explained about the purpose of the research, that participation in research is voluntary and that anyone is allowed to withdraw from participating without any consequence. Researchers requested permission to record and in cases where recording was allowed, we recorded the talk with a mobile phone.

Results

Table 1. List of cooperatives which participated in the research

No	Name of cooperative	Main activity they do	Start date
1	Turengere ibidukikije	Environmental management	2024
2	KOTEREM	Bee keeping	2023
3	COELABERU	Bee keeping	2015
4	Imboni za Rusebeya	Bee keeping	
5	Twite ku bidukikije, Rukeri	Handcraft, poems and cultural songs	2022
6	Abishyizehamwe, Kagano	Bee keeping	2018
7	ANECO	Environmental management	2022
8	Inkuti za Mukura	Bee keeping	2022
9	Abakundinzuki, Mwendo	Bee keeping	2017
10	Imboni za Mukura	Bee keeping and pigs rearing	2021
11	Terimbere muvumvu, Ruhuha	Bee keeping	2019
12	Tubungabunge Mukura twiteza imbere	Bee keeping	2023

Who participate?

This study revealed that Rwanda Development Board (RDB), local leaders, community groups (cooperatives and associations working around the forest), general community members, security organs (District Administration Security Support Organ, locally known as DASSO and the National Police). Albertine Rift Conservation Society (ARCOS) also contribute to the forest management but through community development and agroforestry projects around the forest. Respondents testify that trees on their farmers reduce their dependence on the forest for firewood and timber.

How participate?

Local leaders participate through community mobilization, law enforcement and play a role in selecting projects to be funded by the revenue sharing program. One leader explained: *“Our role is to explain to the local community the importance of managing the forest. Another thing is to punish those who do illegal activities in the park. The other thing is community mobilization and show them the importance of the park, and the importance of managing the park. So just to explain that managing the park is like an investment. I show them how they can benefit from the park in different corners such as social, cultural, heritage, and economic development... Now we charge them 100,00 Frw of fines when someone enters the park illegally to collect resources”*.

Community groups participate by rehabilitating degraded areas in the forest, planting trees on their land to not depend on the forest for trees, raise awareness on forest conservation through community meetings, use arts such as poems and songs to raise awareness on the forest protection and information sharing in case of any illegal activity. One community member said: *“...for example, when we find illegal activities in the park, we call the park and also, we call the police and DASSO. Always these organs are ready to act accordingly. And when they intervene in such a quick manner, people get afraid and they say, oh, we cannot enter the park illegally because those security organs can convict us”*. Another member of the cooperative said: *“We plant trees because when you have your trees, you cannot go to the park to destroy it because you can no longer depend on the forest when you have your trees”*

Why participate?

Motives of participation are mainly grouped into 3 categories. **1) Ecological role of the forest:** Participants participate in the management of the forest because of its ecological role such as flood and erosion control, fresh air provision, water provision (through water sources), bees forage, habitat provision, climate regulation, wind break and rain making. One participant in the focus group discussion said: *“...the other benefit of the park is that it protects us from heavy rain because when, for example, the heavy rain comes and the forest is not there, the flood can destroy our houses and it can wipe away everything. But now we are happy that we have a healthy environment. We don't have erosion and no natural disasters are happening. We are free from all of those hazards because we have the forest”*. Another community member mentioned: *“This forest harbors animals which are only found in this forest in the whole world. Similarly, to plants. We are only missing infrastructures”*.

When speaking about fresh air provision, participants were referring to the cold air which regularly blows even during the sunny day. They believe that the area can turn hot if the forest is removed, hence, they are willing to conserve it. One person said: *“...you see the good air which is coming out from the forest. We hear news somewhere around the world people saying this area is facing hot temperatures, or they don't have rain. All of those are associated with the lack of forests, but now we have a forest here and we are grateful for it”*.

Regarding bee forage, respondents expressed thoughts on how the forest is important for their beekeeping activities. They all beekeeping cooperative members mentioned that they used to do their beekeeping activities inside the forest before it is designated a national park, together with its sister forest, Gishwati. Once the forest is declared a national park, the Rwanda Development Board (RDB) advised all beekeepers to put their beehives in the vicinity of the park, but not inside the park. Beekeepers agreed and they are grateful their bees can still access the forest for nectar collection.

