WILDLIFE CONSERVATION SOCIETY

WORKING PAPER NO. 19

BIODIVERSITY SURVEYS OF THE NYUNGWE FOREST RESERVE

In S.W. Rwanda

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Cover Photo: L'Hoest's monkey, *Cerocopithecus lhoesti*

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BIODIVERSITY SURVEYS OF THE NYUNGWE FOREST RESERVE IN S.W. RWANDA

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A view of Nyungwe Forest

INTRODUCTION

Prioritizing conservation action within protected areas

There is a current move within conservation to establish priorities globally for conservation. This comes as a result of the recognition that the current resources available for conservation are not enough to be able to ensure the protection of all the areas we would like to conserve. The World Wildlife Fund (US) has been developing priorities based on ecoregions (Olson and Dinerstein, 1998) and Conservation International has decided to focus its efforts on biodiversity 'hotspots' around the world (Myers et al., 2000). While the relative merits of either method can be debated, neither method helps determine management priorities within existing protected areas. They identify major regions where action should occur but do not help identify where to apply management action within those regions or within protected areas within those regions. The ecoregional planning initiative of WWF is a move towards defining areas within ecoregions on which to focus conservation efforts, but the areas being defined are still large areas of several thousand square kilometers (D. Olson, pers. comm.).

The techniques that have been developed to help priority setting exercises, however, can be used at a more local scale to evaluate the areas of importance for conservation action within protected areas. This working paper uses biological surveys of mammals, birds and trees within the Nyungwe Forest Reserve in southwestern Rwanda to identify the most important areas within this forest for conservation action. A method is presented that can be used to help define zoning of protected areas, identifying the relative importance of sites within a protected area for conservation.

In East Africa there is currently a move towards allowing local communities some access to protected areas and to allow the 'sustainable use of forests.' Prioritization of the relative value of areas located across a reserve is necessary to allow protected area managers to make informed decisions about where different management activities should be developed within the reserve. For instance, if multiple use zones are to be declared within a protected area for medicinal plant harvesting the method described here will help identify areas of lesser importance within the forest where these activities could be located and where the impacts on the forest and its wildlife would be minimized. Furthermore, the method described here can help determine where tourism sites should be located within protected areas so that tourists are able to view a variety of species without visiting (and negatively impacting) the most important sites for conservation.

In this report, three measures of conservation importance are used: a) species richness; b) species endemism and c) complementarity of sites within the forest

In this report, three measures of conservation importance are used: a) species richness; b) species endemism and c) complementarity of sites within the forest (Chapter 6). Each of these measures is quantified at each survey site, thereby allowing a comparison to be made between the relative importance of each site for each method. Three taxa were selected for study primarily based on the ease of identification using existing taxonomic keys. By choosing very different taxa (mammals, birds and trees), it was hoped that the analysis of all three taxa combined would allow these taxa to act as 'umbrellas' for the weighting of sites for other unsurveyed taxa. The congruence between taxa is also examined to evaluate how well one taxa predicts the importance of sites for another taxa. Nyungwe Forest is a good pilot site at which to test the different measures because it contains a relatively rich fauna and flora while at the same time being rich in endemic species.

The Nyungwe Forest

The Nyungwe Forest Reserve in southwestern Rwanda (2°15' – 2°55' S, 29°00'– 29°30' E) is one of the most biologically important montane rainforests in central Africa. In conjunction with the contiguous forest in Kabira National Park, Burundi, Nyungwe forms one of the largest blocks of lower montane forest in Africa (Weber, 1989; Vedder et al., 1992). Nyungwe includes vast stretches of forest at altitudes (1,600 – 2,950 m ASL) occupied by few other forested areas in Africa. Because it is so large and located at these altitudes, Nyungwe represents a key area for rainforest conservation in central Africa.

