THE STATUS OF BIODIVERSITY IN ECHUYA CENTRAL FOREST RESERVE, SW UGANDA

By

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A Report to Nature Uganda

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Executive summary

Uganda is losing biodiversity at an alarming rate. Habitat change and direct exploitation by humans are among the most important reasons for this crisis. Forest wildlife is particularly affected with a need for harmonious living through collaborative forest management.

This report focuses on the current status of biodiversity in Echuya Central Forest Reserve, SW Uganda. The taxa assessed were the large and small mammals, birds, and plants (trees, shrubs and herbs). Large mammals were surveyed using the camera trapping method, while for small mammals we used Sherman traps, birds were recorded using point counts and mist-nets, and plants were assessed using plots along randomly selected transects. The survey was done in June 2015 for 15 days while the large mammal survey took 30 days. Information on human activities was collected by both camera trapping and transects method.

Except for birds, the other taxa are at a very low diversity in Echuya CFR. Ten species of mammals, including humans, were recorded. Human activities were recorded as the most prevalent at 17 of all 27 sites (contributing to 63% of all the surveyed areas). Dogs, cows and goats were also recorded as signs of human presence. The African Giant Pouched Rat (*Cricetomys gambianus*) was the most recorded non-human mammal species. Three medium sized carnivore species also recorded were the African Golden Cat (*Caracal aurata)*, Serval Cat (*Leptailurus serval)* and the Side-striped Jackal (*Canis adustus)*. Ten species of small mammals were recorded. Many of these species were forest-dependent species. Three Albertine Rift endemics were recorded: rodents - *Lophuromys woosnami* and *Delanymys brookski* and shrew *Ruwenzorisorex suncoides*. *Delanymys brookski* is a rare Albertine Rift endemic restricted to montane swamps in the Kigezi area of Uganda and the bordering areas of DR Congo and Rwanda. The most abundant small mammal species were *Lophuromys flavopunctatus* and *Mastomys natalensis.*

A total of 94 species of birds were recorded for the whole forest of which 15 were Albertine Rift endemics. Because of the forest harboring a substantial number Albertine Rift endemics and

globally threatened bird species, it has made the forest a biodiversity hotspot in terms of species rarity both nationally and within the Albertine Rift.

A total of 20 species of trees ≥10cm dbh were encountered in the whole forest. All the tree species encountered were early pioneers or ‘secondary’ species and late ‘secondary’ species implying that Echuya is a secondary forest. *Macaranga capensis* was the most dominant tree occurring in 65% of the sites surveyed. Seventy two species of herbs and 46 of shrubs were encountered in the whole forest.

None of the taxa was completely inventoried, as their species accumulation/rarefaction curves never reached asymptote values. This indicated that more species of each taxa are likely to be encountered with more sampling effort.

Human activity signs were encountered on 60 out of the 122 sites sampled. Human activity is nearly evenly distributed in the whole forest. Most the activities encountered were; cultivation (gardens) inside a natural forest, cutting of bamboo stems, trees, grazing of livestock and footpaths crossing all through the reserve.

There was no relationship between the species assemblages and the measured environmental variables. The environmental variables include slope angle and aspect, slope position, vegetation type, forest cover/canopy openness, altitude, distance from forest boundary, and human activity occurrence. This indicates that species assemblages of each taxa were not habitat specific.

Recommendations made after this study include; the zoning of Echuya CFR into different management zones with strict enforcement of the Strict Nature Reserves, the involvement of the local communities in the enforcement of the nature reserves e.g. using the local councils and the need for more intense biodiversity surveys of same sites that are likely to reveal more species since this study was limited in time and labor for such surveys.

1. Introduction

Echuya forest was first gazetted with its original boundary description as an undemarcated crown forest of 16 square miles in the Laws of Uganda (1951) by Legal Notice 257 of 1939. After demarcation the gazetted area was amended by Legal Notice 245 of 1947, to 15.21 square miles. All Crown Forests in Uganda were then regazetted as Central Forest Reserves in Legal Notice 41 Notice 324 of 1948. Echuya forest was regazetted by Statutory Instrument No. 11 of 1963, which was amended by Statutory Instrument 206 of 1964. All these regazettement events reflect the forest cover loss events that started then and are still prevalent up to date.

Echuya CFR has 20 percent of its area situated in Bufumbira County in Kisoro District and the remaining 80 percent in Rubanda County in Kabale District. The southern end runs along the north-eastern border of Rwanda (Figure 1). It lies between 1°14´ – 1°21´S and 29°47´ – 29°52´E, covers an area of 34 km^2, with an altitudinal range of 2270 – 2750 m. It is situated on a high altitude ridge running between Lake Bunyonyi, 5 km to east, and Mgahinga Gorilla National Park, 13 km to the south west. It is 11 km east of Kisoro Town. The main Kabale to Kisoro road passes through the northern end. The forest is covered by Uganda Department of lands and Survey map sheets 93/2 and 93/4 (series Y732) at 1:50,000.

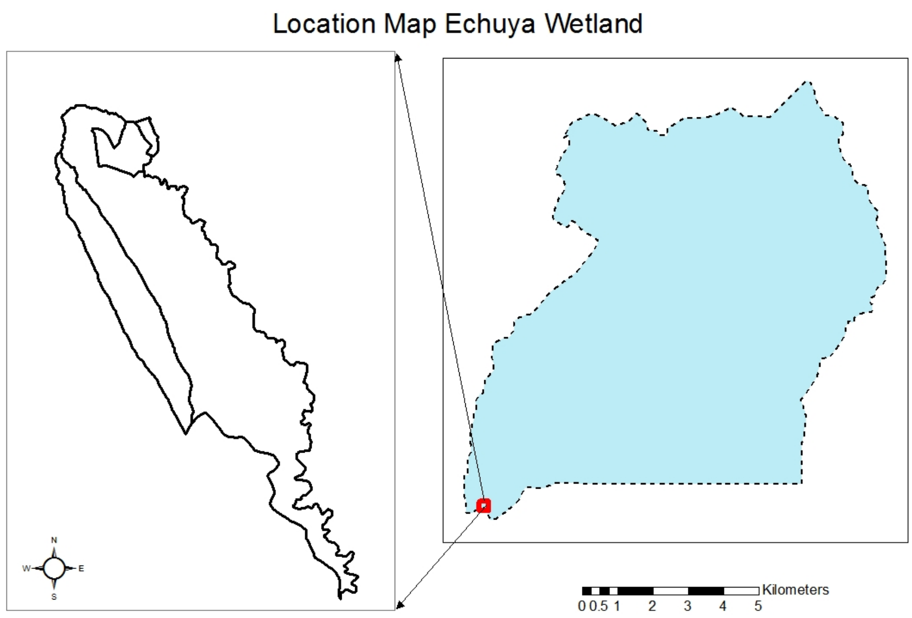


Figure 1 Location of Echuya Central Forest Reserve S.W Uganda

Banana and Tweheyo (2001) describe Echuya as dominated by bamboo, *Sinarundinaria alpina*, and where this is less dense there are woody and herbaceous plants. There are areas of broad leaved forest trees, particularly along the eastern side and at higher altitude northern end, north of Kabale to Kisoro road. The forest also contains the large Muchoya Swamp that runs north to south along the centre of the reserve and drains it to the south. The reserve is surrounded by densely populated agricultural land.

Geologically the area is associated with up warping of the western rift valley, and its underlying rocks are generally phyllites and shales, with some quartz, quartzite and granitic outcrops of the Karagwe-Ankole System. The soils are predominantly humic red loams, moderately to highly acidic and deficient in bases. The climate is tropical with two rainfall peaks from March to May and September to November. Annual mean temperature range, minimum: 7-15°C, maximum: 20-27°C. Annual rainfall: 1,400-1,900 mm.

Echuya Central Forest Reserve (ECFR) is a unique Afromontane habitat and an area of high endemism (Plumptre *et al.,* 2003). However, high human population density, extreme poverty and heavy dependence on forest resources by neighboring communities exert immense pressure on the forest reserve. Based on existing literature, Plumptre *et al.* (2003) compiled the known species' information for seven taxa in ECFR. The same study also reported intense human illegal activities, which were associated with changes in habitat structure and declining trends (and loss) of flora and fauna species.

1.1 Study Rationale

Only few biodiversity status studies have been carried out in ECFR; these include those of Davenport et al. (1996) and Plumptre et al. (2003). The former study was based on field surveys while the latter was based on published and unpublished literature sources. Plumptre et al. (2003) does not provide species lists for the forest but only compares it to the others in the Albertine Rift in terms of species rarity. Even then, twelve years later, we need to understand the changes in biodiversity that could have taken place as a result of anthropogenic perturbations. Other published studies have been on specific taxa and/or aspects of ECFR and include those of Byaruhanga et al. (2001) and Marks, Gnoske and Ngabo (2003) on birds, Banana and Tweheyo (2001) on vegetation changes with specific reference to trees and bamboo and Bitariho and McNeilage (2007) on bamboo population structure.

Nature Uganda has been implementing several community based conservation initiatives since 1998 to curb illegal activities, promote sustainable use of natural resources and enhance biodiversity recovery in ECFR. Six years ago, another of the Nature Uganda's Echuya Forest Conservation Project was introduced with a number of interventions. These included, collaborative forest management, livelihoods and income generating projects, illegal activity monitoring by the local people and forest managers and soil conservation measures. All these activities are geared towards the conservation of biodiversity in Echuya. These and other dearth of data/information highlighted previously was therefore the basis for this study. There was therefore a need to assess the status of biodiversity twelve years since the last assessments were done and after the introduction of new conservation initiatives by Nature Uganda. We filled this gap by conducting a survey of major taxa in Echuya thus.

2. Overall aim and Study Objectives

Overall, the study assessed the current status of biodiversity, the effect of anthropogenic related threats on biodiversity and the impact of sustainable forest management interventions in and around Echuya. The specific study objectives were to:

- Determine the species richness of terrestrial vertebrates (small and large mammals), birds and vegetation (trees, shrubs and herbs) in ECFR
- Review past surveys done on the taxa
- Determine the forest structure and regeneration status of ECFR after objective 1 above
- Document distribution of selected species within Echuya, in relation to human disturbance

3. Materials and Methods

3.1 Large mammals diversity and distribution

We used camera traps to assess the large mammal community composition of Echuya Forest Reserve. Our choice of camera trapping for this study was based on the fact that they provide a non-invasive way of surveying and detecting elusive wildlife, that would otherwise be impossible to survey with other methods (Ahumada, O'Brien & Mugerwa 2015).A camera trap survey was conducted between June to July 2015. Twenty seven camera traps were set at 27 random sites (Figure 2), predetermined using regularly spaced points on a 1x1 km grid overlaying a map of Echuya. The camera traps were thus distributed at a density of one camera per km^2. Specific sites for camera placement were selected using pre-defined GPS-coordinates and in situ-assessment of present active animal paths and activity (Mugerwa et al. 2013). The camera trap grid covered an elevation of between 2200 to 2500 m. Camera traps were set along active animal trails to maximize animal detection on camera traps. Camera traps were attached on trees at a height of 20-50 cm from the ground. This sitting was adequate to capture small-large terrestrial mammals (TEAM Network 2009; Mugerwa et al. 2013). We used the DLC white flash camera traps (www.scountingcameras.com) that take color pictures day and night. Camera traps were set with motion sensor on and with a one second interval between consecutive images. The picture quality was set at 5MP. Date and time was also recorded for each image. Mammal identification and taxonomy from camera trap pictures followed Kingdon (1997) and Wilson & Reeder (2005) respectively.

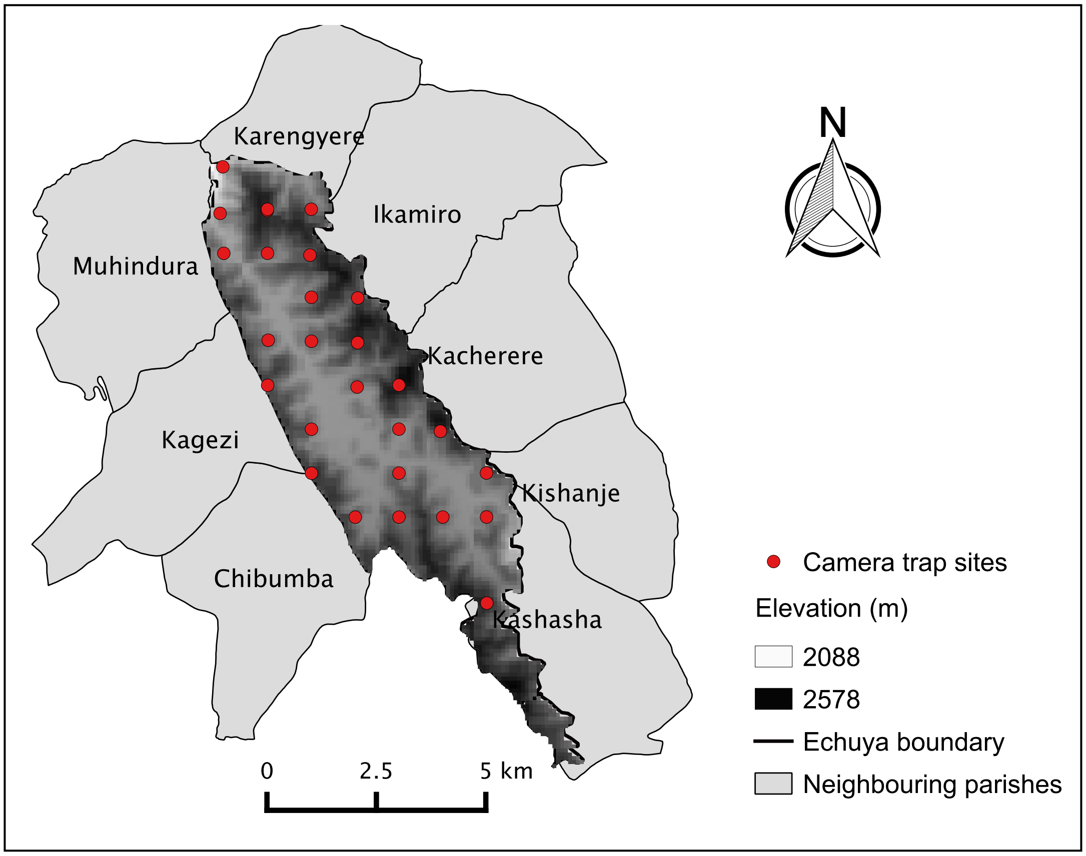


Figure 2 Map showing camera trap locations with elevation in Echuya and the adjacent parishes

3.2 Small mammal, bird and plant diversity and distribution

The field methods were aimed at obtaining qualitative rather than quantitative data, with emphasis on species richness and associations rather than on population densities. Five transects of varying lengths were laid in the forest with the first one being chosen randomly and the rest systematically. The direction of the transects was determined by the terrain of the forest so that they cut across the ridges in a straight line so as to capture expected rapid transitions in vegetation types and environmental gradients based on topography and forest boundary to the interior. Sample sites were purposely set in valleys, mid slopes and ridge tops along the transects so that the distances between the sites were variable. At each site, location geographic coordinates using a Global Positioning System (GPS) and environmental variables – vegetation type (pure bamboo, mixed bamboo, broad leaved forest, swamp, herbaceous and pine plantation), altitude measured with an altimeter, slope steepness measured with a clinometer, slope position (valley, midslope, and ridge top), slope aspect measured with a compass while facing down the slope and canopy openness measured with a densiometer were recorded. Any form of human activity sign observed within the sample plot was also recorded. Straight line distances of each plot from the nearest forest boundary were determined using the measuring tool in ESRI ArcGIS 9.3.1. Each site was visited by three teams – botanical, small mammal and ornithological in succession.

At each site, trees (≥10cm dbh) were identified, enumerated and their dbh measured in 100 sq. m plots. Shrubs and herbs were sampled in a 5×5 m, and in a 2.5×2.5 m plots respectively nested within the larger 10×10 m plot for trees. All the plants were identified to species level.

A team focusing on small mammals visited the same points as the botanical team. Trapping of rodents was done one day after the transects were walked by botanists to reduce the possible deleterious effects, any noise and movements made by the botanical team would have on trap success. At each sample site, 13 Sherman live traps were set once. Traps were baited with ground nut butter and over ripened, mashed yellow bananas. The traps were set between 0800 and 0900 in the morning and checked the next day at the same time. Each trapped animal was weighed, measured, sexed and its reproductive condition assessed. All the external attributes such as fur colour and texture, back colour of fore and hind foot, whisker and other physical features were recorded. Samples were identified to the species level following Delany (1975) nomenclature.

A team focusing on birds visited the same points as the botanical and small mammal teams. Counts of birds were made two days after the transect was walked by mammalogists and botanists to reduce the possible deleterious effects any noise and movements made by other teams would have on observations of birds. At each sample site, a point count was undertaken from a fixed location for a period of 10 minutes between 7 and 10 am. On arrival at each point-count site, the team would wait for about three minutes before beginning to count to allow the birds to settle down. All birds seen, heard or flying over were recorded. The team endeavored to count each individual only once at each site.

Additionally, six mist nets of 12–14m were set at each sample point by 8am and closed by midday. They were checked every 15 minutes and birds found in the nets were identified and then released. Because of time and personnel constraints, mist nets were only set in sample sites located in valleys.

3.3. Data analysis

3.3.1 Large mammals diversity and distribution

Species data from all camera sites was collated into Microsoft Excel spreadsheets. The data was then imported into R software package “rich” for species richness estimation (Rossi 2011). A rarefaction curve was generated to determine the average number of randomized species richness for our sampling intensity. A thousand (1000) runs were run for all randomizations. The resultant species accumulation curve was plotted using the package "ggplot2".

3.3.2 Modeling human activity occurrence and species habitat selection

Resource Selection Functions (RSFs) is an increasingly employed approach in predicting species habitat selection in relation to selected predictor variables (hereafter “covariates”). RSFs combine GIS data (covariates) and used (presence) as well as available animal locations data to develop spatially explicit predictive resource selection models (Montgomery et al. 2013, 2014).

3.3.3 Preparing covariates’ data

The covariates included; environmental factors (elevation, slope aspect, slope angle, forest cover, distance from forest boundary) and human activity occurrence. Data for the environmental covariates was downloaded as raster files from the internet and extracted using selected modules in GRASS (http://grass.osgeo.org/) version 7.1 open source GIS software. The covariates’ data was downloaded as raster files were; the Shuttle Radar Topography Mission (SRTM) (http://glcf.umd.edu/data/srtm/) and Landsat Tree Cover (http://glcf.umd.edu/data/landsatTreecover/). Both the SRTM and Landsat tree cover raster files were downloaded at 90 m resolution. Using specialized modules in GRASS (Table 1); elevation, slope aspect and slope angle data was derived from the SRTM raster file. The human activity occurrence was generated using records of humans and their commensals (dogs, cows and goats) on camera traps to generate their relative likelihood of occurrence. Forest cover, slope angle and distance from forest boundary were used as predictor variables to generate the human activity occurrence. Data on distance from forest boundary was generated using the r. cost module of GRASS and the MMQGIS plugin of QGIS version 2.8.2-Wien (www.qgis.org, Development Team, 2014). All covariate data from raster files was extracted using the QGIS plugin "Zonal statistics". We used each mammal species' observation point as "used response variable", and generated random "available points" using a 4:1 ratio (4 "available" points for each "use" point; Montgomery et al. 2013, 2014). We assumed that all area within a buffer of 1 km diameter around each camera trap site is available to species. We therefore created a 500 m buffer around each "use" location. All covariates were selected based on expert knowledge of the forest boundary by resource selection of the species.

Table 1 Summary of predictor variables and GIS methods for transformation

Covariates	GRASS module	QGIS plugin
Distance from forest boundary (km)	r.cost	MMQGIS
Forest cover (%)		Zonal statistics
Slope angle	r.slope	Zonal statistics
Slope aspect	r.aspect	Zonal statistics
Human activity occurrence	RSF	Raster calculator, then Zonal statistics

3.3.4 Predictive models for human activity occurrence and species' habitat selection

For this analysis, Echuya is considered to be available for the mammal species with different relative probability of use. We assumed that the mammals select some habitats and environmental features over others. Predictive models were generated using a Generalized Linear Model (GLM) logistic regression based on a RSF, comparing used and available habitat. GLM's with a binomial error distribution were used. Prior to implementing the models, all the continuous predictor variables were z-transformed to a mean of zero and a standard deviation of one to remove the influence of different units of the predictors (Schielzeth 2010).