2) Economic drivers: Local stakeholders are willing to conserve the forest because of economic benefits of the park including revenue sharing incentives, tourism potential and market for their products. One participant mentioned: *“as we become more developed I will buy even a car. For example, our cooperative received 2 million francs through the revenue sharing program”*.

3) Infrastructures: Respondents testify that some infrastructures were built because the forest is there. For example, a health center, a market and a honey collection center was built for the community. They are also expecting many more facilities. They are expecting tarmac roads, more health facilities and schools. One participant of the focus group discussion put it this way: *“People living in the vicinity of the park have been advised to protect it and some of those people around the park have got support from the revenue sharing program. And we are expecting many more things. Anyone who is living near the park will get a lot of benefits. Now, because it is approved as a national park, it's up to us to protect it by planting trees and we will get different infrastructures like roads. Another participant said: “The government agreed to build a health center for us because we used to pass through the forest to access the other health centers in Ndaro sector. Now, the health center has been approved and the land has been demarcated. Construction activities will start very soon but now no one will cross the forest to look for health care services.”*

Challenges to the conservation of the Mukura Forest

Human wildlife conflicts: Negative interaction between human and wild animals is still a problem in area. The most cited animal is an animal called “Impuhwe”. It is believed to be “Honey badger”, scientifically *Mellivora capensis*. It destroys the beehive, eat honey and bees. It was reported by all beekeeping cooperatives (n10). One participant: *“Impuhwe is very dangerous. When it comes, it urinates on its tail, wipe all bees, some of them fly away, these which don't fly away are eaten together with honey. And it cannot go away completely. It goes and comes back to look for another*

beehive to destroy and another one and another one'. The other key issue in human wildlife conflicts around the forest is the case of wild dogs which prey on livestock for local people and participants are still hesitating on whether they are from the forest or if they are wondering individuals in the community.

When asked about the compensation program, all beekeepers mentioned that it is not satisfying. It is costly to follow up, long, slow and people get relatively very low compensation in comparison to the actual value of the damaged property. Speaking about the case of Impuhwe one participant said: *"We buy a beehive with bees for 15,000 Frw and when the "Impuhwe" comes, it destroys the beehive, eat hone and bees. And if you start claiming for compensation, you go first to the cell office, then you go to the sector office, then go to the police office and then to Kigali. And at the end, they say that they will give you 20,000 Frw with the transport of 10,000 Frw. It is 10,000 frw to go to the cell office round trip. It is 4,000 Frw to go to the sector office roundtrip. Then another 10,000 Frw to Kigali roundtrip. Now it is 24,000 plus time spent during this claiming process. We took a decision to no claim to avoid further loss."*

Discussion

Findings of this study show that RDB, local leaders, local community and security organs are involved in the management of Mukura Forest and no NGO is involved directly to the Forest management. While participating actors are important, involvement of NGOs is also needed to ensure the sustainable conservation of Mukura Forest. According to Kusters et al. (2022), NGOs play a big role in forest management in terms of advocacy, promoting inclusiveness and strengthening the local capacity. Particularly, NGOs play a big role in training local people on key skills such as forest management techniques, vegetation stock analysis and the use modern conservation technology such as Global Positioning System (GPS) (Gupta et al., 2020).

Local stakeholders are willing to protect Mukura Forest because of its ecological role. Similarly, Kimengsi et al., (2019) found that stakeholders are motivated to participate because they are aware that forest play enormous ecological role. Stakeholders living around the forest have high local ecological knowledge despite their limited or educational background. This knowledge is necessary to keep them going even when economic benefits are not evident or is not enough. Research also shows that some communities are willing to protect the forest for future generation, in such a way that actors commit themselves to inherit the forest to the next generation in the same condition as their ancestors provided it to them (Kimengsi et al., 2019, Acheampong et al., 2018).

The other key factor which is the most important for local stakeholders' participation in the forest conservation is economic benefits such revenue sharing incentives and market for their products. This is consistent with findings by Dolisca et al., (2006) who showed that people who get more benefits from the forest are more likely to participate in its conservation. These authors further suggest that providing opportunities to local stakeholders to increase incomes is the most important factor in stimulating participation. Without economic improvement opportunities for local people

to benefit from the forest, it is nearly impossible to get them involved in forest management (Wunder, 2000).