Although less species rich than several other forests in the Albertine Rift (the western branch of the Great Rift Valley; e.g. Butynski et al., 1997; McNeilage et al., 1998, Omari et al., 1999), Nyungwe supports an abundance of plant and animal life. More than 260 species of trees and shrubs have been found at Nyungwe (Dowsett, 1990), including at least 24 that are believed to be endemic to the Albertine Rift. Nyungwe is also one of the most important sites for bird conservation in Africa with a total of 260 bird species, 25 of which are endemic to the Albertine Rift. Thirteen species of primates are known to inhabit the forest, including chimpanzees (*Pan troglodytes schweinfurthii*), owl-faced guenons (*Cercopithecus hamlyni*) and Angolan black and white colobus monkeys (*Colobus angolensis ruwenzorii*), the latter living in groups of more than 300 individuals.

The forest at Nyungwe is also interrupted by two large swamps, Kamiranzovu and Uwasenkoko. Kamiranzovu Swamp covers approximately 13 km^2 and is one of the largest peat bodies in Africa (Hamilton, 1982).

Temperatures at Nyungwe are generally cool with an average minimum temperature of 10.9° C and an average maximum temperature of 19.6° C (Sun et al., 1996). The mean annual rainfall of 1,744 mm (Sun et al., 1996) is typical for an African rainforest. A major dry season occurs between July and August and a minor dry season takes place between December and January. A recent analysis of the phenological patterns at Nyungwe over a two-year period found that fruit production peaks between March and May, leaf flush peaks in July and August, and flower production peaks in December and January (Sun et al., 1996).

History of Conservation in Nyungwe

Nyungwe was first gazetted as a forest reserve in 1933, yet this status did not prevent people from utilizing the forest. Mining for gold began as early as 1935, following the introduction of alluvial mining techniques by the Belgian colonial administration, and by the 1950s, there were an estimated 3,000 Rwandan miners working in the Nyungwe watershed (Fimbel and Kristensen, 1994). However, gold miners were not the only people exploiting the forest. The forest has been used for a wide range of activities including honey collection, wood cutting, hunting of animals, and small scale agriculture. In fact, between 1958 and 1979 the forest reserve was reduced in size from 1,141 km^2 to 971 km^2 through encroachment by local farmers (Weber, 1989).

The forest has been used for a wide range of activities including honey collection, wood cutting, poaching of animals, and small scale agriculture

In 1967 the Swiss technical assistance program decided to focus on the forestry sector in Rwanda. They initiated a pilot project along the northern edge of Nyungwe Reserve where they established buffer plantations of pine trees and constructed sawmills. The project also placed an emphasis on protecting the remaining natural forest.

In the mid-1970s, representatives of the United Nations Man and Biosphere Program briefly visited Rwanda and soon thereafter published a proposal advocating the complete protection of the entire Nyungwe Forest as an International Biosphere Reserve (Budowski, 1975). This plan was not followed through with, however, both because the proposal was seen by Rwandans as insensitive to their interests and because national parks already made up 10% of the country at the time (Weber, 1989).

In 1984, the Rwandan Ministry of Agriculture, with funds from the Swiss government, completed a management plan for Rwanda's remaining natural forests (Gishwati, Mukura, Nyungwe, and Parc National des Volcans; DGF, 1984; Fimbel & Kristensen, 1994). For Nyungwe, the goal of this plan was to ensure the conservation of the forest by subdividing it into (1) forest fringe zones where some timber harvesting would be permitted (~10% of all forest area), (2) natural reserve zones where minimal use would be allowed (~40% of all forest area), and (3) protected forest management areas where resources could be used sustainably (~50% of all forest area). Pine plantations were to be planted on the edges of the forest to mark the boundaries of the forest reserve and to act as buffers between local communities and the interior of the forest. Once this framework for the management of Nyungwe was established, the forest was divided into four different sectors managed by the Swiss, French, European Development Fund and World Bank, respectively.

In 1984, the New York Zoological Society (now the Wildlife Conservation Society) began working at Nyungwe. The Projet Conservation de la Forêt Nyungwe (PCFN) was established and a research station at Uwinka in the northwest sector of the forest was established. During the early stages of the project, PCFN staff concentrated on undertaking surveys and initiating research on the fauna and flora in the forest around Uwinka. The final report from the initial assessment phase noted that Nyungwe's terrestrial mammal fauna had been depleted by hunting, but that primates were still abundant and that the primate community was exceptionally species rich with at least 13 species existing in the reserve (Vedder, 1988). Vedder (1988) recommended establishing a tourism project, developing education programs for the local communities surrounding the reserve, and training Rwandan biologists in forest ecology and management.