The "drboundary" function in "MuMin" package version 1.10 (Barton 2014) was used to compute all possible models. Models were later sorted based on a cut-off of Akaike Information

Criteria for small samples (AICc) value of less than 2 (AICc <2) ("candidate models", Burnham & Anderson 2002). The response variable was the "use/available", where 1 represented used mammal's locations and 0 the randomly generated available points. The predictor variables were the covariates. Since none of the candidate models achieved a high AICc weight (>0.9), we performed model averaging to generate the beta coefficients of covariates together with their relative importance. The averaged model coefficients of the three most important covariates together with their raster files were then entered into the QGIS's "raster calculator" command to generate the likelihood of habitat use (ranges between 0 and 1; where 0 is no occurrence and 1 is complete occurrence). The generated likelihood of occurrence was later converted into the predicted habitat selection using the equation:

$$\frac{2.7183\hat{}A}{(1+(2.7183\hat{}A))}$$

Where; A is the predicted likelihood of occurrence = $B_0 + (B_1X_1) + (B_2X_2) +..+ (B_nX_n)$, B_0 is the intercept, B_n is the estimated coefficient for covariate X_n, and X_1, X_2 and X_n are the predictors. 2.7183= e^A value as QGIS does not currently perform e^x.

The responding predicted habitat selection was then generated in QGIS. All statistical tests were performed at 5% level of significance in R (R Development Core Team, 2014- http://www.R-project.org

3.3.5 Plants, birds and small mammals diversity and distribution

Species data was coded as number of individuals for trees and present/absent for shrubs, herbs, small mammals and birds sampled at each sample site. For each taxa, we estimated the species richness and diversity for each sampled site, plotted a species accumulation curve, described the pattern of species composition across the sampled sites using the Principal Coordinates Analysis (PCoA) and related the variation in species composition across sites to categorical environmental variables (slope position, vegetation type, and human activity) using Analysis of Similarities (ANISOM) and quantitative environmental variables (slope angle, slope aspect, canopy openness, and distance from forest boundary) using a Mantel test. All statistical analyses were performed using R open source statistical software version 3.2.1 (R Core Team 2015) with add-on package Biodiversity.R 2.5-3 (Kindt and Coe 2005).

4.0 Results

4.1 Large mammals diversity and distribution

From the expected total camera days of 810 camera days (27 sites sampled for 30 days each), we collected data for a total 667 camera days. This is because one camera trap was stolen during the survey. The average number of sampling days per camera site was 24±0.67 (mean ± standard error of the mean) camera days. We recorded 1255 images belonging to ten species of mammals. Humans were the most recorded mammal at 17 of 27 sites, hence the highest naïve occupancy value. Dogs, cows and goats were also recorded as signs of human presence. The giant African pouched rat (*Cricetomys gambianus*) was the most recorded non-human mammal species. Three medium sized carnivore species were recorded; the African golden cat, Serval cat and the Side Striped Jackal. A summary of species, the number of sites where they were recorded and their respective naïve occupancy is given in Table 2.

Table 2 Recorded species at Camera trap sites in Echuya Central Forest Reserve

Animal	Genus	Species	No. of sites	Naïve occupancy*
Humans	*Homo*	*Sapiens*	17	0.63
Giant African pouched rat	*Cricetomys*	*Gambianus*	12	0.44
Servaline genet	*Genetta*	*Servalina*	6	0.22
African golden cat	*Caracal*	*Aurata*	4	0.15
Blue Monkey	*Cercopithecus*	*Mitis*	2	0.07
Mash cane rat	*Thryonomys*	*Swinderianus*	2	0.07
Meadow rat	*Myomys*	*Fumatus*	2	0.07
Cow	*Bos*	*Taurus*	1	0.04
Dog	*Canis*	*Lupus*	1	0.04
Goat	*Capra*	*Aegagrus*	1	0.04

Serval cat	*Leptailurus*	*Serval*	1	0.04
Side striped jackal	*Canis*	*Adustus*	1	0.04
Slender mongoose	*Herpstes*	*Sanguinea*	1	0.04
Target rat	*Stochomys*	*Longicaudatus*	1	0.04

The species are listed in order of decreasing number of sites where they were recorded. Naïve * Computed as the number of sites where the species was recorded divided by the total number of sites (N=27) and is a surrogate of species abundance (Rovero & Marshall 2009; Ahumada et al. 2011)

4.1.1 Species richness estimation of large mammals

A cumulative species richness of eleven species of terrestrial mammals was estimated for Echuya with a mean value of 2.18 species per site. The rarefaction curve of terrestrial mammal species did not reach an asymptote (Figure 3). The rarefaction curve was estimated by the Jackknife1 species richness estimator**.** The curve did not reach asymptote, stopping at around 9 species for mammals.

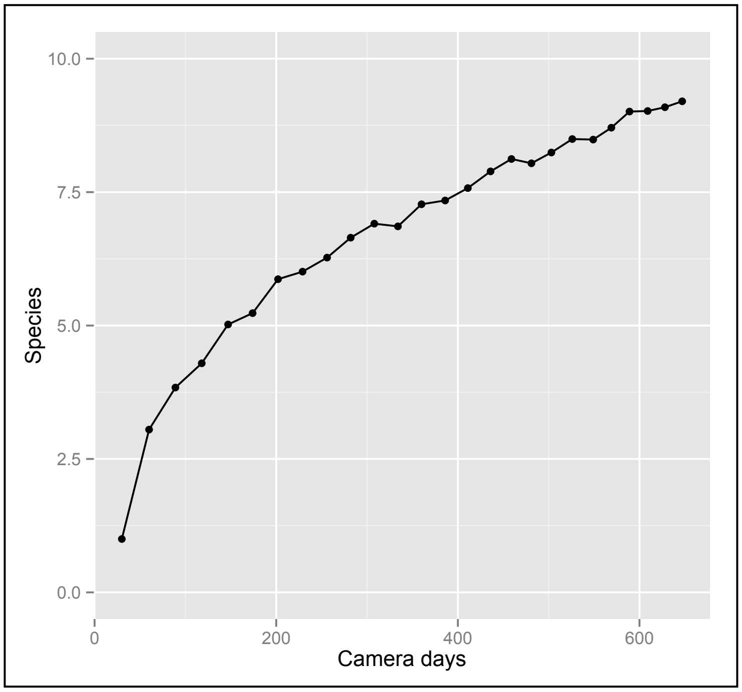


Figure 3 Rarefaction curve showing species accumulation with sampling effort (camera trap days) for the mammal species detected by camera trapping in Echuya

4.1.2 Human activity occurrence prediction

None of the considered covariates showed significant relationship with human activity occurrence. However, the averaged model coefficient and covariate importance values showed that slope angle, slope aspect and forest cover (Table 3) were the most important factors predicting human activity occurrence in Echuya, all appearing in 4 candidate models. The predicted likelihood of occurrence of human activity in Echuya is shown in Figure4. The relationships between human activity occurrence and considered covariates are graphically shown in Figure5.

Table 3 Model averaged coefficients from the binomail GLM predicting human activity occurrence in Echuya

	Estimate	Std. Error	Adjusted SE	z value	[1]Pr (>|z|)	Significance
(Intercept)	-1.42	0.27	0.28	5.15	<0.0001	***
Slope angle	**0.38**	**0.29**	**0.29**	**1.28**	**0.20**	
Forest cover	**0.35**	**0.29**	**0.29**	**1.21**	**0.23**	

Distance from forest boundary	0.25	0.30	0.31	0.80	0.43	
Slope aspect	**-0.05**	**0.27**	**0.27**	**0.18**	**0.86**	
Elevation	0.02	0.27	0.27	0.08	0.94	
Significance codes:	0 '***'	0.001 '**'	*' 0.01 '*'	0.05 '.'	0.1 ' '	1
Relative variable importance:						
	Slope angle	Slope aspect	Forest cover	Distance from forest boundary	Elevation	
[2]Importance:	0.41	0.39	0.3	0.06	0.06	
[3]N containing models:	4	4	4	1	1	

Where; [1]the probability test value, [2]the probability that a given covariate will appear in the best candidate model, and [3]the number of models in which a given covariate appears. The best predicting covariates for mammal habitat selection is shown in "bold".

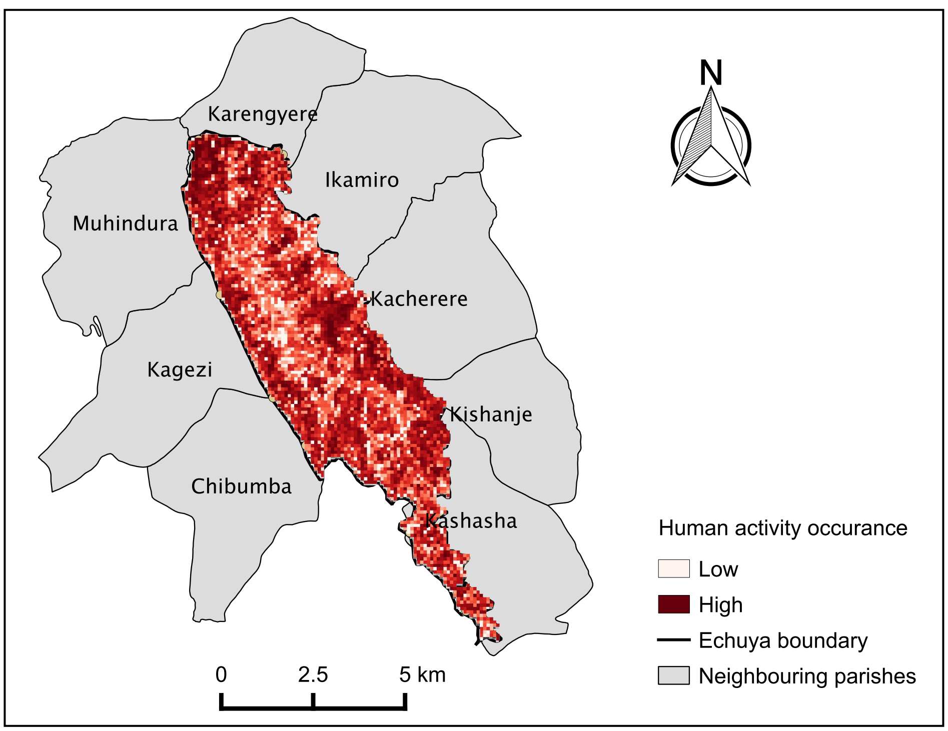


Figure 4 Predicted likelihood of human activity occurrence in Echuya

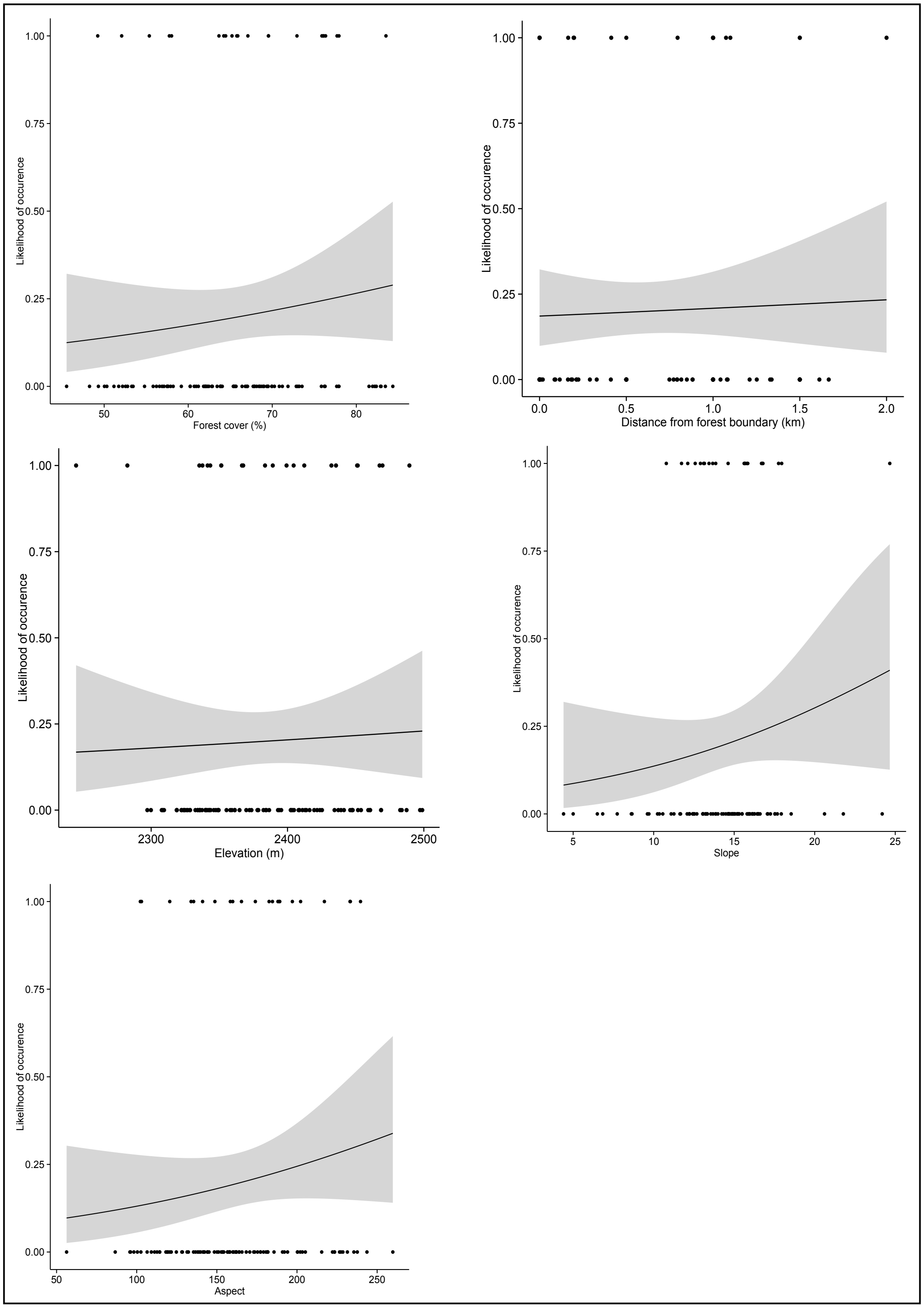


Figure 5 Relationships between human activity occurrence and considered covariates. On the Y-axis is the likelihood of human activity occurrence, and on the X-axis is the covariate (starting from left upper corner)

4.1.3 Predicted large mammal habitat selection

Habitat selection by Echuya mammals was positively related to all the considered covariates. However, none of the relationship was statistically significant (Table 4). All the considered covariates were not significantly associated to habitat selection of Echuya mammals. However, slope angle, slope aspect and forest cover were identified as the most important predictors of mammal habitat selection in Echuya, appearing in 5, 3 and 3 candidate models respectively (Table 4). The predicted habitat selection of mammals in Echuya is shown in Figure 6, and its relationships with covariates in Figure 7.

Table 4 Model averaged coefficients from binomial GLM predicting mammal habitat selection in Echuya

	Estimate	Std. Error	Adjusted SE	z value	[1]Pr(>|z|)	Significance
(Intercept)	-1.41	0.24	0.25	5.71	<0.0001	***
Slope angle	**0.34**	**0.26**	**0.26**	**1.30**	**0.20**	
Slope aspect	**0.30**	**0.24**	**0.24**	**1.22**	**0.22**	
Human activity occurrence	0.26	0.27	0.28	0.96	0.34	
Forest cover	**0.21**	**0.25**	**0.25**	**0.86**	**0.39**	
Distance from forest boundary	0.17	0.27	0.27	0.63	0.53	
Elevation	0.08	0.24	0.24	0.35	0.73	
Significance codes:	0 '***'	0.001 '**'	*' 0.01 '*'	0.05 '.'	0.1 ' '	1

Relative variable importance:

	Slope angle	Slope aspect	Forest cover	Human activity	Distance from forest boundary	Elevation
[2]Importance:	0.42	0.27	0.2	0.16	0.12	0.05
[3]N containing models:	5	3	3	2	2	1

Where;[1] the probability test value, [2]the probability that a given covariate will appear in the best candidate model and [3]the number of models in which a given covariate appears. The best predicting covariates for mammal habitat selection is shown in "bold".