Among other economic benefits of the forest, the tourism revenue sharing program was reported to be successful in motivating local people to participate in conservation activities. Snyman et al., (2023) revealed that 95% of respondents who were involved in the revenue sharing program reported that it increased community support for conservation. However, the tourism revenue program is only designed to support community groups or general infrastructures such as roads, health facilities or school, not individual people (Munanura et al., 2016). This is probably because it is very difficult to ensure accountability of individual people regarding the use of the grant.

Findings of this study show that the local community use agroforestry as a tool to reduce their dependence on the Mukura Forest. Trees on farm play a big role in biodiversity conservation through three different ways: (i) suitable habitat provision for forest species which had previously suffered from deforestation (ii) make a landscape matrix that allows the movement of forest species among patches; (iii) and the provision of alternative livelihoods for the local community, which in turn relieve pressure on the remaining forest (Gardner, 2022). Agroforestry systems (AFS) deliver (1) provisioning services such as food, energy, and fodder; (2) regulatory services such as microclimate regulation, erosion control, desertification mitigation, carbon sequestration, pest control and floods control; and (3) supporting services such as soil fertility improvement, biodiversity conservation, and pollination (Sileshi et al., 2007). Native trees in agroforestry systems especially play a vital role in sustaining rural livelihoods through different products and services they can offer (Dhanya et al., 2014).

A key challenge in the Mukura forest conservation reported by respondents is human wildlife conflicts and if it is not addressed well, it deters the local community to conserve the park since this issue threatens the community livelihood (Kimengsi et al., 2019). This problem was also reported around Nyungwe National Park where wildlife animals cause economic losses through crop raiding (Umuziranenge, 2019). Later in 2021, the same author found out that wild animals not only raid crops but also carnivorous attack livestock. In the worst cases community members revenge by killing animals involved (Umuziranenge et al., 2021).

Unfortunately, victims of human wildlife conflicts complain about the ineffectiveness of the compensation program. The process is long, slow, expensive and victims of the loss are paid less than what they lost (Umuziranenge, 2019). This problem was also reported in Kenya and claims are exactly the same (MacLennan et al., 2009). Moreover, human wildlife problems and the ineffective compensation scheme goes with hidden costs, which affect the social, psychological, health and economic wellbeing of affected people (Karanth et al., 2018). For example, some people including school children are forced to guard their crops, which reduces school attendance (Umuziranenge, 2019).

Conclusion and recommendations

This study shed light on who is involved in the management of Mukura Forest, why, how and explored existing challenges to the conservation of the park. The study demonstrated that RDB, local leaders, community groups, wider community members and security organs play a role in the forest conservation. Stakeholders conserve the forest because of ecological services provided by the forest, economic benefits and infrastructure development associated to the existence of the forest. Stakeholders play different roles: Local leaders, security organs and RDB mostly participate by law enforcement and community mobilization. Community groups and general community members participate through tree planting on their farms as part of agroforestry, forest rehabilitation through tree planting and refilling pits created through illegal mining. The key emergent challenge to park conservation is human wildlife conflicts, and there is no straightforward solution to this problem. This study recommends:

- 1) Participatory governance for effective conservation of Mukura Forest
- 2) Provide training to local beekeeping cooperatives on modern beekeeping to increase the quantity and quality of the honey production around the Mukura National Park and mitigate bees predation problem
- 3) Tourism development (hiking, camping...) for revenue sharing
- 4) Community development projects for poverty alleviation (community work, cultural centres...)
- 5) Alternative source of fodder and firewood such agroforestry and planting of fodder grasses in farmlands of local people
- 6) Advocate for the infrastructure development (roads....)
- 7) More research about community development and biodiversity of Mukura
- 8) Concerned, actors need to discuss how the compensation scheme can be improved to better serve victims of human wildlife conflicts
- 9) NGOs and private companies are encouraged to join a network of stakeholders who manage the Mukura Forest directly
- 10) Conduct a study on how to reduce human wildlife conflicts around the Forest.
- 11) Extra funding is needed to expand biodiversity assessment to cover the entire forest and publish the findings in a peer-reviewed journal

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