With financial support from USAID, PCFN staff began implementing Vedder's (1988) recommendations in 1987. Over the following years, PCFN staff installed an extensive trail system and built modest tourist facilities at Uwinka, and commenced an education program for the local communities. Unfortunately, the violence that engulfed Rwanda in early 1994 would result in the destruction of many of the research and tourist facilities at Uwinka, and effectively put an end to tourism at Nyungwe for the remainder of the decade.

The 100 days during which most of the genocide was carried out were a period of violence and suffering almost unparalleled in modern human history

The 100 days during which most of the genocide was carried out were a period of violence and suffering almost unparalleled in modern human history (Human Rights Watch, 1999). No part of Rwanda, including the Nyungwe area, escaped the extermination campaigns by extremist Hutu militia members known as Interahamwe. Since many of them were targets of the *genocidaires*, senior PCFN staff fled the country (Fimbel and Fimbel, 1997), but most of the junior staff remained and continued working despite the threats they faced in the forest. This dedication on the part of the junior staff was particularly impressive considering that they failed to receive any payment for their work throughout much of 1994 (Fine, 1995; Fimbel and Fimbel, 1997). The project hired a new director in 1995, Eugene Rutagarama, who was succeeded in 1997 by Michel Masozera, and more recently by Ian Munanura, the current director of PCFN. Under the guidance of Rutagarama and Masozera, the research station and tourist facilities at Uwinka have been repaired and a small stream of researchers and tourists have begun to return to Nyungwe.

Long-term biological research at Nyungwe

Long-term biological research began at Nyungwe in 1987 when Amy Vedder commenced ecological research on a group of Angolan black and white colobus monkeys (*Colobus angolensis*) near Uwinka. During the next 7 years, additional research on primate behavioral ecology was conducted on l'hoesti's monkeys (*Cercopithecus lhoesti*) and blue monkeys (*Cercopithecus mitis*) by Beth Kaplin (Kaplin, 1998; Kaplin, 2001; Kaplin et al., 1998; Kaplin and Moermond 1998, 2000) and on colobus monkeys by Cheryl Fimbel (Fimbel et al., 2001). During the same period, Chin Sun (Sun, 1995; Sun and Moermond, 1997; Sun et al., 1997a, 1997b) studied the behavioral ecology of 3 sympatric turaco species (*Corythaeola cristata*, *Musophaga johnstoni*, *Tauraco schuetti*) inhabiting the Uwinka area. Sun, Kaplin and others also collaborated on a study of the phenological patterns of more than 500 trees near Uwinka (Sun et al., 1996). The genocide put a halt to most biological research in 1994, but several projects have been initiated or re-initiated at Nyungwe over the past few years. Current research at Nyungwe is being carried out by Rwandan WCS field staff and focuses on phenological monitoring (supervised by Michel Masozera and Beth Kaplin), chimpanzee (*Pan troglodytes*) ecology (supervised by Michel Masozera and Ian Munanura), habituation of owl-faced guenons (*Cercopithecus hamlyni*; supervised by Michel Masozera and Ian Munanura), and colobus monkey behavior and grey-cheeked mangabey (*Lophocebus albigena*) ecology (supervised by Peter Fashing, Felix Mulindahabi and Nga Nguyen).

Prior biodiversity surveys at Nyungwe

Although a number of intensive ecological and behavioral studies have been carried out around Uwinka, far less has been done to catalogue and examine the patterns of biodiversity across the entire Nyungwe Forest reserve. The earliest surveys of animals in the reserve were carried out in the late 1970s. At this time, Storz (1982) conducted a one-year survey to catalogue the mammals inhabiting Nyungwe, while Jean-Pierre Vande Weghe made numerous short visits over a several year period to record avifauna in the forest. Storz's study was followed by a more quantitative survey of the mammals in the northwest of the reserve by Vedder (1988) in the late 1980s. In late 1989 and early 1990, R. Dowsett and F. Dowsett-Lemaire carried out a survey at Nyungwe that concentrated mostly on birds, but also focused on mammals, butterflies, amphibians and plants (Dowsett, 1990). Dowsett (1990) and Dowsett et al. (1990) combined the results of their own surveys with those that had been done before to provide a reasonably thorough list of species for the reserve. Nevertheless, Dowsett (1990) opined that there were probably other species not sighted during the surveys that might also inhabit the reserve (Dowsett, 1990). This suspicion soon proved to be correct when the rare owl-faced guenon, *Cercopithecus hamlyni*, was discovered to be living in the bamboo forest in Nyungwe's southern sector (Gibson, 1992).