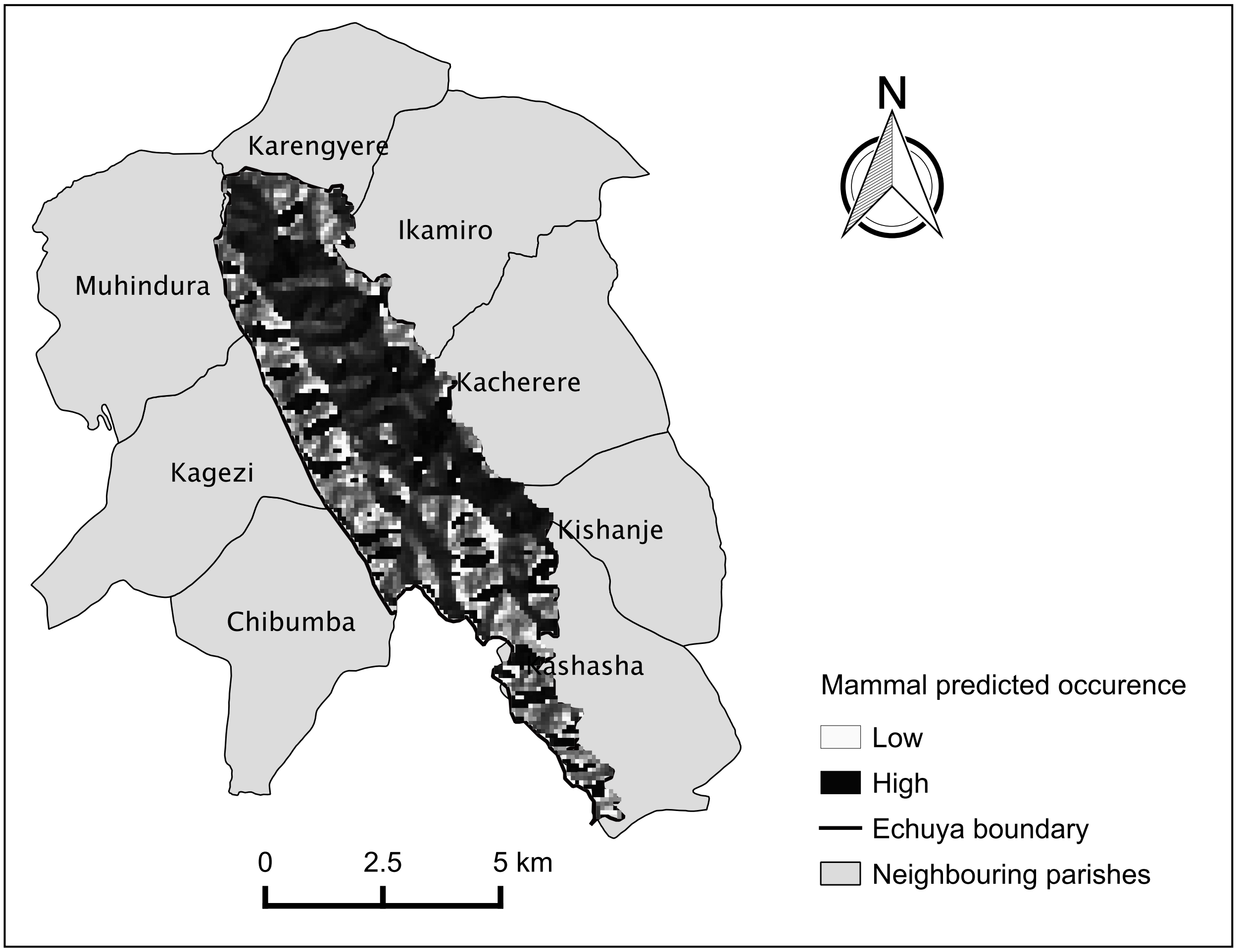


Figure 6 Predicting habitat selection of terrestrial mammals in Echuya

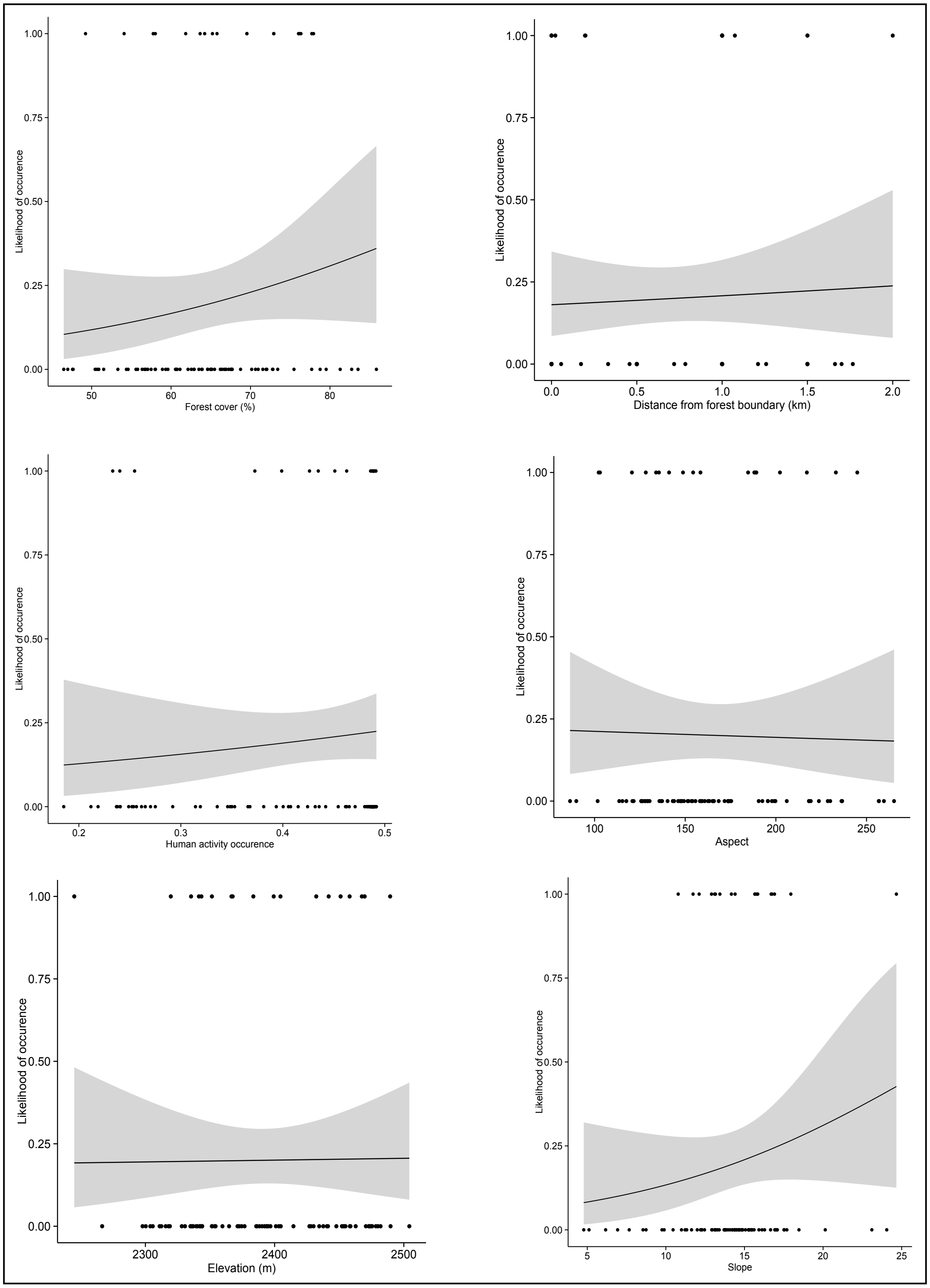


Figure 7 Relationships between mammal habitat selection and covariates. Y-axis = the likelihood of habitat selection, X-axis is the covariate

4.2 Environmental variables along the transects

A total of 122 sites were sampled along five transects. Majority of the sites (75) were in the most dominant vegetation type – the broad leafed trees, 13 in mixed bamboo, 21 in the herbaceous, 7 in pure bamboo, 4 in the swamp and only one in pine plantation. One sample point had bare ground with no vegetation cover. The altitudinal range of the sites ranged from 2,130 to 2,530m asl, slope steepness averaged 18°, 60 sites were in mid slopes, 32 sites on ridge tops while 30 were located in valleys. Slope aspect of the sites averaged 145°. The mean canopy openness of the sites was 89.9% and distance of the sample sites from the forest boundary averaged 825 m with the nearest plot to the forest boundary being at a distance of 1.5 m while the furthest from forest boundary was at a distance of 2,163 m.

4.3 Small mammal diversity and distribution

Rodents were sampled along two transects with 58 sample sites. However, rodents were encountered at only 35 sites. Seventeen sample sites were located in the most dominant vegetation type – the broad leafed trees, 6 in mixed bamboo, 5 in herbaceous, 6 in pure bamboo and 1 in a swamp. The altitudinal range of the sites was from 2,200 to 2,530m asl, slope steepness averaged 15°, 16 sites were in mid slopes, 11 sites on ridge tops while 8 were in the valleys. Slope aspect of the sites averaged 143°. The mean canopy openness of the sites was 88.6% and distance of the sample sites from the forest boundary averaged 1,306 m with the nearest plot to the forest boundary being at a distance of 3.1 m while the furthest from forest boundary was at a distance of 2,162 m. Human activity signs were encountered in more than half of the rodent sample sites with bamboo harvesting being the most commonly encountered type of human activity sign.

4.3.1 Species richness and diversity of small mammals across sites

Ten species of rodents and one shrew species were encountered (Table 5). The small mammal species diversity was high in sites on the western and eastern boundaries in the north of the forest (Figure 8). This trend was not repeated on transect located south of the forest. Species richness per site varied from one to four while the Shannon diversity varied from zero to 1.4. The most widespread species were the Harsh-flurred Mouse (*Lophuromys flavopunctatus)* and Multimammate Rat (*Mastomys natalensis).* Two Albertine Rift endemic species – Delany's

Mouse (*Delanymys brooksi*), Woosnam's Brush-flurred Rat (*Lophuromys woosnami*) and Osgood's Montane Shrew (*Rwenzorisolex suncoides*) were found. Osgood's Montane Shrew is vulnerable to extinction according to the IUCN.

Table 5 Rodent and shrew species recorded in Echuya CFR in June 2015

Species	**Habitat type**	**IUCN Category**	**Albertine Rift endemic** (AR)
Rodents			
Dasymys incomtus	Swamp open habitats		
Delanymys brooksi	Aquatic/swamp (highland)		AR
*Hybomys unvittatus**	Closed forest		
Lophuromys flavopunctatus	Widespread		
Lophuromys woosnami	Forest boundary (highland)		AR
*Mastomys natalensis**	Open/grassland		
*Mastomys sp**	Open/grassland		
Mylomys dybowskyii	Open/grassland		
*Stochomys longicaudatus**	Closed forest		
*Uranomys ruddi**	Open/grassland		
Shrew			
*Ruwenzorisorex suncoides** (Shrew)	Swamp forest (highland)	Vulnerable	AR

*Not previously recorded for ECFR

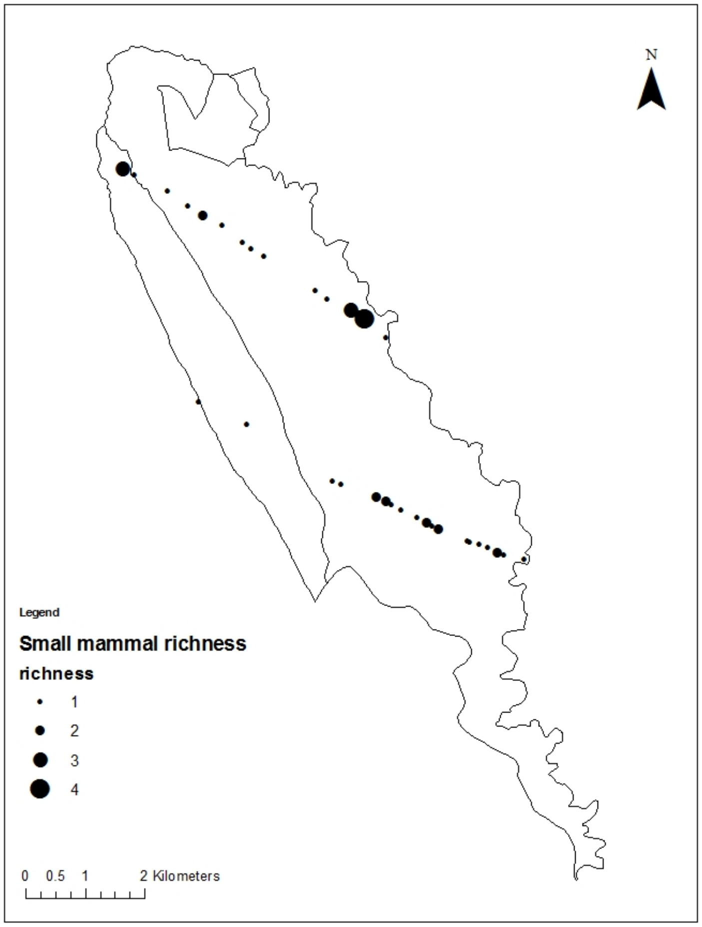

N
Legend
Small mammal richness
richness
1
2
3
4
0 0.5 1 2 Kilometers

Figure 8 Small mammal species richness in Echuya

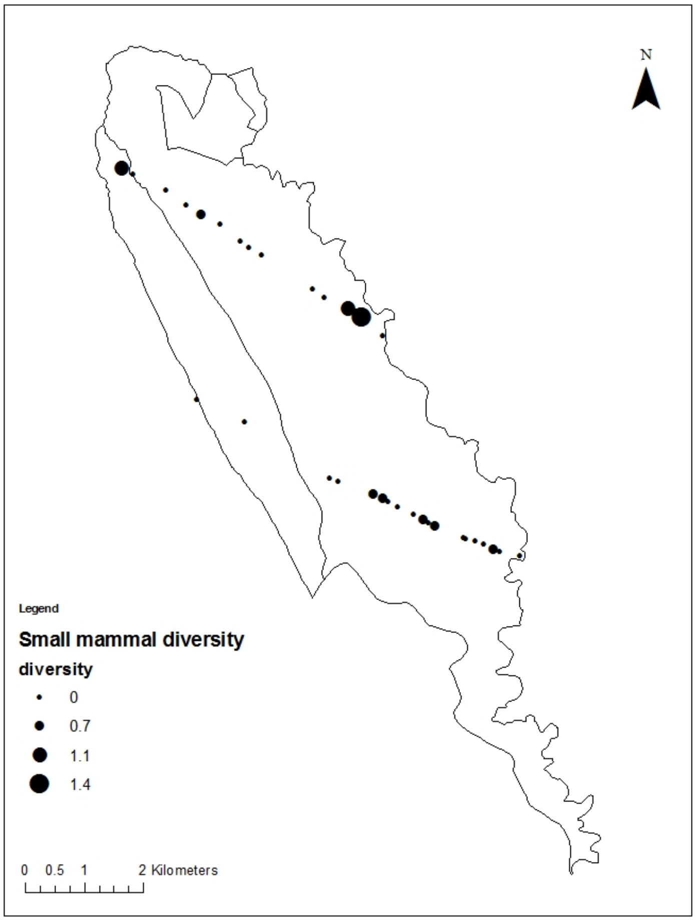


Figure 9 Small mammal species diversity in Echuya

The curve (Figure 10) is a plot of the number of small mammal species richness as a function of the number of sample sites. The slope of the curve remained steep and the asymptote was not reached indicating that more small mammals remain unrecorded.

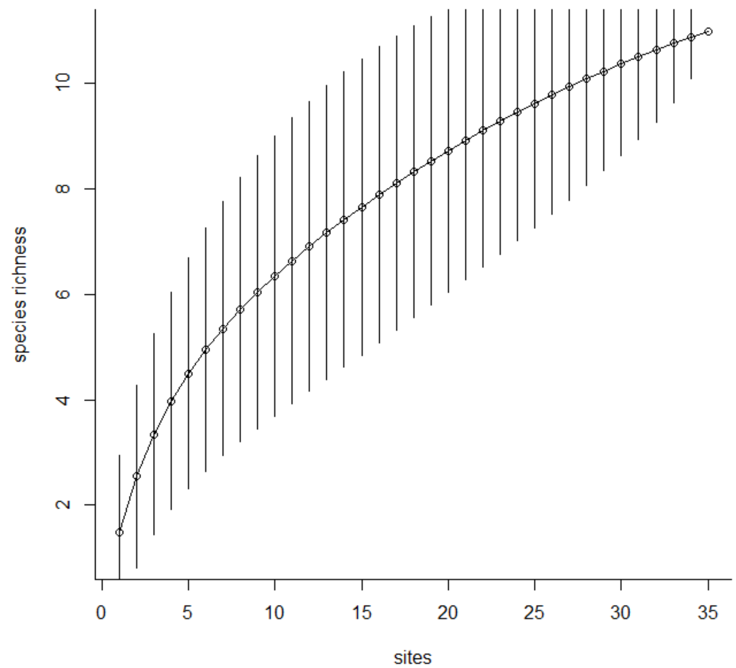


Figure 10 Species accumulation curve for the small mammal dataset, the bars indicate +2 and -2 is the SD

Since our small mammal survey did not cover the entire forest, we made some predictions, based on the sites sampled, for the total species richness using different methods – the first- and second-order Jackknife, Chao and bootstrap formulae. The estimates are quite similar, giving a range of 13 to 16 species.

4.3.2 Species composition of small mammals across sites

To unravel the pattern in small mammal species composition across sites, we plotted the sample sites on an ordination graph using the Principal Coordinates Analysis (PCoA). Sites with similar small mammal species composition are clustered together and dissimilarity is measured by how far apart the sites are displayed on the ordination graph. Figure 11 shows a confidence ellipse on an ordination graph where 95% of the sites with the same small mammal species composition were expected to occur. The clustering structure on the ordination graph was given an ecological interpretation by correlating the tree species composition with categories within each environmental variable measured.

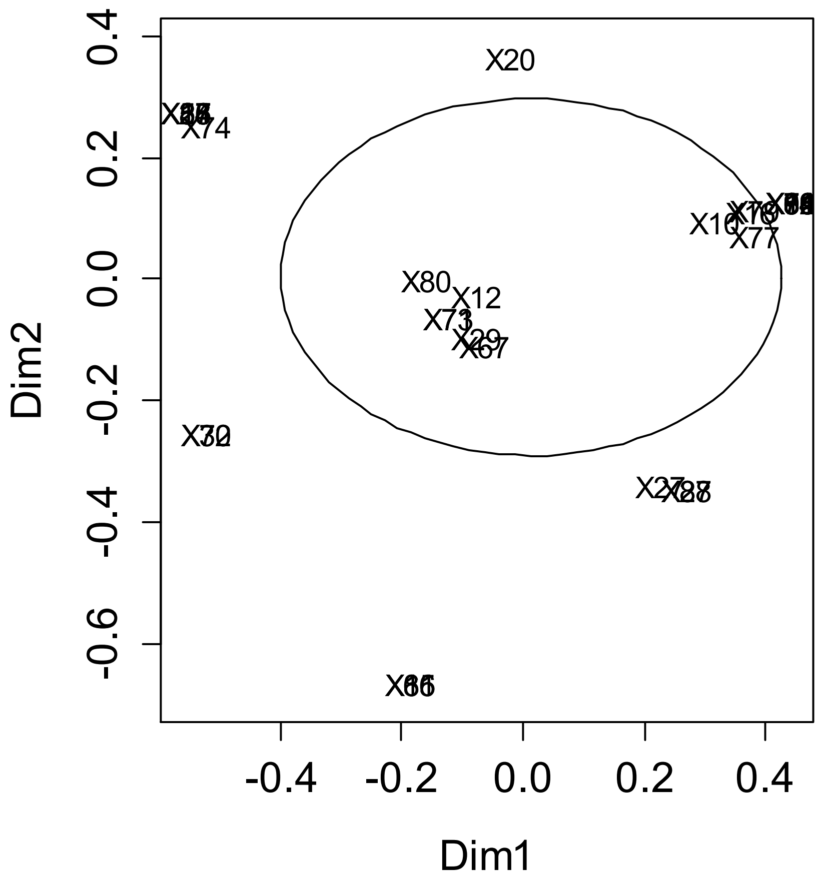


Figure 11 Small mammal species composition dissimilarities across sites in Echuya

Using the ANISOM (Analysis of Similarity) test, it was found that there was a very low or no correlation (R≤0.1) between the categories in each categorical environmental variable and small mammal species composition (Table 6). This means that there were several sites that were located in the same category of each environmental variable but had different small mammal species composition and several sites that were in different categories of each environmental variable but had similar small mammal species composition.

The Mantel test showed that there was a very weak or no correlation (R≤0.1) between small mammal species composition and each of the quantitative environmental variables measured

(Table 6). This means that the majority of the sites have many small mammal species in common irrespective of differences in the measured environmental variables.

Table 6 Differences in Small mammal species composition with environmental variables

Environmental variable	***Test***	***R statistic***	***Significance***
Slope position	ANOSIM	-0.02	0.593
Vegetation type	ANOSIM	-0.01	0.477
Human activity	ANOSIM	-0.02	0.668
Altitude	Mantel	0.01	0.586
Slope angle	Mantel	0.07	0.05
Slope aspect	Mantel	0.03	0.727
Canopy openness	Mantel	0.02	0.357
Distance to forest boundary	Mantel	0.05	0.159

Lack of impact by the measured environmental variables on small mammal species composition site pattern was further revealed by plotting two of the variables – categorical variable vegetation type, and a quantitative variable – distance from each site to the nearest forest boundary onto the ordination graph. Many sites from different vegetation types have similar small mammal species composition and at the same time, sites from similar vegetation types have different species composition (Figure 12). This is indicated by the overlap of the confidence ellipses. Also, sites from the same distance from forest boundary of each site (e.g., at 1,000 m asl on Figure 13) had different species composition. This implies that small mammal species site composition in Echuya was not habitat specific.

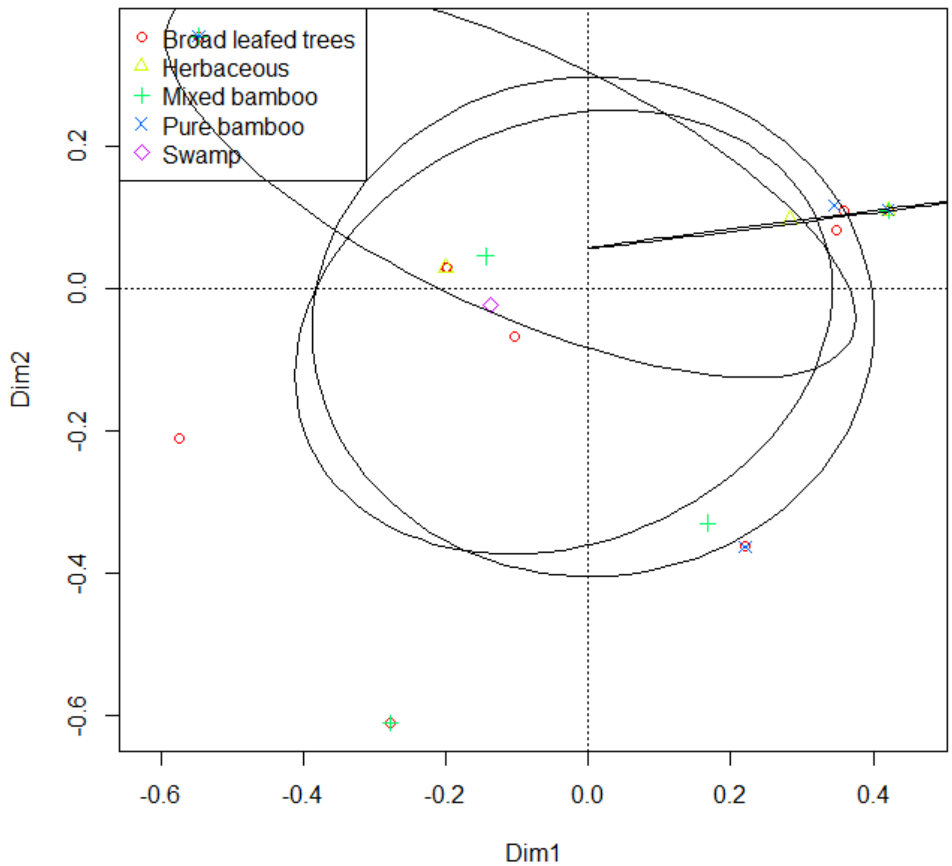


Figure 12 Small mammal species composition and vegetation types in Echuya

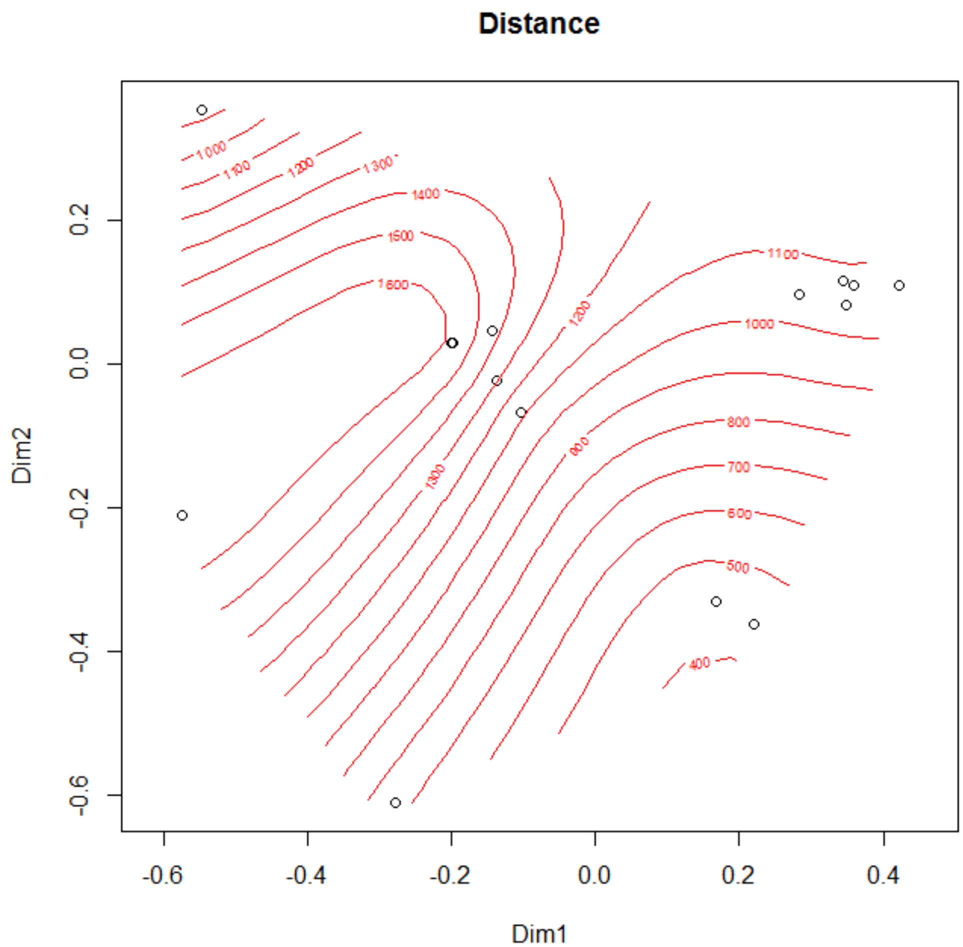


Figure 13 A contour for quantitative environmental variable-distance from forest boundary

4.3.4 Previous work on small mammals

A comparison was made of this study and previous surveys of small mammals (Table 7). Five species of rodents and one of shrew have not been previously recorded for ECFR (Table 5). But the total species richness is nearly the same like the immediate last survey.

Table 7 A comparison of this study with previous surveys for small mammals

Researcher/study	Extent/Sites covered	Methods used/adapted	Total species recorded	No. of Albertine Rift endemic species
This study	2 transects covering sites in north, central and south of the reserve sampled for 13 days in June 2015	Sherman traps	11 (10 rodents and 1 shrew)	3 (2 rodents and 1 shrew)
Davenport et al (1996)	3 blocks each 1 km^2 sampled in south and north of the reserve for 8 days (3 days in Aug 1993 and 5 days in Nov 1994)	Combination of Breakback, Sherman, Longworth and Pitfall traps	9 (6 rodent and 3 shrew)	2 (1 rodent and 1 shrew)
Delany (1975), Kingdon (1971-1974)	Muchuya swamp and possibly the forest at the edge of the swamp	?	20 (16 rodents and 4 shrews)	5 (3 rodents and 2 shrews)

4.4 Diversity and distribution of birds

A total of 58 sites were sampled for birds using point count technique. Majority of the sites (32) were in the most dominant vegetation type – the broad leafed trees, 9 in mixed bamboo, 9 in herbaceous, 6 in pure bamboo and 2 in a swamp. The altitudinal range of the sites was from 2,200 to 2,530m asl, slope steepness averaged 17°, 28 sites were in mid slopes, 16 sites on ridge tops while 14 were in the valleys. Slope aspect of the sites averaged 143°. The mean canopy openness of the sites was 88.5% and distance of the sample sites from the forest boundary averaged 968 m with the nearest plot to the forest boundary being at a distance of 1.5 m while the furthest from forest boundary was at a distance of 2,162 m. Human activity signs were encountered in more than half of the sites sampled. Bamboo cutting was the most commonly encountered type of human activity sign in the bird sample sites.

4.4.1 Species richness and diversity of birds across sites

A total of 94 species of birds were recorded for the whole forest. Ninety two bird species were recorded using the point count technique while 27 bird species were captured in mist nets. Except for two species (Kivu Ground Thrush (*Zoothera tanganjicae*) and Red Throated Alethe (*Alethe poliophrys*) all the other species captured in the mist nets were also observed during the point counts. Species richness per site varied from 3 to 15 while Shannon diversity index varied from 1.1 to 2.7 per site. There was no discernible difference in the spatial distribution of species richness and diversity across the sites (Figures 14 and 15). The most commonly observed bird species was the Yellow Whiskered Greenbul (*Andropadus latirostris*) occurring in 66% of the sample sites. The rest of the bird species occurred in less than 35% of the sample sites

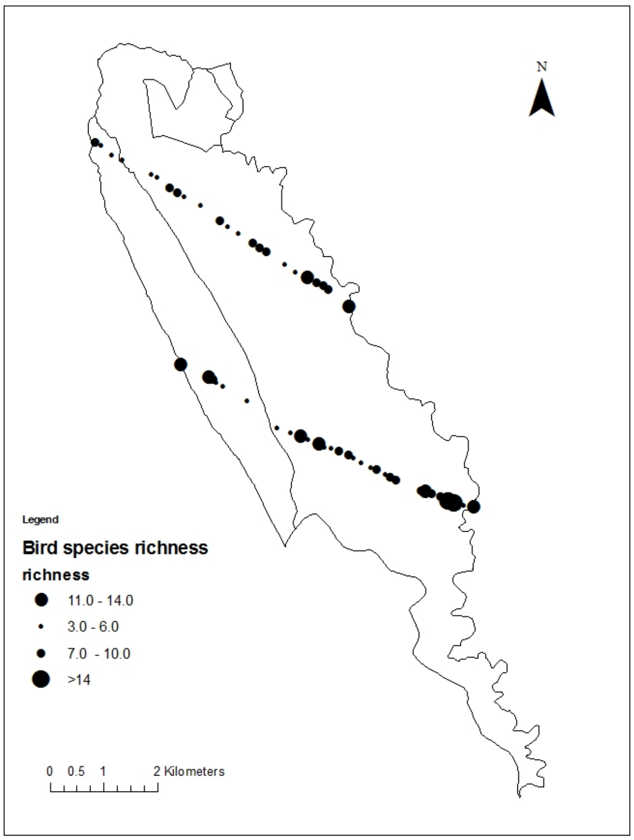


Figure 14 Bird species richness in Echuya

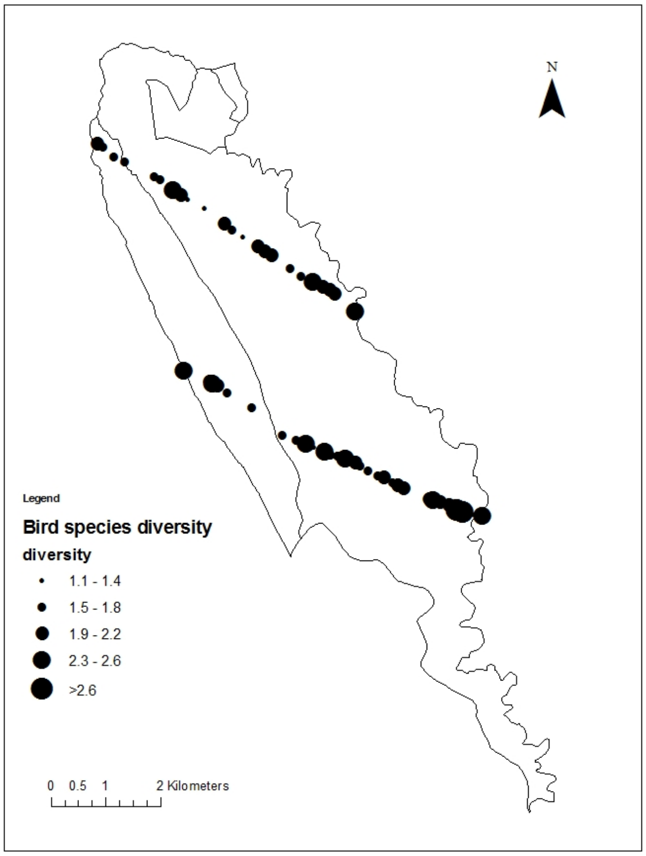


Figure 15 Bird species diversity in Echuya

The curve (Figure 16) is a plot of the number of bird species richness as a function of the number of sample sites. The slope of the curve remained steep and the asymptote was not reached indicating that more bird species remain unrecorded.

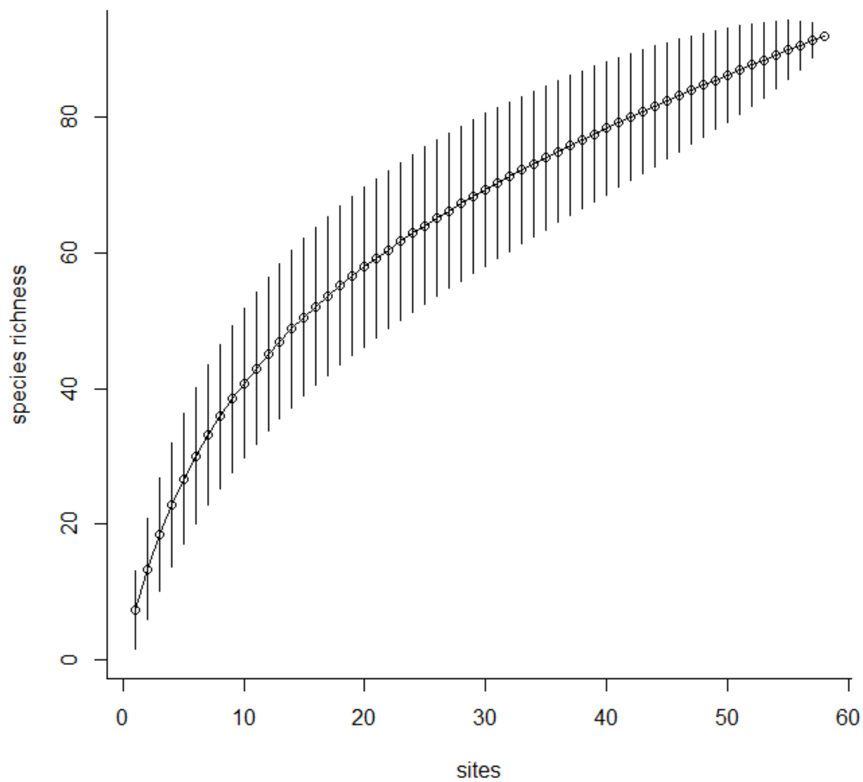


Figure 16 Species accumulation curve for the bird datasets. The bars indicate +2 and -2 SD

Since our bird survey did not cover the entire forest, we made some predictions, based on the sites sampled, for the total species richness using different methods – the first- and second-order Jackknife, Chao and bootstrap formulae The estimates varied, giving a range of 108 to 210 species.

4.4.2 Albertine Rift endemic birds diversity and distribution

Fifteen Albertine Rift endemic bird species were encountered. Thirteen species were observed during the point counts and an additional two species were mist netted. The distribution of these species across the reserve is presented in Figure 17. The western part of the forest seemed to be poor in Albertine Rift endemic species but this is not definitive.

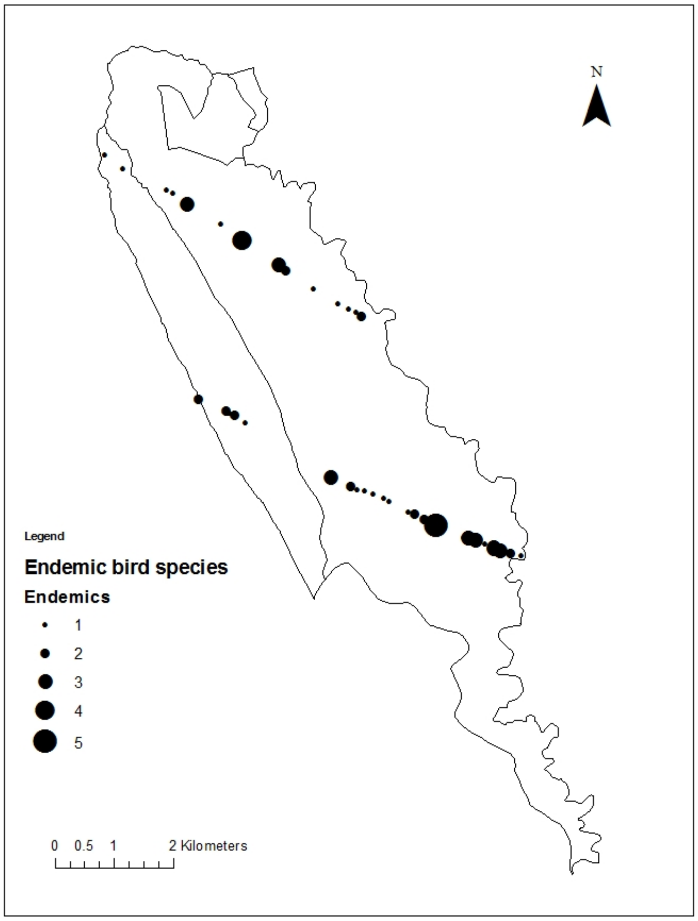


Figure 17 Albertine Rift endemic bird species in Echuya

Key species encountered previously and recorded during this study include:

i) Globally threatened species

Grauer's Rush Warbler (*Bradypterus graueri*) – Endangered

Kivu Ground Thrush (*Zoothera tanganjicae*) – Near-threatened

ii) Restricted range species – Albertine Rift Mountains

Handsome Francolin (*Francolinus nobilis*)

Red-throated Alethe (*Alethe poliophrys*)

Kivu Ground Thrush (*Zoothera tanganjicae)*

Archer's Robin-chat (*Cossypha archeri*)

Collared Apalis (*Apalis ruwenzorii*)

Red-faced Woodland-warbler (*Phylloscopus laetus*)

Grauer's Rush Warbler (*Bradypterus graueri*)

Rwenzori Batis (*Batis diops*)

Regal Sunbird (*Nectarinia regia*)

Dusky Crimson-wing (*Cryptospiza shelleyi*)

Strange Weaver (*Ploceus alienus*)

Stripe-breasted tit (*Parus fasciiventer*)

Ruwenzori night jar (*Caprimulgus ruwenzorii*)

4.4.3 Species composition of birds across sites

To unravel the pattern in the bird species composition across sites, we plotted the sample sites on an ordination graph using the Principal Coordinates Analysis (PCoA). Sites with similar bird species composition are clustered together and dissimilarity is measured by how far apart the sites are displayed on the ordination graph. Figure 18 shows a confidence ellipse on an ordination graph where 95% of the sites with the same bird species composition were expected to occur. The clustering structure on the ordination graph was given an ecological interpretation by correlating the tree species composition with categories within each environmental variable measured.

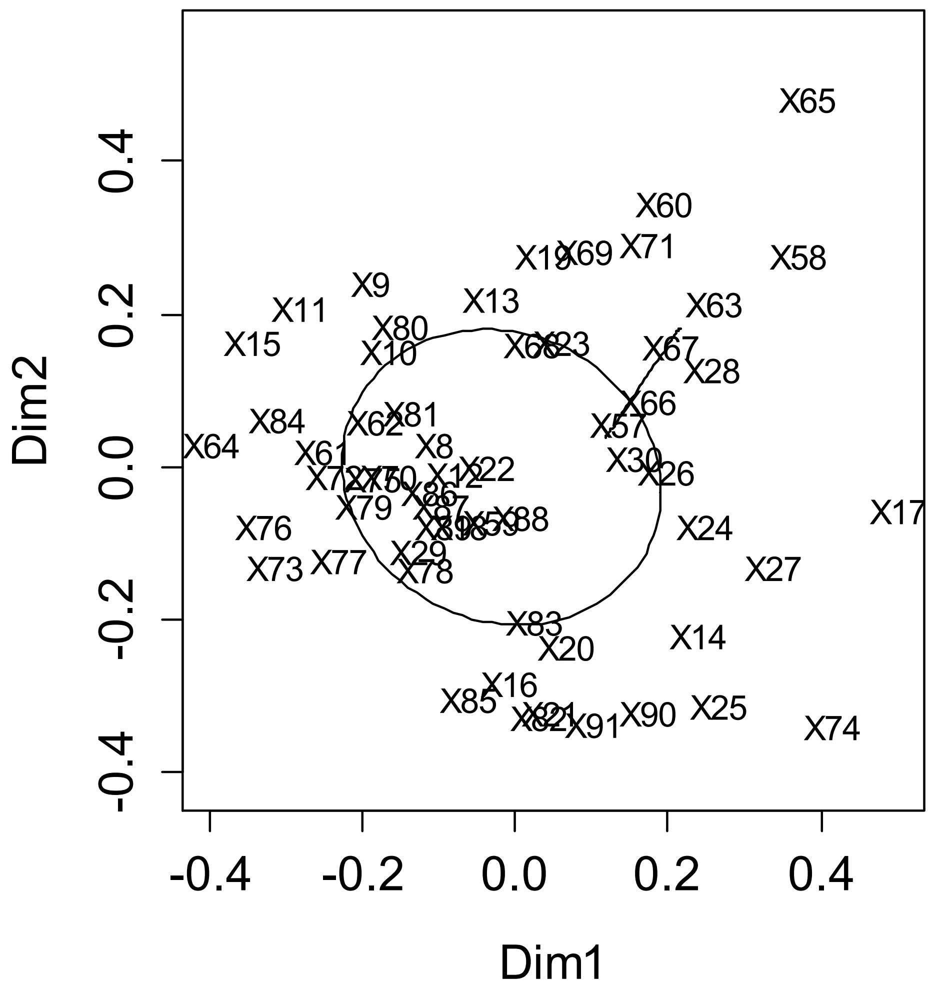


Figure 18 Bird species composition dissimilariities across sites in Echuya

Using the ANISOM (Analysis of Similarity) test, it was found that there was a very low or no correlation (R≤0.2) between the categories in each categorical environmental variable and bird species composition (Table 7). This means that there were several sites that were located in the same category of each environmental variable but had different bird species composition and several sites that were in different categories of each environmental variable but had similar bird species composition.

The Mantel test showed that there was a very weak or no correlation (R≤0.1) between bird species composition and each of the quantitative environmental variables measured (Table 8). This means that the majority of sites have many bird species in common irrespective of differences in the measured environmental variables.

Table 8 Differences in bird species composition with environmental variables

Environmental variable	***Test***	***R statistic***	***Significance***
Slope Position	ANOSIM	0.04	0.02
Vegetation type	ANOSIM	0.2	0.001
Human activity	ANOSIM	0.06	0.01
Altitude	Mantel	0.07	0.06
Slope angle	Mantel	0.01	0.31
Slope aspect	Mantel	0.00	0.42
Canopy openness	Mantel	0.09	0.47
Distance to forest boundary	Mantel	0.04	0.08

Lack of impact by the measured environmental variables on bird species composition site pattern was further revealed by plotting two of variables – categorical variable vegetation type, and a quantitative variable – altitude onto the ordination graph. Many sites from different vegetation types have similar bird species composition and at the same time, sites from similar vegetation types had different species composition (Figure 19). This is indicated by the overlap of the confidence ellipses. Also, sites from the same altitudinal range (e.g., ≥ 2,330m asl on Figure 20) have different species composition. This implies that the bird species site composition in Echuya is not habitat specific.