The rare owl-faced guenon, *Cercopithecus hamlyni,* was discovered to be living in the bamboo forest in Nyungwe's southern sector

Nyungwe survey schedule and general survey techniques

The surveys of trees, birds, mammals and signs of human use described in this report were conducted from June 22 – August 26, 1999. At the outset, PCFN staff members were divided into six survey teams: two teams to focus on mammals and human signs, two teams to focus on birds, and two teams to focus on plants. Each team was taught the survey methods during a one-week training course at Uwinka led by Alastair McNeilage and Andrew Plumptre. Most staff members were already familiar with many of the survey techniques through their participation in PCFN's long-term monitoring project on mammals and birds near Uwinka. Skills covered during the training course at Uwinka included GPS operation, map reading, compass and altimeter use, hipchain use, estimation of nest and dung ages, and data recording. During the final stage of the training course, the six teams cooperatively surveyed Uwinka. After the survey of Uwinka had been completed, the surveyors split into two groups of three teams each so as to more efficiently survey the remaining 12 sites. Over the next two months, the two groups surveyed six sites each. A map of the sites surveyed is provided in Figure 1.1.

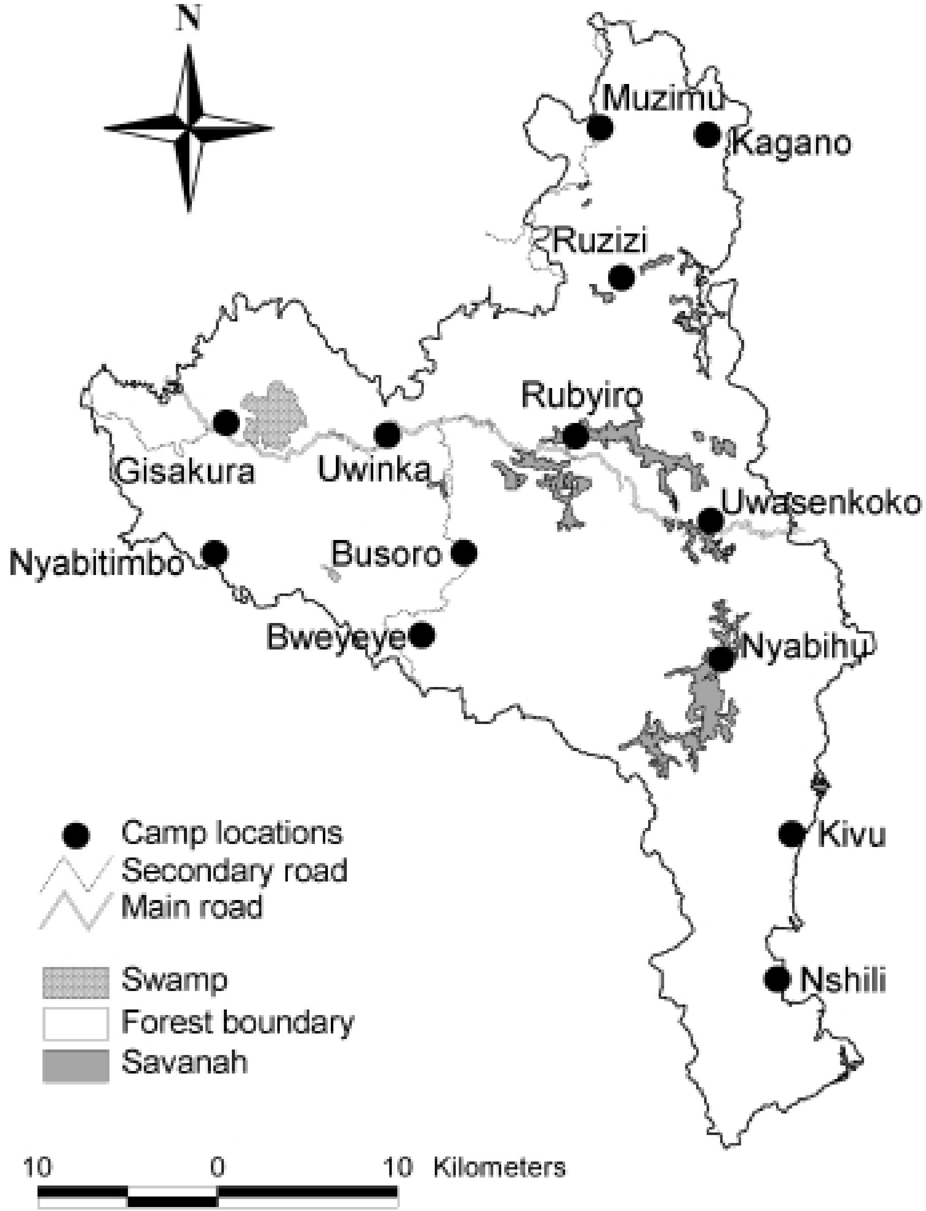


Figure 1.1. Map of the Nyungwe Forest showing the locations of sites used as base camps during the biodiversity surveys.

Upon first arriving at a site, the surveyors set up camp and planned out the next day's activities. Bird team members set up mist nets on the day of arrival which they then checked early each morning for the remainder of their days at the camp site. On the second morning, the mammal and human signs team established and surveyed the first 'reconnaissance route' (Walsh and White, 1999; see Chapter 2). The botany team followed behind the mammal and human signs team, while the bird team waited until the next morning to walk the reconnaissance route. A total of 4-8 reconnaissance routes were walked by