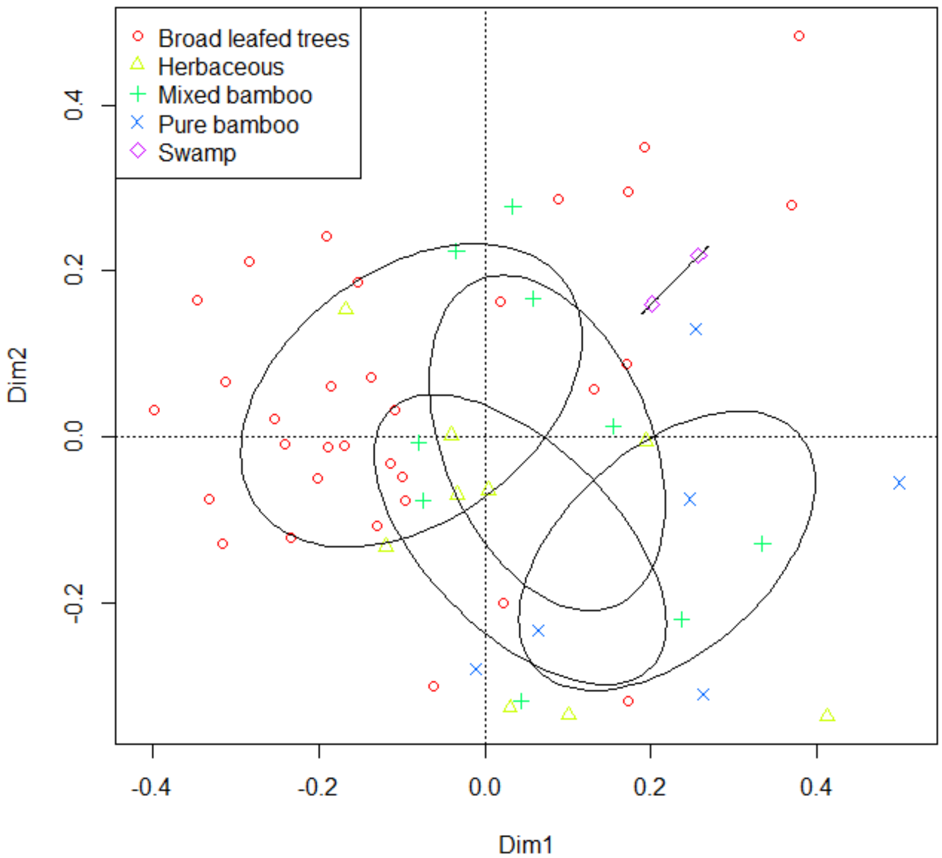


Figure 19 Different symbols for different categories of environmental variable vegetation type

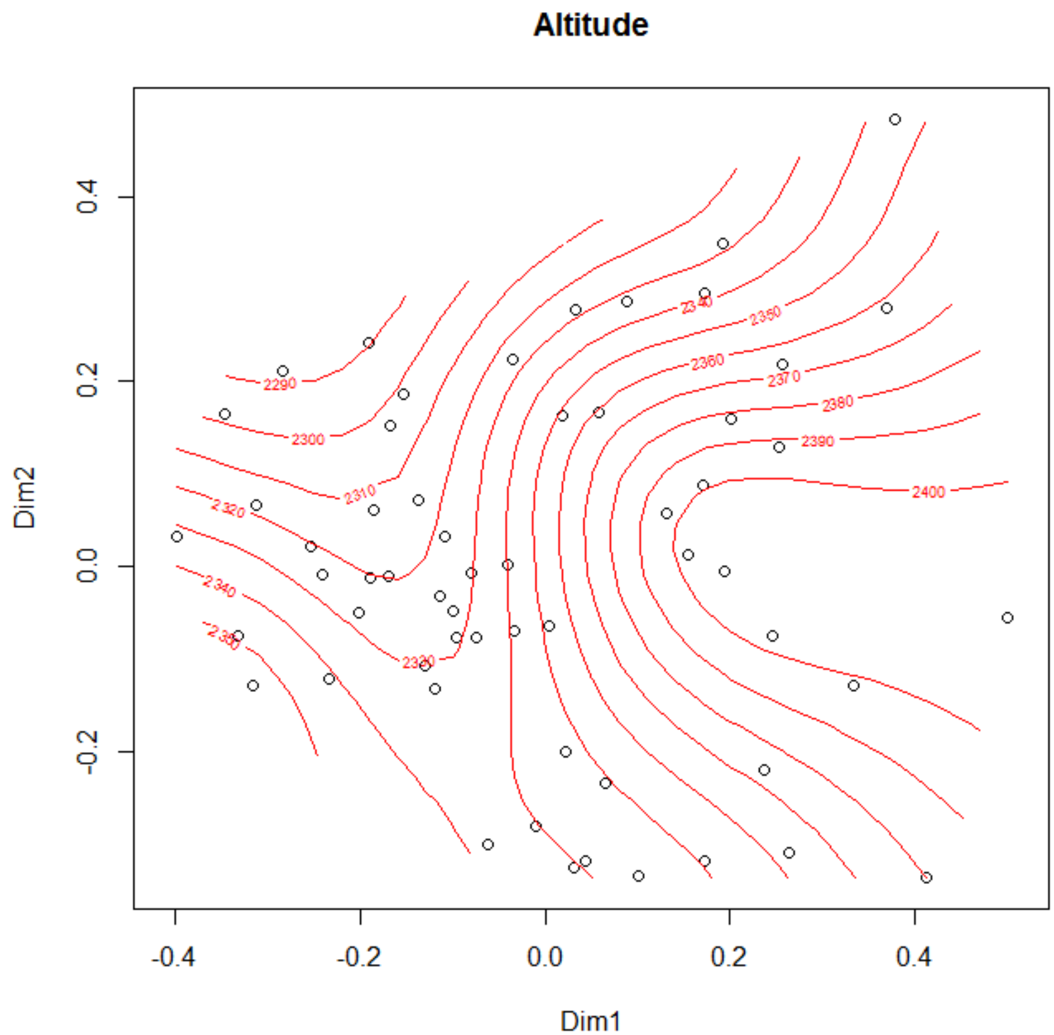


Figure 20 A contour for quantitative environmental altitude

4.4.4 Previous work on birds

A comparison was made of this study and similar detailed surveys of birds that have been made in ECFR (Table 9). The number of bird species encountered is very close to the total number of species known for the forest.

Table 9 A comparison of this study with previous bird surveys

Researcher/study	Extent/Sites covered	Methods used/adapted	Total species recorded	No. of Albertine Rift endemic species
This study	2 transects, sampled covering sites in north, central and south of the reserve for 12 days of sampling in June 2015	Point count and mist-netting	94	15
Byaruhanga et al. 2001 (compiled from Davenport et al. 1996 and Marks et al. 2003)	?	?	100	12
Davenport et al (1996)	19 blocks each 1 km^2 sampled covering southern and northern parts of the reserve for 9 days (5 days in Aug 1993 and 4 days in Nov 1994)	Observation and Mist-netting,	74	8

4.5 Diversity and distribution of trees

A total of 122 sites were sampled but only 83 had trees ≥10cm dbh. The 83 sample sites were the ones considered for analysis of tree species richness and diversity. Majority of the sites (74) were in the most dominant vegetation type – the broad leafed trees, 7 in mixed bamboo and one each in the herbaceous and pure bamboo. The altitudinal range of the sites was from 2,130 to 2,530m asl, slope steepness averaged 21°, 49 sites were in mid slopes, 26 sites on ridge tops while 8 were in the valleys. Slope aspect of the sites averaged 154°. The mean canopy openness of the sites was 92.7% and distance of the sample sites from the forest boundary averaged 825 m with the nearest plot to the forest boundary being at a distance of 1.5 m while the furthest from forest boundary was at a distance of 2,163 m. Human activity signs were encountered in more than half of the tree sites sampled. Footpaths, bamboo cutting, and tree cutting were the most commonly encountered type of human activity signs in the sample sites.

4.5.1 Species richness and diversity of trees across sites

A total of 20 species of trees ≥10cm dbh were encountered in the whole forest. All the tree species encountered were early pioneers or 'secondary' species and late 'secondary' species implying that Echuya is a secondary forest. *Macaranga capensis* was the most dominant tree occurring in 65% of the sites surveyed, while *Psychotria mahonii* and *Neoboutania macrocalyx* occurred in 31 and 16 percent of the surveyed sites respectively. The rest of the tree species were mostly occasional and rare.

Site species richness ranged from one to four species with majority of the sites (84%) having only one or two species. Figure 21 shows that generally, sites on the western part and southeastern areas of the forest seem to be more species rich and diverse than the eastern part.

Patterns of spatial variation in tree species diversity (H') are shown in Figure 22. The western part of the forest seems to be more diverse than the eastern part. H´ ranged from zero to 1.33 but with 42% of the sites having H' between 0 and 0.3 and 34% of the sites having H' between 0.6 and 0.9.

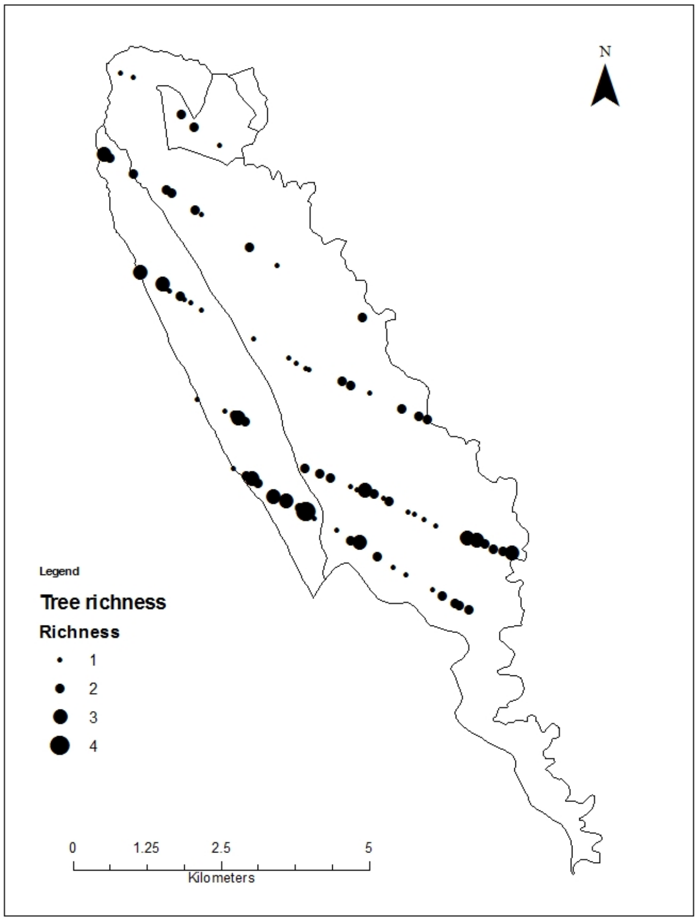


Figure 21 Tree species richness in Echuya

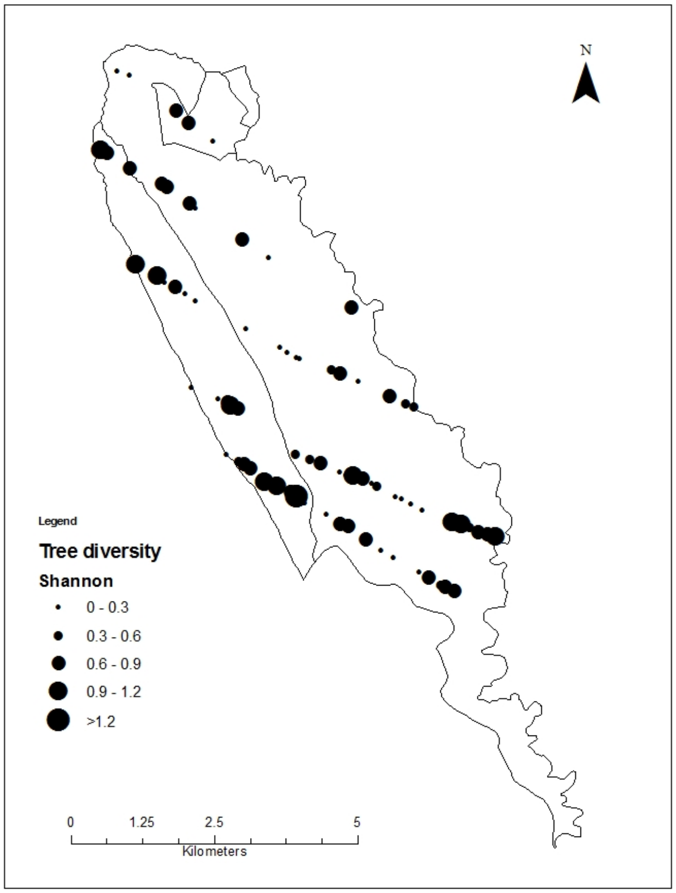


Figure 22 Tree species diversity in Echuya

The curve (Figure 23) is a plot of the number of tree species richness as a function of the number of sample sites. The slope of the curve remained steep and the asymptote was not reached indicating that more tree species remain unrecorded.

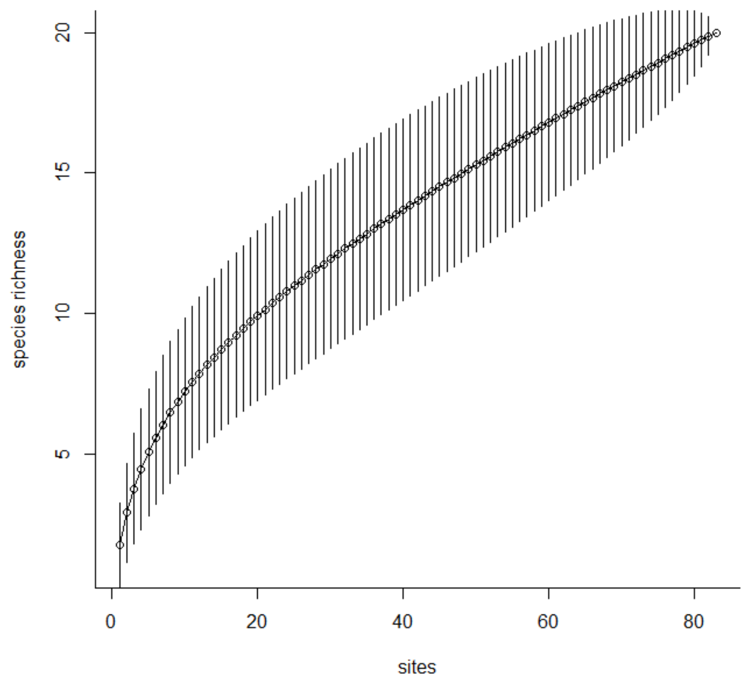


Figure 23 Species accumulation curve for the tree dataset. The bars indicate +2 and -2 SD

Since the accumulation curve did not reach asymptote, we made some predictions, based on the sites sampled, for the total species richness using different methods – the first- and second-order Jackknife, Chao and bootstrap formulae . The estimates varied, giving a range of 24 to 50 species.

4.5.2 Species composition of trees across sites

To unravel the pattern in the tree species composition across sites, we plotted the sample sites on an ordination graph using the Principal Coordinates Analysis (PCoA). Sites with similar tree species composition are clustered together and dissimilarity is measured by how far apart the sites are displayed on the ordination graph. Figure 24 shows a confidence ellipse on an ordination graph where 95% of the sites with the same tree species composition were expected to occur. The clustering structure on the ordination graph was given an ecological interpretation by correlating the tree species composition with categories within each environmental variable measured.

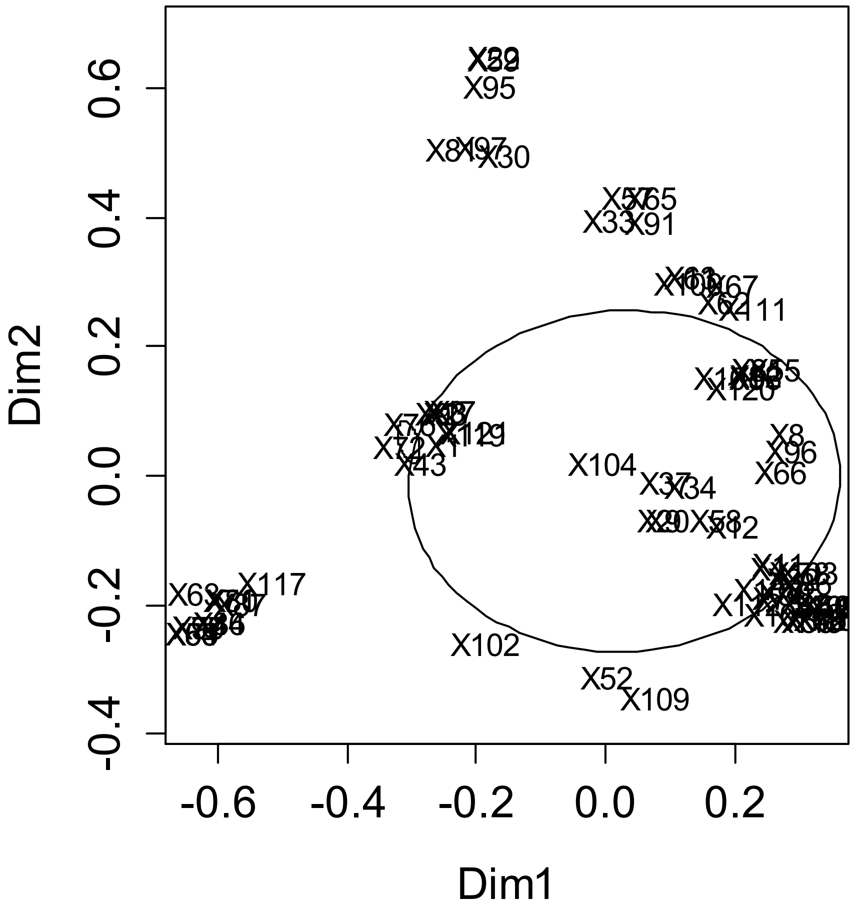


Figure 24 Tree species composition dissimilarities across sites in Echuya

Using the ANISOM (Analysis of Similarity) test, it was found that there was a very low or no correlation (R≤0.2) between the categories in each categorical environmental variable and tree species composition (Table 8). This means that there were several sites that were located in the same category of each environmental variable but had different tree species composition and several sites that were in different categories of each environmental variable but had similar tree species composition.

The Mantel test showed that there was a very weak or no correlation (R≤0.1) between tree species composition and each of the quantitative environmental variables measured (Table 10).

This means that the majority sites have many tree species in common irrespective of differences in the measured environmental variables.

Table 10 Differences in tree species composition with environmental variables

Environmental variable	***Test***	***R statistic***	***Significance***
Slope Position	ANOSIM	0.09	0.03
Vegetation type	ANOSIM	0.17	0.05
Human activity	ANOSIM	0.00	0.40
Altitude	Mantel	0.1	0.01
Slope angle	Mantel	0.03	0.13
Slope aspect	Mantel	0.00	0.41
Canopy openness	Mantel	0.05	0.14
Distance to forest boundary	Mantel	0.06	0.03

Lack of impact by the measured environmental variables on tree species composition site pattern was further revealed by plotting two of variables – categorical slope position, and a quantitative variable – altitude onto the ordination graph. Many sites from different slope positions (top, mid and valley) have similar tree species composition and at the same time, sites from similar slope positions have different species composition (Figure 25). This is indicated by the overlap of confidence ellipses. Also, sites from the same altitudinal range (e.g., $\geq$ 2,360m asl on Figure 26) have different species composition. This implies that the tree species in Echuya are not habitat specific.

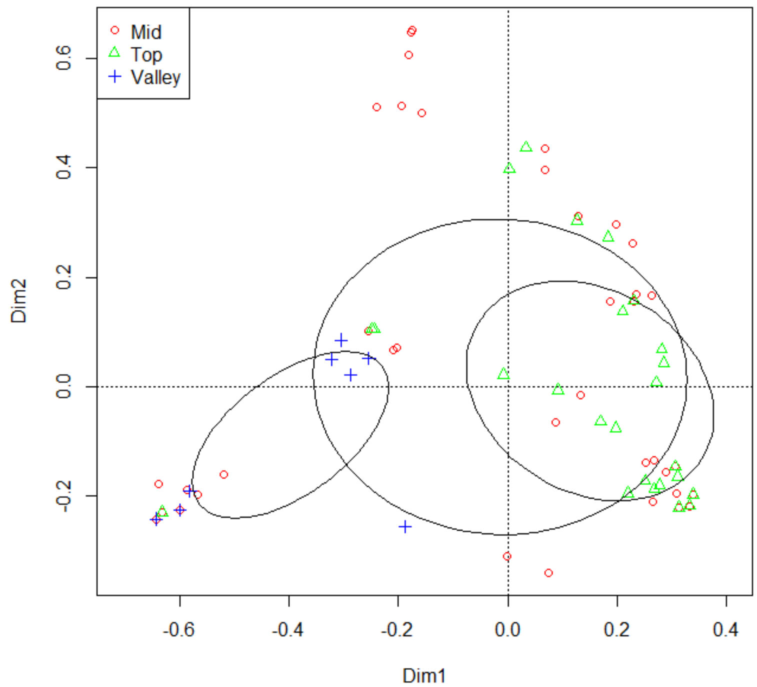


Figure 25 Different symbols for different categories of environmental variable slope position

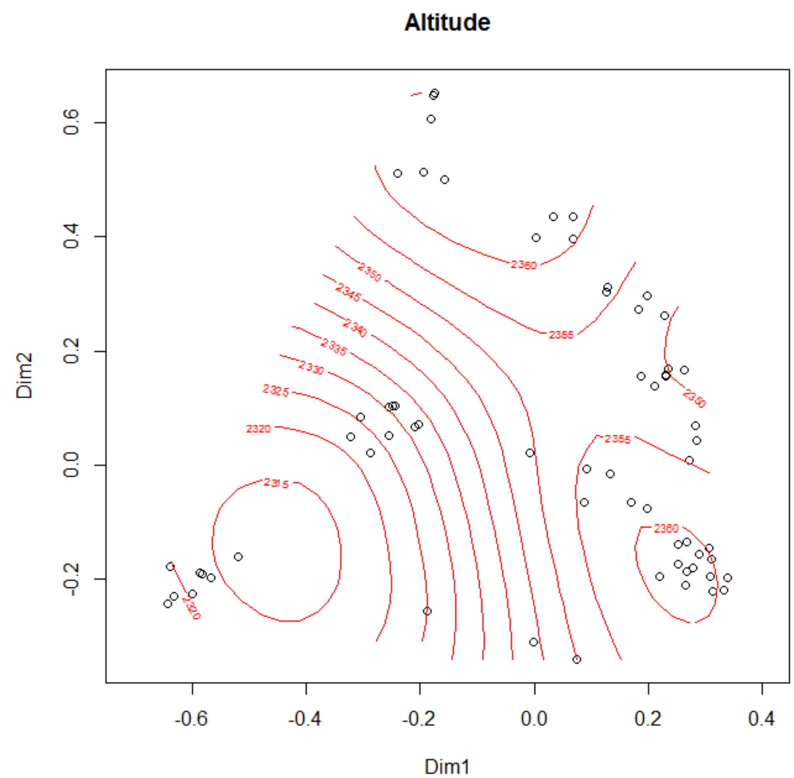


Figure 26 A contour for qualitative environmental altitude

4.4.4 Previous work on trees

A comparison was made of this study and similar detailed surveys of trees that have been made in ECFR (Table 11).

Table 11 A comparison of this study with previous tree surveys

Researcher/study	Extent/Sites covered	Methods used/adapted	Total species recorded	No. of Albertine Rift endemic species
This study	5 transects, sampled covering sites in north, central and south of the reserve for 12 days of sampling in June 2015	10×10 m quadrats	20	0
Daveport et al. 1996	10 transects following paths of least	Observation and abundance estimates based	35 (a tree was not defined by minimum dbh)	0

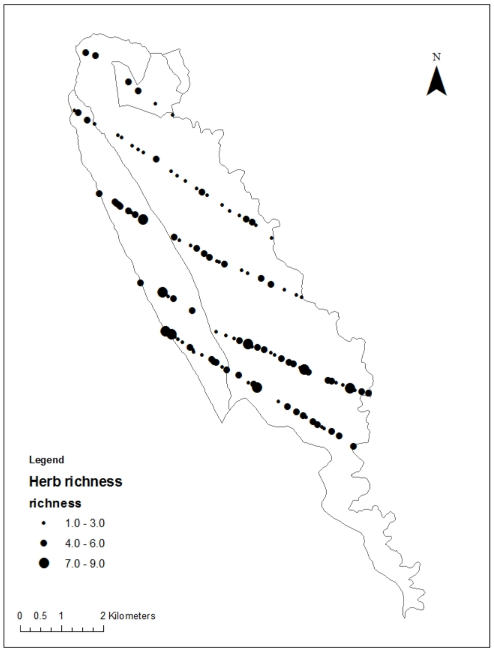
	resistance	on DAFOR		

4.6 Diversity and distribution of shrubs and herbs

A total of 119 sites had herbs and/or shrubs. Majority of the sites (73) were in the most dominant vegetation type – the broad leafed trees, 13 in mixed bamboo, 21 in the herbaceous 7 in pure bamboo, 4 in a swamp and only one in pine plantation. The altitudinal range of the sites was from 2,130 to 2,530m asl, slope steepness averaged 18°, 59 sites were in mid slopes, 31 sites on ridge tops while 29 were in the valleys. Slope aspect of the sites averaged 145°. The mean canopy openness of the sites was 89.9% and distance of the sample sites from the forest boundary averaged 825 m with the nearest plot to the forest boundary being at a distance of 1.5 m while the furthest from forest boundary was at a distance of 2,163 m. Human activity signs were encountered in more than half of the sample sites. Footpaths, bamboo cutting, and tree cutting were the most commonly encountered type of human activity signs in the sample sites.

4.6.1 Species richness and diversity of shrubs and herbs across sites

Seventy two species of herbs and 46 of shrubs were encountered in the whole forest. Site species richness for herbs and shrubs ranged from 1 to 8 species with majority of the sites having only one or two species. Figures 27 and 28 show that generally, sites on the western part and southeastern areas of the forest seem to be more herb and shrub species rich and diverse than the eastern part. But the herb and shrub species seemed evenly distributed in the forest.



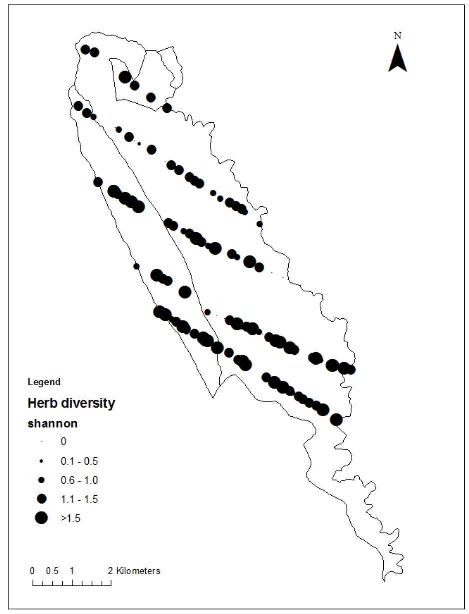
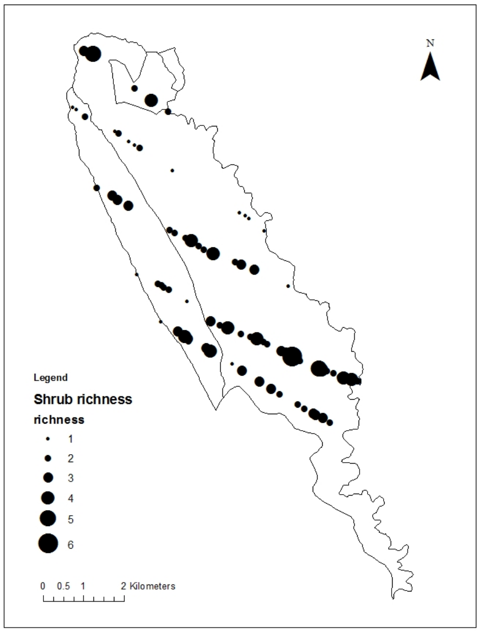


Figure 27 Herb species richness (left map) and diversity (right) in Echuya



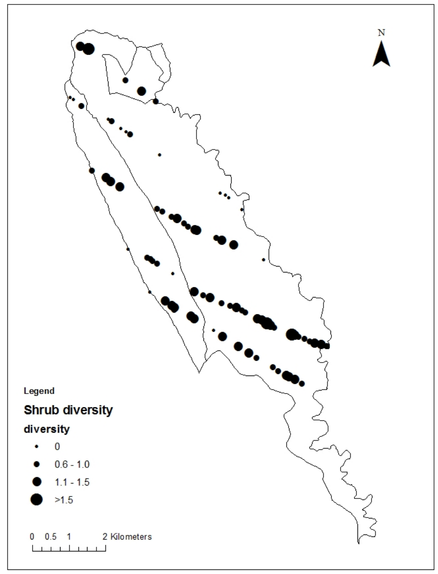


Figure 28 Shrub species richness (left map) and diversity (right) in Echuya

The curves (Figure 29 and 30) is a plot of the number of herb and shrub species richness as a function of the number of sample sites. The slope of the curves remained steep and the asymptote was not reached indicating that more herb and shrub species remain unrecorded.

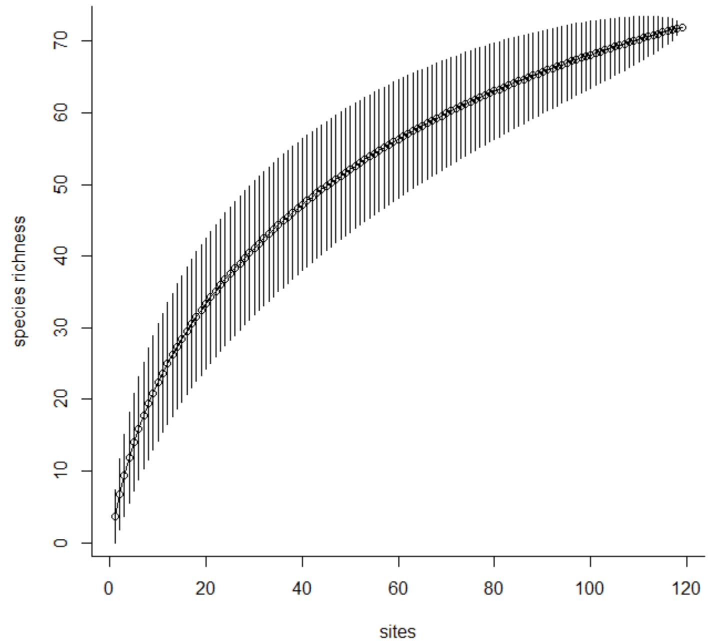


Figure 29 Species accumulation curve for the herb dataset. The bars indicate +2 and -2 SD

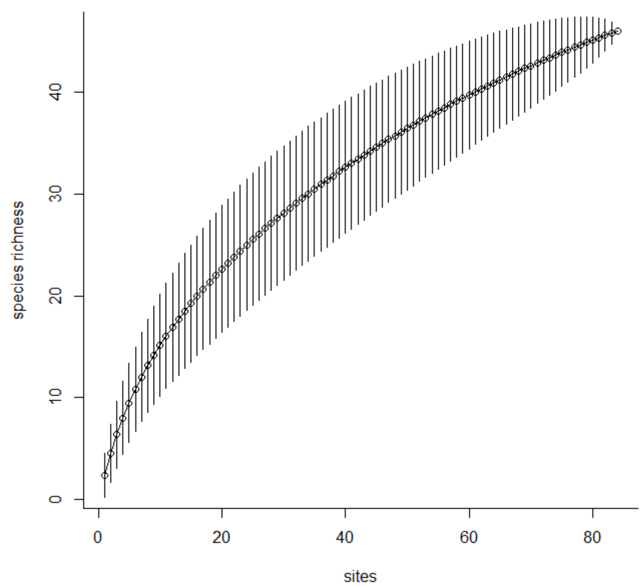


Figure 30 Species accumulation curve for the shrub dataset. The bars indicate +2 and -2 SD

As with other taxa, the herb and shrub species composition across sites were not correlated with any environmental variable (Table 12).

Table 12 Differences in herb species composition with environmental variables

Environmental variable	***Test***	***R statistic***	
		Herbs	***Shrubs***
Slope Position	ANOSIM	0.12	0.04
Vegetation type	ANOSIM	0.19	0.1
Human activity	ANOSIM	-0.00	0.03
Altitude	Mantel	0.14	0.13
Slope angle	Mantel	0.03	0.06
Slope aspect	Mantel	0.00	0.02
Canopy openness	Mantel	0.17	0.1

4.6 Distribution of human activities

Of the 122 sample sites, human activity signs were encountered in half of the sample sites (60 sites) with footpaths, bamboo harvesting, and tree cutting being the most commonly encountered type of human activity signs in the sample sites (48 sites). From Figure 31, it can be seen that human activity is nearly evenly distributed in the whole forest. Details of each human activity are described below.

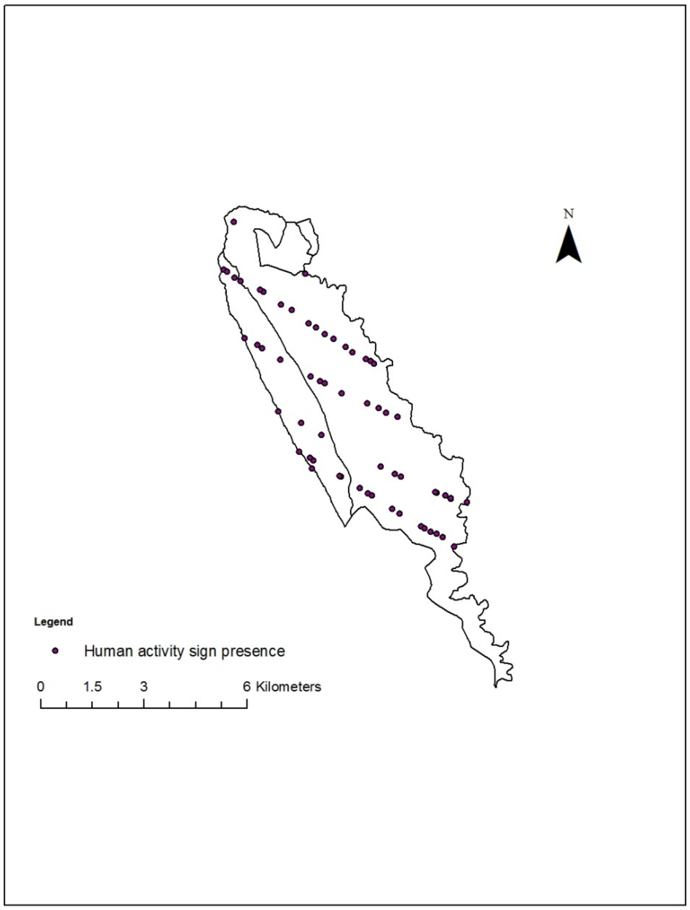


Figure 31 Spatial distribution of human activity signs in Echuya

4.6.1 Agricultural encroachments

During this survey, we encountered an area of about 12 ha inside the forest that had been cleared of forest vegetation (Plate 1) and more than half of the cleared area was already planted with Irish potatoes (Plate 2). The clearing of the forest seem to be continuing as freshly cut forest was also observed.

Plate 1. Agricultural encroachment in Echuya CFR, Uganda

Plate 2. Part of the Echuya where natural forest has been replaced with Irish potato gardens

4.6.2 Bamboo harvesting

Signs of bamboo harvesting were encountered in 16 out of the 122 sites surveyed. The bamboo in Echuya has been a subject of intense monitoring of recent (Bitariho and McNeilage 2007; Ssali and Bitariho 2013). The trend shows an increase in intensity of bamboo harvesting which is greatly affecting the health and regeneration of the bamboo population (Plate 3).

Plate 3. Intense bamboo harvesting in the pure bamboo zone of Echuya CFR

4.6.3 Livestock grazing

We found evidence that livestock, usually cattle, had entered five of the 122 sites sampled. A cow, goat and a dog were camera trapped each at one site out of 27. Grazing, trampling and watering signs were observed along the major footpaths within the forest (Plate 4) Livestock are brought into the reserve for grazing and watering.

Plate 4. Cattle grazing within Echuya CFR interior

4.6.4 Human footpaths

We define a ‘footpath’ as a trail that is obviously well used and along which we suspect an average of one or more persons pass each day. This survey found 15 out of the 122 sample sites were traversed by well used trails. These well-used footpaths provide access to a large part of the reserve. Most, perhaps all, the remainder of the reserve can be reached by people using less distinct paths. The footpaths are used by people either to collect produce or move from one side of the forest to the other. The main Kisoro-Kabale road that crosses the forest in the north also contributes to overharvesting of forest resources especially bamboo (Ssali and Bitariho 2013).

4.6.5 Tree cutting and other non-timber harvests

Other forest products harvested include trees (Plate 5), vines, firewood and trapping of Handsome Francolin (*Francolinus nobilis).*

Plate 5. A cut *Macaranga capensis* tree in Echuya

5.0 Discussion

5.1Diversity and distribution of large mammals

Terrestrial (ground dwelling) mammals are a key component of tropical forests that provide important ecosystem services (Struhsaker 1997; Weber 2001). At the same time they are the most threatened by human driven habitat loss (Laurance et al. 2006; Beschta and Ripple 2009) and direct exploitation through hunting (Brodie et al. 2009, 2015; Sherif and Love 2013; Ahumada et al. 2013). Human activity will thus compromise the ability of terrestrial mammals to sustain tropical forest ecosystems, with implications on ecosystem functioning (Laurance et al. 2006; Ahumada et al. 2011; Estes et al. 2011; Effiom et al. 2013), global climate (Brodie et al. 2009) and local livelihood (Cincotta, Wisnewski and Engelman 2000).

The impacts of human activity on tropical forest mammals are most prevalent in tropical forests that are characterized by a high human density surrounding them (Ahumada et al. 2011; Ahumada et al, 2013; Cincotta, Wisnewski&Engelman 2000). Echuya forest reserve ("Echuya") is one of such tropical forests (Plumptre et al. 2003). A unique afro-montane forest habitat, Echuya is characterized by high levels of both legal and illegal human activity.

The methods commonly used for terrestrial mammal inventories include: line transects (Plumptre 2000), direct counts (Silveira, Jácomo & Filho 2003), indirect evidence e.g. nests, tracks and signs (Plumptre & Reynolds 1997), trapping (Kasangaki, Kityo & Kerbis 2003), interviews with local people (Andama 2000) and camera trapping (Tobler et al. 2008; Mugerwa et al. 2013). Camera traps have become increasingly popular as technology has improved and costs have decreased (Tobler et al. 2008). Camera traps have been used to estimate species richness (O'Brien, Kinnaird &Wibisono 2011; Mugerwa et al. 2013), to estimate community structure and diversity (Ahumada et al. 2011), and to detect species presence (Sheil and Mugerwa 2013; Mugerwa 2013).

This is the first systematic survey of terrestrial mammals in Echuya since Plumptre et al. (2003).This is also the first study to predict human activity occurrence in Echuya, and its relationships (together with environmental factors) with terrestrial mammal habitat selection. We recorded 10 mammal species. The rarefaction curve did not reach asymptote, suggesting that some species were not recorded in the study. Slope angle, slope aspect and forest cover were the most influencing factors for both human activity occurrence and terrestrial mammal habitat selection. Generally, human activity occurrence did not significantly influence terrestrial mammal habitat selection (table4), suggesting no obvious spatial avoidance of humans. It is possible that Echuya mammals avoid humans temporally, and not spatially as observed for other wildlife communities (Rasmussen & Macdonald 2011). These results suggest that environmental factors have more influence on how mammals in Echuya select their habitat. Our modeling revealed that human activity is widely spread in Echuya, especially to the west, north and eastern edges of the forest reserve;hence strategies against human illegal activities should be focused accordingly.

5.1.1 Species richness and composition of large mammals

Our sampling effort was inadequate to detect a great proportion of species in the terrestrial mammal community of Echuya, as reported by previous studies (Plumptre et al. 2003) who reported over 20 mammal species to occur in Echuya. This confirms the need for well over 1,000 camera days to detect a complex forest-dwelling community of terrestrial mammals (Tobler et al. 2008; Rovero et al. 2010). In any case, the Plumptre et al 2003 study did not use camera traps as in our case and this could be the reason for the differences with ours. Therefore, these results may not necessarily mean that the defaunation is/has been happening in Echuya since then. The difference in species recorded could be due to the difference in methods or difference in the survey seasons, in this study and Plumptre et al. (2003). It is also worth noting that Plumptre et al. (2003) relied mostly on published reports, without empirical evidence of species occurrence.

Nevertheless, we acknowledge that our camera trap survey clearly missed some species known to occur in Echuya, notably the Olive baboon (*Papioanubis)*. Such species could be that they, perhaps, occur in low densities or restricted habitats, which were not covered by our camera trap grid. Rovero et al. (2014) recommended that it takes much greater effort to capture such species. Indeed, the rarefaction species cumulative curve did not reach asymptote, indicating that there are some species we did not detect.

The survey recorded interesting species, with important ecosystem functions. These includedthree carnivore species; the African golden cat, serval and the side striped jackal. These three carnivore species are receiving increased conservation attention, as they remain the apex predators in African tropical forests, following the continued extirpation of leopards *Pantherapardus*. Furthermore, the African golden cat is most susceptible to human driven habitat change, as it is the only forest obligate carnivore species in African tropical forests (Mugerwa et al. 2013; Bahaa-el-din et al. 2014).