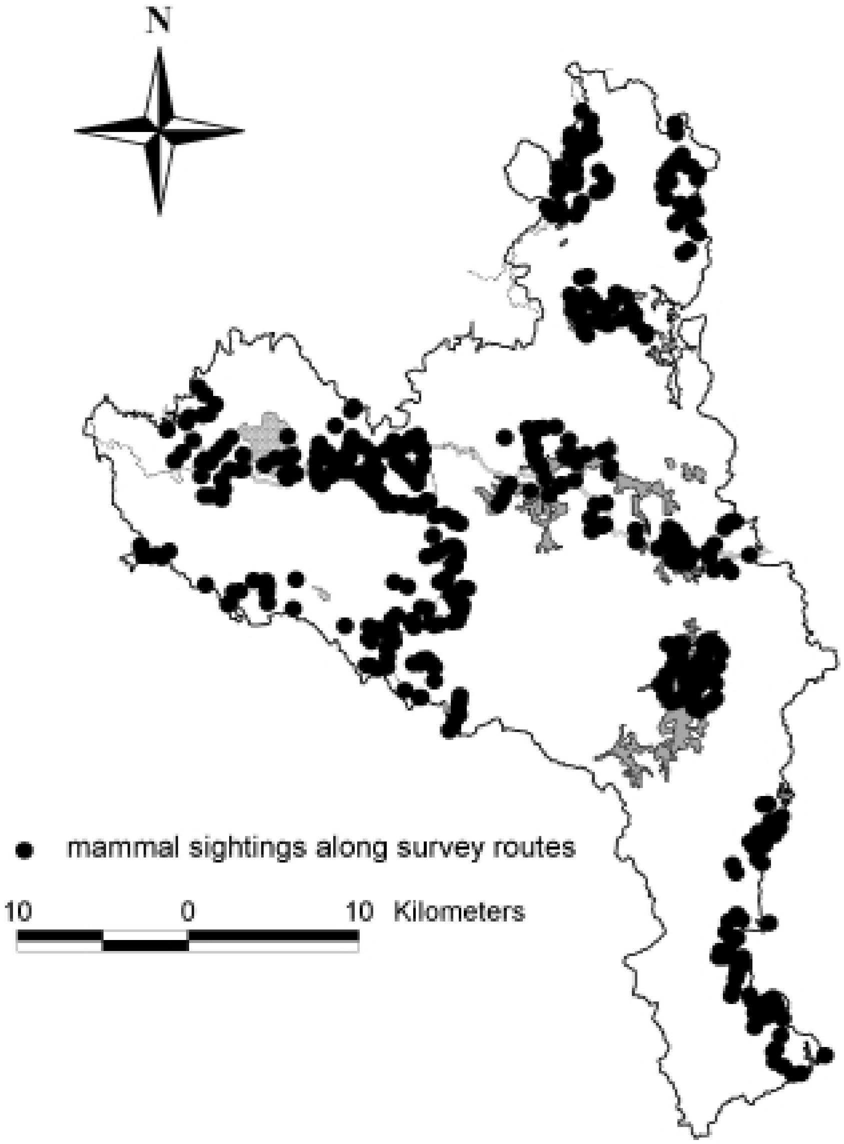


Figure 1.2. Paths taken during reconnaissance surveys of the Nyungwe Forest.

The specific methods employed by each of the teams and the results of the surveys conducted by these teams will be discussed in the next three chapters. In Chapter 2, we focus on the species richness and distribution of mammals within the reserve and the levels of human impact on different areas of the reserve. In Chapter 3, we describe the species richness, diversity, and distribution of birds in the reserve. In Chapter 4, we focus on tree species richness, diversity and distribution in the reserve. In Chapter 5, we discuss the results of the long-term monitoring program for birds and mammals in the Uwinka and Gisakura areas. Finally, in Chapter 6, we integrate the results presented in previous chapters and identify priority areas for conservation within the reserve.

The main road through Nyungwe Forest

MAMMAL DISTRIBUTIONS AND HUMAN IMPACTS

Introduction

Nyungwe has long been recognized as having one of the most species rich montane rainforest primate communities in Africa (Vedder, 1988). Less is known, however, about the other mammals inhabiting the reserve. At least 20 mammal species are believed to be endemic to the Albertine Rift, most of them rodents and insectivores (Burgess et al., in prep.). Because our surveys mainly focused on large mammals, we did not investigate the distribution of many of the Albertine Rift endemics. However, we did attempt to determine the distribution and relative abundance of three mammals believed to be near endemics to the Albertine Rift (Note: "near endemic" refers to species whose ranges are almost, but not entirely, restricted to the Albertine Rift): one large rodent, the Ruwenzori sun squirrel (*Heliosciurus ruwenzori*), and two primate species, l'hoest's monkey (*Cercopithecus lhoesti*) and the owl faced monkey (*Cercopithecus hamlyni*). In addition, we were able to determine the distribution and abundance of a number of other large mammal species across the reserve.