High human activity occurrence in Echuya was recorded (17 of 27 camera sites). High prevalence of human activity in human dominated landscapes as Echuya is not uncommon (Plumptre et al. 2003; Ahumada et al. 2011; Mugerwa et al. 2013). Forest cover was identified as one of the important predictors of human activity in Echuya (Table 3), with a positive association between the two (Fig. 4). This is particularly an interesting result, as it shows that human activity is most prevalent in good quality intact forests. Human presence in areas of high forest cover could be attributed to the fact that forest resources collected by local people are most abundant in areas with good quality forest cover. Moreover, high forest cover forests naturally have higher species diversity and abundance (Ahumada et al. 2011) for human exploitation. These two factors are likely to be the attractants of people in areas with high forest cover.

5.1.2 Habitat selection by large mammals

Habitat selection by large mammals in Echuya was not significantly associated withall the considered covariates (Table 4). However, slope angle, slope aspect and forest cover were the most important covariates, whilehuman activity occurrence was not. Mammals naturally choose good quality habitat, which provides both good cover against predators (for prey species), but also abundant prey. Although, a weak positive association between mammal habitat selection and human activity occurrence was observed (Fig. 6), our models predicted some edge avoidance by Echuya mammals. Terrestrial mammal avoidance of forest edges in human dominated landscapes is not uncommon (Mugerwa et al. 2013; Rovero et al. 2014), and has been suggested as a strategy to avoid human encounters that are most prevalent at forest edges (Olupot 2009; Olupot, Barigyira and Chapman 2009). Since human activity was predicted for most area of Echuya, there is a potential spatial overlap between Echuya mammals and humans. The small acreageof Echuya does not provide niches to wildlife to allow large scale spatial avoidance, leaving no option to wildlife, but to use the same habitat as people. Although wildlife may exhibit behavioural features (such as temporal and fine scale spatial avoidance) that enable them to coexist with humans (Rasmussen & Macdonald 2011; Erb et al. (2012)), this result is of high conservation value. Spatial overlap between wildlife and human increases the vulnerability of the former to direct encounters with people, direct competition for resources and to lethal remote human activity such as snares (Olupot 2009).

5.2 Diversity and distribution of small mammals

Few field studies of small mammals have been conducted in ECFR (Davenport et al. 1996). It is only in the highland swamp of Muchuya that several previous surveys were concentrated (Delany 1975; Kingdon 1971-74) and is where the holotype for the rare highland swamp species *Delanymys brookski*, an Albertine Rift endemic was recorded. This field study is the second to that of Davenport et al. (1996) to survey a large part of the forest for small mammal species richness and diversity as well as distribution within the forest.

Ten species of rodents and one shrew species were recorded during this survey. This study predicted the entire forest to have 13 to 16 species of small mammals. However, Davenport et al. (1996) lists 16 species of rodents and four of shrews known to occur in the forest. During this study, we recorded five species of rodents and one of shrew that had not been recorded in previous surveys. This now makes five shrews and 21 rodent species to be known from ECFR (Appendix 8.1).

Many of the species recorded were forest-dependent. Three Albertine Rift endemics were recorded: rodents – Woosman's Bush-furred Rat (*Lophuromys woosnami)* and Delany's Swamp Mouse *(Delanymys brookski)* and a shrew - Osgood's Montane Shrew *Ruwenzorisorex suncoides.* Delany's Swamp Mouse is a rare Albertine Rift endemic restricted to montane swamps in the Kigezi area of Uganda and the bordering areas of DR Congo and Rwanda (Kingdon 1971-74). The shrew *Ruwenzorisorex suncoides* is also classified as vulnerable to extinction by IUCN.

The small mammal species diversity is very low. This is not surprising given the high altitude of Echuya. Similar conclusion was arrived at for similar habitat - the bamboo zone in Bwindi (Kasangaki et al. 2003) and Rwenzori mountains (Misonne 1963). According to Happold and Happold (1989), high altitude climate becomes progressively more temperate and alpine with seasonal or regular frosts at night. Many small mammal species are not adequately adapted to living under such conditions. Another reason for the low small mammal diversity could be fluctuations in the extent of forest cover following past forest clearance 2,200 BP (Taylor 1990). Given that we only sampled the non-flying small mammal species during the study which are amongst the poor colonizers (Kingdon 1971-1974; Rodgers et al. 1982; Howell and Kingdon 1993), it is probable that many forest-dependent small mammal species could not disperse from the small forest refugia elsewhere into Echuya when the forest was re-vegetated because of less mobility.

There is a high similarity in small mammal species composition between the sampled sites within the forest. This can be attributed to the small size of the forest and lack of sharp boundaries between the habitat types. For example, the altitudinal range of the forest is very narrow implying that some small mammal species' altitudinal range might be greater than that of the whole forest and the vegetation types may not be so well structured so that there is free movement of small mammals between the different microhabitats.

Species accumulation curve did not reach the asymptotic value indicating that the species list derived from this short sampling period is likely to be far from complete. More effort is likely to reveal more species.

5.3 Diversity and distribution of birds

Birds are perhaps the best inventoried taxa in Echuya. Previous studies include Davenport et al. (1996), Mark et al. (2003), Byaruhanga et al. (2001) and Plumptre et al. (2003). Because of the forest harboring a substantial number of Albertine Rift endemics and globally threatened bird species, it has made the forest a biodiversity hotspot in terms of species rarity both nationally (Howard et al. 2000) and within the Albertine Rift (Plumptre et al. 2003). This study was an inventory of bird species to determine the species diversity and distribution.

Echuya Central Forest Reserve is an Important Bird Area in Uganda (IBA) (Byaruhanga *et al.* 2001), including the Muchuya swamp, is known to have a total of 100 bird species recorded of which 12 are Albertine Rift endemics. This study recoded 94 bird species of which 15 were Albertine Rift endemic species. Some highland biome species in the reserve, recorded included such rare species as Handsome Francolin, Rwenzori Batis, Strange Weaver and Dusky Crimson-wing.

There is a high similarity in bird species composition between the sampled sites within the forest. This can be attributed to the small size of the forest that makes the habitat types have no sharp boundaries. For example, the altitudinal range of the forest is very narrow implying that some bird species' altitudinal range might be greater than that of the whole forest and the vegetation types may not be so well structured so that there is free movement of birds between the different microhabitats.

Echuya is intensively exploited because it is the only natural forest remaining in a highly populated area. However, the forest has considerable bird species diversity, and contains many bird species of high conservation value, making it rank highly in terms of rarity value (Howard *et al*. 2000).

Species accumulation data indicate that the species list derived from this short sampling period is likely to be far from complete.

5.4 Diversity and distribution of trees

Early field trips in Echuya were conducted in 1936, 1937 and 1939 by Eggeling, Sangster, and Cree respectively, and data collected during these visits probably influenced the gazetting of Echuya as a forest reserve (Watt 1956). Watt (1956) and Kingston (1968) recorded *Sinarundinaria alpina* as the dominant shrub in the reserve. A more thorough inventory of trees and shrubs species was done in 1993/4 (Davenport et al. 1996). Changes in the vegetation between 1954 and 1990 were recorded by Banana and Tweheyo (2001) noting a reduction in area previously covered by bamboo. Bitariho and McNeilage (2007) looked at the population structure of bamboo with respect to human use.

Echuya forest is not tree species rich. Its tree diversity is very low and is generally a young secondary forest. This is evidenced by the predominance of pioneer or colonizing forest tree species and complete absence of primary forest tree species (Davenport *et al*. 1996; Banana and Tweheyo 2001; this study), even canopy structure with few gaps as well as absence of lianas, epiphytes and large trees. Banana and Tweheyo (2001) provide evidence that in the recent past, the forest was dominated by bamboo. However, the area dominated by bamboo was reduced from 72 percent to less than 40 percent of the forest area between 1954 and 1990 and that of broad leafed tree mixture increased from 17 to 51 percent over the same period. The changes in the vegetation of the forest reflect the environmental history of the area. Areas around Muchuya swamp are believed to have persistently been kept clear of forest during the Holocene ca. 2,200 BP coinciding with the influx of Bantu-speaking agriculturalists and iron-smelting technology (Taylor 1990). Bamboo in Echuya was observed to occur at a rather low altitudinal range 2,286 – 2,500 m compared to other forests – Rwenzori, Elgon, Sabinyo, Mgahinga where it is found at c. 2,450 – 3,050 m (Lind and Morrison 1974; Hamilton 1984). In view of the abundance of fast growing forest trees within the bamboo and the aberrant altitudinal position of bamboo, Hamilton (1984) considers the bamboo forest in Echuya not as an individual forest type, but rather a successional stage toward lower montane forest following montane forest clearance of the past (2,200 B.P.). Tree species richness and diversity reflect the succession trend in the forest with areas in the western part of the forest having high values of richness and diversity because they were colonized by pioneer tree species earlier than the eastern part. Tree colonization of the bamboo is probably accelerated by overexploitation of bamboo (Bitariho and McNeilage 2007) and heavy loads of climbers that suffocate short bamboo (Banana and Tweheyo 2001). Intensive harvesting of bamboo and bamboo death due to heavy climber creates gaps leading to a drastic increase in light level and soil temperature triggering the germination and growth of the light-demanding tree species.

The tree species associations in Echuya were found not to be habitat specific. Being a forest in its early succession stages, the vegetation is predominated by *Macaranga capensis* a forest generalist, *Psychotria mahonii* a non-forest dependant and *Neoboutania macrocalyx* a forest edge species. Such species occupy several different microhabitats. These tree species have light seeds that are dispersed at a distance, often by wind, the reason they are widely distributed but species-poor-efficient dispersal reduces the development of distinct populations (Ghazoul and Sheil 2010). There were few sites in valleys with big trees compared to other slope positions. The valleys are dominated by dense herbaceous growth and are largely devoid of trees because they are water logged through most of the time of year (Hamilton 1969).

Species accumulation data indicate that the species list derived from this short sampling period is likely to be far from complete.

5.4 Diversity and distribution of shrubs and herbs

There are very few studies that have focused on shrubs and herbs in Ugandan forests involving quantitative studies (Poulsen 1997). This is especially so for the non-woody component such as the herbaceous plants on the forest floor, despite the obvious advantage of easy access to forest floor plants. This project had an obvious niche of focusing on ground herbs, a life form which has previously been much overlooked.

Herb and shrub diversity is quite high (72 and 46 species respectively) and they are evenly distributed in the forest. This is because the forest is young and with an open canopy favoring luxuriant undergrowth due to enough light reaching the ground. Herbs are particularly favored by the high level of human disturbance within the forest.
Species accumulation data indicate that the species list derived from this short sampling period is likely to be far from complete.

5.5 Distribution of human activities

The impacts of human activity on tropical forest biodiversity are most prevalent in tropical forests that are characterized by a high human density surrounding them (Ahumada et al. 2011; Ahumada et al, 2013; Cincotta, Wisnewski & Engelman 2000). Because it is the only natural forest accessible in the area in a matrix of a dense human population living a subsistence lifestyle, the local people depend entirely on Echuya for most of their natural resource needs. For example, it is the only source of bamboo for Kigezi area as other sources in the region, Bwindi and Mgahinga, are national parks. In this study, evidence of various human activities was observed within the reserve. People were recorded at 17 of 27 sites by camera traps and domestic animals - dogs, cows and goats - were captured at one site each as signs of human presence. Along the line transects, visible signs of human activity were encountered in 60 out of the 122 sites sampled. There is a high possibility that some human activity signs were not recorded because they were less distinct. Human use of the forest was relatively evenly spread throughout the forest meaning that the whole forest is impacted. Given the small size of Echuya, it is likely that no area in the reserve is free from human disturbance. This makes studies of human impacts on flora and fauna difficult as one cannot find an area to act as a control.

One very worrying aspect of human activity in Echuya is the agricultural encroachment. Unlike other human activities such as bamboo harvesting and livestock grazing that are reported to have been going on for a long time, agricultural encroachment is recent. Given the small size of the reserve, we believe the NFA staff stationed at the reserve is aware of it. Agriculture, more than any other human activity, has the greatest impact on forest structure and composition as it leads to complete destruction of the forest ecosystem (Howard 1991). It is therefore important to examine why the problem has occurred now in a reserve that has little history of agricultural encroachment.

5.6 Conclusion

One potential critique of the this survey is that it is a snap shot in time and it is possible that the taxa populations move around and change in abundance both seasonally and over several years. This is a problem with short surveys that are undertaken. There is need to undertake a similar survey in another season to get a better picture of the taxa surveyed.

Overall, we recorded less species of terrestrial mammals compared to previous surveys. We, however, cannot attribute this difference in species richness to defaunation by humans or to the failure of conservation efforts by NFA. The difference could be due to various reasons; natural fluctuations in populations, seasonality, species interactions, disease, climatic events and community level processes. However, we highlight the high prevalence of human activity in Echuya. Human activity is thus a major threat to mammals and other taxa in Echuya. We also highlight the importance of forest cover in influencing habitat selection of Echuya mammals. We therefore, recommend that the current conservation efforts be strengthened to mitigate human activities, especially those that are likely to reduce forest cover such as tree and bamboo harvesting. Such conservation strategies should target the western, northern and eastern edges of the forest, where, the highest human activity occurrence was predicted.

Furthermore, to gain a better understanding of population trends and corresponding drivers for Echuya terrestrial mammals requires continued monitoring using standardized protocols. The Institute of Tropical Forest Conservation (ITFC), the Uganda Wildlife Authority and the Tropical Ecology Assessment and Monitoring Network (TEAM; www.teamnetwork.org) have been (for past 7 years) monitoring terrestrial vertebrates in Bwindi Impenetrable National Park.

The generated data set has not only highlighted important trends for some populations, but also the use of camera trap data for monitoring tropical forest mammal communities (please see http://wpi.teamnetwork.org/wpi/welcome). Continued monitoring of terrestrial vertebrates using standardized methods following this baseline study will be the only way to measure the impacts of NU conservation initiatives on wildlife conservation in Echuya.

We also encountered fewer species of other taxa (vegetation, birds and small mammals) than what was recorded in previous studies. This could be attributed to sampling within a few days and one season. More effort, like repeated sampling of same sites and in a different could possibly yield a more species including those not reported for the forest. This is evidenced by the small mammal species recorded as new to the forest. However, our results still provide a good picture of the status of biodiversity in the forest. The sampling sites were not significantly different in terms species composition for all the taxa and the species composition of all taxa was not correlated with the environmental variables. This can be attributed to the small size of the forest so that probably the species' altitudinal range is greater than that covered by the forest. Also, the whole forest is still in succession stages as evidenced by trees taking over areas previously covered by bamboo, predominance of pioneer trees like *Macaranga sp* and the aberrant altitudinal position of bamboo. This means that apart from the swamp, other habitat types are probably not used differentially by the fauna. Human activity, which was found to cover the whole forest, could be making some of the species utilize unsuitable habitats by constantly fleeing forest areas that are frequently disturbed by people.

5.7 Specific Recommendations

1. The management plan for Echuya CFR divides the forest into management zones. There is the Strict Nature Reserve that should be managed as a no-go area except with permission. Currently, it is heavily exploited by local people. It is recommended that the Strict Nature Reserve should be protected from all anthropogenic disturbances by marking its boundary so that it is made explicit. The area should be routinely patrolled to prevent any illegal activity taking place.

2. NFA officials at Echuya should immediately put to an end the deforestation and cultivation of crops (Irish potatoes) within the reserve (the natural forest area). The encroached area

should be planted with bamboo to accelerate forest regeneration. NFA should strengthen cooperation with the local governments and courts. Enforcement of the regulations cannot be effective without timely and clear punishment for violators.

3. The Collaborative Forest management communities established by NFA with assistance of NU should be empowered and facilitated to apprehend people conducting illegal activities in the reserve. This can be done by linking the CFM groups to Local Council (LC) government structures (LC 1, LC 3 to LC 5)

4. Decrease on the over utilization of forest resources. The forest resources currently removed from the reserve, especially bamboo, are far more than what is recommended in the management plan.

5. This was a one off survey and done in a very short time spanning a single season. Many species could have been missed as indicated by the species accumulation/rarefaction curves. More intense surveys of same sites are likely to reveal more species and are therefore recommended.
6. Population studies of the Albertine Rift endemics need to be undertaken so that there is more information about the species (habitat, abundance). Such information can be used to show changes over time in relation to NU initiatives.

6. REFERENCES

Ahumada, J.A., Silva, C.E.F., Gajapersad, K., Hallam, C., Mugerwa, B., Hurtado, J., Martin, E., et al. (2011) Community structure and diversity of tropical forest mammals: data from a global camera trap network. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*. 366, 2703-2711.

Ahumada, J.A., Hurtado, J. & Lizcano, D. (2013) Monitoring the Status and Trends of Tropical Forest Terrestrial Vertebrate Communities from Camera Trap Data: A Tool for Conservation. PLoS ONE 8(9): e73707. doi: 10.1371/journal.pone.0073707

Ahumada, J.A., O'Brien, T. & Mugerwa, B. (2015) Camera trapping as a monitoring tool at national and global levels.*Camera Trapping for Wildlife Research* (eds F. Rovero. & F. Zimmerman). Pelagic Publishing.

Andama, E. (2000) Checklist of the mammals of Bwindi Impenetrable National Park, South-Western Uganda. Unpublished report. Institute of Tropical Forest Conservation, Bwindi.

Banana AY and Tweheyo M 2001. The ecological changes of Echuya afromontane bamboo forest, Uganda. *African Journal of Ecology* 39, 366-373.

Bahaa-el-din, L., Henschel, P., Butynski, T. M., Macdonald, D. W., Mills, D., Slotow, R., & Hunter, L. (2015). The African golden cat Caracal aurata: Africa's least-known felid. *Mammal Review*, *45*, 63-77

Bahaa-el-din, L., Henschel, P., Butynski, T. M., Macdonald, D. W., Mills, D., Slotow, R., & Hunter, L. (2015). The African golden cat Caracal aurata: Africa's least-known felid. *Mammal Review*, *45*, 63-77.

Barton, K. (2014). MuMIn: Multi-model inference. R package version 1.10.0. http://CRAN.R-project.org/package=MuMIn

Beschta, R.L. & Ripple, W.J. (2009) Large predators and trophic cascades in terrestrial ecosystems of the western United States. *Biological Conservation,* 142, 2401-2414.

Bitariho R and McNeilage A 2007.Population structure of montane bamboo and causes of its decline in Echuya Central Forest Reserve, SW Uganda. *African Journal of Ecology* 46, 325-332

Brodie, J.F. & Gibbs, H.K. (2009) Bush meat hunting as climate threat. *Science*, 326, 364-365.

Brodie, J.F., Giordano, A.J., Zipkin, E.F., Bernard, H., Mohd-Azlan, J. & Ambu, L. (2015) Correlation and persistence of hunting and logging impacts on tropical rainforest mammals. *Conservation Biology*, 29, 110-121.

Burnham, K. P. & Anderson, D. R. (2002) Model selection and multimodel inference: a practical information-theoretic approach. 2nd ed. New York, Springer-Verlag.

Byaruhanga A, Kasoma P and Pomeroy D 2001. *Important Bird Areas in Uganda*. East Africa Natural History Society, Kampala

Cincotta, R.P. & Wisnewski, J. & Engelman, R. (2000) Human population in the biodiversity hotspots.*Nature*, 404, 990-992.

Davenport T, Howard P and Matthews R (editors) 1996.*Echuya and Mafuga Forest Reserves*. Biodiversity Report No. 22. Forest Department, Kampala, Uganda.

Delany MJ 1975. *The rodents of Uganda*. British Museum of Natural History, London

Effiom, E.O., Nuñez-Iturri, G., Smith, H.G., Ottosson, U. & Olsson, O. (2013) Bush meat hunting changes regeneration of African rainforests.*Proceedings of the Royal Society B: Biological Sciences*, 280(1759).

Erb, P.L., McShea, W.J. & Guralnick, R.P. (2012) Anthropogenic influences on macro-level mammal occupancy in the Appalachian trail corridor. *PLoS ONE* 7(8): e42574. doi:10.1371/journal.pone.0042574

Estes, J.A., Terborgh, J., Brashares, J.S., Power, M.E., Berger, J., Bond, W.J., et al. (2011) Trophic Downgrading of Planet Earth. *Science*, 333, 301-306.

Fernandez, H.M. & Elisabeth S. Vrba, E.S. (2005) Body size, biomic specialization and range size of African large mammals. *Journal of* Biogeography, 32, 1243–1256

Ghazoul J and Sheil D 2010. *Tropical rain forest ecology, diversity and conservation.* Oxford.

Hamilton AC 1969.The vegetation of SW Kigezi.*Uganda Journal* 34(1), 175-199.

Hamilton AC 1984.*Deforestation in Uganda*.Oxford University Press, Nairobi.

Happold DCD and Happold M 1989. Biogeography of small montane mammals in Malawi, Central Africa.*Journal of Biogeography* 16, 353 – 367.

Howard P, Davenport TRB, Kigenyi FW, Viskanic P, Baltzer MC, Dickinson CJ, Lwanga J, Matthews RA and Mupada E 2000. Protected area planning in the tropics: Uganda's national system of forest nature reserves. *Conservation Biology* 14 (3) 858-875

Howell K and Kingdon J 1993. Mammals in the forests of East Africa. In: Lovett JC, and SK Waser (Eds). Biogeography and ecology of the rain forests of eastern Africa.Cambridge University Press, Cambridge.

Kasangaki A, Kityo R and Kerbis J 2003. Diversity of rodents and shrews along an elevational gradient in Bwindi Impenetrable National Park, SW Uganda.*African Journal of Ecology* 41, 115-123.

Kindt R and Coe R 2005.*Tree diversity analysis.A manual and software for common statistical methods for ecological and biodiversity studies.* World Agroforestry Centre (ICRAF), Nairobi. ISBN 92-9059-179-X.

Kingdon J. (1971-1974) East African Mammals: An Atlas of Evolution, Vols I, IIA and IIIB. Academic Press, London

Kingdon, J. (1997) The Kingdon field guide to African mammals. Academic Press Ltd.

Kingston B 1968. *Working Plan for Echuya Central Forest Reserve, Kigezi District, Uganda.* First Revision for the Period 1967-1977. Pp. 16. Entebbe: Uganda Forest Department. Cyclostyled

Laurance, W.F., Croes, B.M., Tchignoumba, L., Lahm, S.A., Alonso, A., Lee, M.E, et al. (2006) Impacts of Roads and Hunting on Central African Rainforest Mammals.*Conservation Biology*, 20,1251-1261.

Lind EM and Morrison MES 1974. *East African Vegetation*. Longman, London

Marks BD, Gnoske TP and Ngabo CKM 2003. Addition to the avifauna of Bwindi Impenetrable Forest and Echuya Forest Reserve, Uganda. *Scopus* 23, 1-6.

Misonne X 1963. Les rongeurs du rwenzori et desregions volsines. *Explor. Parc Natn Albert denx ser* 14, 1 -164.

Montgomery, R. A., Roloff, G. J., & Millspaugh, J. J. (2013). Variation in elk response to roads by season, sex, and road type.*The Journal of Wildlife Management*, 77, 313-325

Montgomery, R.A., Roloff, G.J., Millspaugh, J.J. & Nylen-Nemetchek, M. (2014).Living amidst a sea of agriculture: predicting the occurrence of Canada lynx within an ecological island. *Wildlife Biology*, 145-154.

Mugerwa, B., Sheil, D., Ssekiranda, P., van Heist, M. & Ezuma, P. (2013) A camera trap assessment of terrestrial vertebrates in Bwindi Impenetrable National Park, Uganda. *African Journal of Ecology*, 51, 21-31.

Mugerwa, B. (2013) First photographic record of the Serval cat (*Leptailurus serval*) in Bwindi Impenetrable National Park, southwestern Uganda.*CAT News***59**Autumn, 30-31.

Olupot, W. (2009)A variable edge effect on trees of Bwindi Impenetrable National Park, Uganda, and its bearing on measurement parameters. *Biological Conservation,* 142, 789-797.

Olupot, W., Barigyira, R. & Chapman, C.A. (2009) The status of anthropogenic threat at the people-park interface of Bwindi Impenetrable National Park, Uganda. *Environmental Conservation,* 36, 41–50.

Plumptre, A.J. (2000) Monitoring mammal populations with line transect techniques in African forests. *Journal of Animal Ecology,* 37, 356-368.

Plumptre, A.J., Behangana, M., Davenport, T., Kahindo, C., Kityo, R., Ndomba, E.R., Ssegawa, P., Eilu, G, Nkuntu, D. & Owiunji, I. (2003) The biodiversity of the Albertine rift. Albertine rift technical report No.3, WCS, New York.

Plumptre, A.J., Kayitare, A., Rainer, H., Gray, M., Munanura, I., Barakabuye, N., Asuma, S., Sivha, M. &Namara, A. (2004) The socio-economic status of people living near protected areas in the central Albertine rift. Albertine rift technical reports, 4. 127pp.

Plumptre, A. J.and Reynolds, V. (1997) Nesting Behavior of Chimpanzees: Implicationsfor censuses. *International Journal of Primatology,*18, 475-485.

Poulsen AD 1997.*Plant diversity in the forests of Western Uganda and Eastern Zaire* (Preliminary results).AAU Reports 36.University of Copenhagen.

R Core Team 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

Rasmussen, G.S.A. & Macdonald, D.W. (2011) Masking of the zeitgeber: African wild dogs mitigate persecution by balancing time. *Journal of Zoology*, 286, 232-242.

Rodgers WA, Owen CF and Homewood KM 1982. Biogeography of East African forest mammals. Journal of Biogeography 9, 41-54

Rossi, J.P. (2011) rich**:** An R Package to Analyze Species Richness. *Diversity*, *3,* 112-120

Rovero, F. & Marshall, A. R. (2009) Camera trapping photographic rate as an index of density in forest ungulates. *Journal of Applied Ecology46*, 1011–1017.

Rovero, F., Tobler, M. & Sanderson, J. (2010) Camera trapping for inventorying terrestrial vertebrates. *Manual on field recording techniques and protocols for All Taxa Biodiversity Inventories and Monitoring* (eds J. Eymann., J. Degreef., C. Häuser., C., C.J .Monje., Y. Samyn. & D. VandenSpiegel), pp. 100 –128. Abc Taxa.

Rovero, F., Martin, E., Rosa, M., Ahumada, J. A. & Spitale, D. (2014) Estimating Species Richness and Modelling Habitat Preferences of Tropical Forest Mammals from Camera Trap Data. *PLoS ONE*, *9*(7).

Schielzeth, H. (2010). Simple means to improve the interpretability of regression coefficients. *Methods in Ecology and Evolution,***1**, 103–113.

Sheil, D. & Mugerwa, B. (2013) First pictures of hunting African golden cat.*CAT News***58**Spring, 20-12.

Sheriff, M.J. & Love, O.P. (2013) Determining the adaptive potential of maternal stress. *Ecology Letters*, 16, 271-280.

Silveira, L., Ja´Como, A.T.A. & Filho, A.J.F.D. (2003) Camera trap, line transect census and track surveys: a comparative evaluation. *Biological Conservation*, 114, 351–355.

Taylor D 1990. Late Quaternary pollen records from two Ugandan mires: evidence for environmental change in the Rukiga Highlands of south-west Uganda. *Palaeogeography, Palaeoclimatology, Palaeoecology* 80: 283-300.

Taylor D 1990. Late Quaternary pollen records from two Ugandan mires: evidence for environmental change in the Rukiga Highlands of south-west Uganda. *Palaeogeography, Palaeoclimatology, Palaeoecology* 80: 283-300.

TEAM Network (2009) Terrestrial Vertebrate Protocol Implementation Manual, v. 3.1. Tropical Ecology, Assessment and Monitoring Network, Centre for Applied Biodiversity Science, Conservation International, Arlington, VA, USA.

Tobler, M. W., Carrillo-Percastegui, S. E., Pitman, R. L., Mares, R. & Powell, G. (2008) An evaluation of camera traps for inventorying large- and medium-sized terrestrial rainforest mammals. *Animal Conservation.* **11**, 169–178.

Watt AWM 1956. *Working Plan for Echuya Central Forest Reserve, Kigezi District, Uganda. Period 1956-60*. Pp. 15. Entebbe: Uganda Forest Department. Cyclostyled.

Wilson, D.E. & Reeder, D.M. (2005) Mammal species of the world: Third Edition. A taxonomic and geographic reference.Johns Hopkins University Press, Baltimore.

7 APPENDICES

Appendix 1. List of rodent species recorded from Echuya (Kingdon 1971-74 and Delany 1975[#], Davenport et al. 1996*, and this study 2015[±]) and their conservation status

Species	**Habitat type**	**IUCN category**	**Albertine Rift endemic** (AR)
Rodents			
Dasymys incomtus[#*±]	Swamp open habitats		
Dasymys montanus[#*]	Aquatic/swamp (highland)	Vulnerable	AR
Delanymys brooksi[#±]	Aquatic/swamp (highland)		AR
Dendromus mesomelas[#]	Forest edge		
Hybomys unvittatus[±]	Closed forest		
Grammomys dolichurus[#]	Forest edge		
Lophuromys flavopunctatus[#*±]	Widespread		
Lophuromys woosnami[#*±]	Forest boundary (highland)		AR
Mus bufo[#]	Closed forest (highland)		AR
Mus minutoides[#]	Widespread		
Mus triton[#]	Open/grassland		
Mastomys natalensis[±]	Open/grassland		
Mastomys sp[±]	Open/grassland		

Mylomys dybowskyii[#±]	Open/grassland		
Oenomys hypoxanthus[#]	Forest edge		
Otomys denti[#]	Open/grassland		
Otomys tropicalis[#*]	Open/grassland		
Praomys jacksoni[#*]	Forest edge		
Stochomys longicaudatus[±]	Closed forest		
Thamnomys venustus[#]	Closed forest (highland)		
Uranomys ruddi[±]	Open/grassland		
Shrews			
Crocidura maurisca[#]	Swamp forest		Near-endemic
Crocidura olivieri[#*]	Widespread		
Ruwenzorisorex suncoides [±]	Swamp forest (highland)	Vulnerable	AR
Sylvisorex granti[#*]	Closed forest		
Sylvisorex lunaris[#*]	Closed forest		AR

Appendix 2. List of bird species recorded in Echuya

Bird species	**Conservation status**
African Dusky Flycatcher	
African Harrier Hawk	
African Hill Babbler	
African Paradise Flycatcher	

Archer's Robin-chat	Endemic
Augur buzzard	
Baglafetcht weaver	
Baked chested cuckoo	
Banded parinia	
Barn swallow	
Barred long tailed cuckoo	
Bearded wood packer	
Black cap	
Black crowned tchagra	
Black cuckoo-shrike	
Black headed wax bill	
Black headed wax bill	
Black sow-wing	
Black throated apalis	
Blue headed coucal	
Bronze sunbird	
Brown capped weaver	
Brown throatetd wattle eye	
Chestnut throated apalis	
Chin-spot batis	
Chubb's sisticola	
Cinnamon bracken warbler	
Cinnamon chested bee eater	
Collared apalis	Endemic
Collared sunbird	
Common bulbul	
Common stone chat	
Crowned horn bill	
Doherty's bush shrike	
Double toothed barbet	
Dusky crimson wing	Endemic
Evergreen forest warbler	
Grauer's rush sunbird	
Grauer's rush warbler	Endemic
Grauer's warbler	

Grey crowned crane	
Grey-backed camaroptera	
Grey-headed negro finch	
Handsome francolin	Endemic
Kivu ground-thrush	Endemic
Klaas cuekoo	
Long crested eagle	
Malachite sunbird	
Montane oriole	
Mountain buzzard	
Mountain greenbul	
Mountain illadopsis	
Mountain masked apalis	
mountain yellow warbler	
Narina Trogon	
Northern puff back	
Olive green camaroptera	
Olive pigeon	
Olive thrush	
Pin tailed wydah	
Red chested cuckoo	
Red eyed dove	
Red faced woodland warbler	Endemic
Red-throated Alethe	Endemic
Regal sunbird	Endemic
Ring naked dove	
Rock martin	
Rwenzori batis	Endemic
Rwenzori night jar	Endemic
Scaly breasted illadopsis	
scoherty's bush shrike	
Sharp's starling	
Slate coloured-boubou	
Speckled mousebird	
Strange weaver	Endemic
Streaky seedeater	
Stripe-Breasted tit	Endemic
Tambourine dove	

Thick-billied seed eater	
Tropical boubou	
Variable sunbird	
Waller's starlling	
White browed crombec	
White browed scrub robin	
White chinned parinia	
White eyed slaty flycatcher	
White starred robin	Endemic
White-naped raven	
Yellow bill	
Yellow bishop	
Yellow rumped tinkerbird	Endemic
Yellow whiskerd greenbul	
Yellow white eye	

Appendix 3. List of tree species recorded in Echuya

Scientific name	**Habitat type**
Afrosersasifera cerasifera	F
Agauria salicifolia	F
Aidia maicrantha	Fn
Alangium chinense	F
Albizia grandibracteata	Fn
Albizia gummifera	Fg
Allanblackia kimbiliensis	Fn
Allophylus abyssinicus	F
Allophylus ferugineus	F
Allophylus macrobotrys	F
Aningereria adolfi-friederici	F
Anigeria altissima	Fg
Anthocleista vogelli	Fn
Antiaris toxicaria	Fg
Bersama abyssinica	Fn
Dombeya torida	F
Eucalyptus	Exotic
Hagenia abyssinica	Fn
Galinira saxafraga	F
Lepidotrichillia volkensii	F
Macaranga capensis	Fg
Maesa lanceolata	Fn

Mimulopsis capensis	Fn
Morella salicifolia	Fn
Neoboutonia macrocalyx	F
Nuxia congesta	F
Mystroxylon aethiopian	F
Polyscias fulva	Fn
Psychotria mahoni	Fn
Rytigyinia kigeziensis	Ud
Xymalos monospora	Fg

Key: F – Forest interior; Fg – Forest generalist; Fn – Forest non-dependent; Ud - Undetermined

Appendix 4. Small Mammal Inventory Data Sheet

Date	Time	Species	Site	Trap Type	Bait used	BM (g)	Age	Reprd status	ToL (mm)	TL (mm)	HBL (mm)	EL (mm)

Appendix 5. Bird Inventory Data Sheet

Bird Point Counts

Site	Date	Time	Species	< 20 metres			Flyovers		
				0-3 min	4–5 min	6–10 min	0-3 min	4–5 min	6–10 min

Bird Mist Nets

Site	Date	Net No.	Species	Time captured (within 45 min)	Weather and wind	Time nets open	Time nets closed

Appendix 6. Vegetation Sampling Data Sheet

Environmental characteristics

Site Number:

GPS Coordinates:

Vegetation type:

Altitude:

Slope angle:

Slope position:

Aspect:

Canopy openness:

Ground cover:

Human activity sign(s):

Tree 10 x 10 metre plot

Genus	***Species***	***dbh (cm)***

Shrubs 2.5 x 2.5 metre plot

Genus	*Species*	*No. of individuals*

Herbs 1 x 1 metre plot

Genus	*Species*	*No. of individuals*

Appendix 7. Location coordinates of sampling sites for vegetation, small mammals and birds

	WGS 84 Coordinate system	
Sampling sites	**Eastings**	**Northings**
Transect 1 Plot 1	810412	9863745
Transect 1 Plot 2	810636	9863667
Transect 1 Plot 3	811433	9863049
Transect 1 Plot 4	811657	9862836
Transect 1 Plot 5	811764	9862758
Transect 1 Plot 6	812084	9862525
Transect 1 Plot 7	812490	9862246
Transect 2 Plot 1	810132	9862361
Transect 2 Plot 2	810229	9862299
Transect 2 Plot 3	810435	9862129
Transect 2 Plot 4	810623	9862032
Transect 2 Plot 5	811182	9861761
Transect 2 Plot 6	811276	9861710
Transect 2 Plot 7	811522	9861517
Transect 2 Plot 8	811672	9861424
Transect 2 Plot 9	811787	9861345
Transect 2 Plot 10	812105	9861190
Transect 2 Plot 11	812454	9860898
Transect 2 Plot 12	812598	9860792
Transect 2 Plot 13	812807	9860671
Transect 2 Plot 14	813067	9860481
Transect 2 Plot 15	813198	9860389
Transect 2 Plot 16	813321	9860332
Transect 2 Plot 17	813675	9860098
Transect 2 Plot 18	813863	9859951
Transect 2 Plot 19	814094	9859834
Transect 2 Plot 20	814266	9859742
Transect 2 Plot 21	814405	9859686
Transect 2 Plot 22	814493	9859613
Transect 2 Plot 23	814861	9859294
Transect 3 Plot 1	815598	9857873
Transect 3 Plot 2	815459	9857923
Transect 3 Plot 3	815172	9858059
Transect 3 Plot 4	814849	9858191
Transect 3 Plot 5	814624	9858331
Transect 3 Plot 6	814302	9858460
Transect 3 Plot 7	814154	9858524
Transect 3 Plot 8	813741	9858665
Transect 3 Plot 9	813609	9858714

Transect 3 Plot 10	813547	9858747
Transect 3 Plot 11	813379	9858839
Transect 3 Plot 12	813257	9858925
Transect 3 Plot 13	813068	9859042
Transect 3 Plot 14	812924	9859110
Transect 3 Plot 15	812660	9859248
Transect 3 Plot 16	812520	9859309
Transect 3 Plot 17	811773	9859724
Transect 3 Plot 18	811595	9859849
Transect 3 Plot 19	811495	9859915
Transect 3 Plot 20	811439	9859952
Transect 3 Plot 21	811414	9859969
Transect 3 Plot 22	811237	9860062
Transect 3 Plot 23	811188	9860085
Transect 3 Plot 24	811135	9860136
Transect 3 Plot 25	811111	9860161
Transect 3 Plot 26	810735	9860368
Transect 4 Plot 1	811718	9858226
Transect 4 Plot 2	812185	9858014
Transect 4 Plot 3	812242	9857985
Transect 4 Plot 4	812338	9857943
Transect 4 Plot 5	812388	9857889
Transect 4 Plot 6	812511	9857833
Transect 4 Plot 7	812960	9857547
Transect 4 Plot 8	813532	9857046
Transect 4 Plot 9	813780	9856956
Transect 4 Plot 10	813965	9856884
Transect 4 Plot 11	814101	9856829
Transect 4 Plot 12	814297	9856751
Transect 4 Plot 13	814408	9856682
Transect 4 Plot 14	814535	9856674
Transect 4 Plot 15	814691	9856613
Transect 4 Plot 16	814857	9856539
Transect 4 Plot 17	814945	9856485
Transect 4 Plot 18	815105	9856394
Transect 4 Plot 19	815277	9856319
Transect 4 Plot 20	815390	9856274
Transect 4 Plot 21	815545	9856177
Transect 4 Plot 22	815636	9856127
Transect 4 Plot 23	815749	9856081
Transect 4 Plot 24	826224	9855884
Transect 4 Plot 25	816271	9855864
Transect 4 Plot 26	816297	9855851

Transect 4 Plot 27	816308	9855852
Transect 4 Plot 28	816419	9855819
Transect 4 Plot 29	816574	9855766
Transect 4 Plot 30	816721	9855688
Transect 4 Plot 31	816735	9855683
Transect 4 Plot 32	816841	9855651
Transect 4 Plot 33	816876	9855645
Transect 4 Plot 34	817025	9855602
Transect 5 Plot 35	817192	9855572
Transect 5 Plot 1	812314	9857050
Transect 5 Plot 2	812453	9856977
Transect 5 Plot 3	812540	9856915
Transect 5 Plot 4	812624	9856867
Transect 5 Plot 5	812735	9856791
Transect 5 Plot 6	812915	9856670
Transect 5 Plot 7	812983	9856625
Transect 5 Plot 8	810397	9856566
Transect 5 Plot 9	813204	9856498
Transect 5 Plot 10	813436	9856381
Transect 5 Plot 11	813492	9856335
Transect 5 Plot 12	813539	9855318
Transect 5 Plot 13	813683	9856200
Transect 5 Plot 14	813788	9856129
Transect 5 Plot 15	814076	9855997
Transect 5 Plot 16	814311	9855833
Transect 5 Plot 17	814442	9855781
Transect 5 Plot 18	814518	9855701
Transect 5 Plot 19	814752	9855561
Transect 5 Plot 20	815025	9855382
Transect 5 Plot 21	815247	9855254
Transect 5 Plot 22	815466	9855122
Transect 5 Plot 23	815624	9855029
Transect 5 Plot 24	815695	9854993
Transect 5 Plot 25	815857	9854883
Transect 5 Plot 26	815960	9854822
Transect 5 Plot 27	816067	9854770
Transect 5 Plot 28	816135	9854721
Transect 5 Plot 29	816308	9854658
Transect 5 Plot 30	816493	9854553
Transect 5 Plot 31	816826	9854294