Human disturbance has long been a problem at Nyungwe (Weber 1989), though it is believed to have intensified in the years following the genocide in 1994. One of the purposes of our survey was to investigate patterns of human disturbance and the effects of this disturbance on the large mammal communities across the reserve.

Methods

A set of standardized methods were used to conduct surveys for mammals and human signs at 13 sites around the forest. At each site, the mammal and human signs team conducted up to 8 'reconnaissance surveys' (Walsh and White, 1999). Reconnaissance surveys followed pre-existing human or animal paths wherever practical to minimize disturbance to the forest and to increase the distance that could be covered on a given day. Since line transect samples were not conducted in addition to reconnaissance surveys, the bias in measures of relative abundance introduced by walking along existing trails during reconnaissance surveys could not be determined (Walsh and White, 1999). Most reconnaissance routes followed paths that looped back to or near the starting point, and in many cases it was necessary to cut paths so that the reconnaissance route could achieve this configuration. On those occasions when it proved necessary to cut a path, team members chose the route of least resistance (i.e. least undergrowth or other obstacles) in the general direction in which they were heading.

At each site, the mammal and human signs team conducted up to eight 'reconnaissance surveys'

The areas to be surveyed at a given site were selected so as to be as representative as possible of the overall habitat composition of the site and to maximize the area that could be covered. Surveys also covered forested areas in as many directions as possible around each campsite.

Each reconnaissance survey route at a site was assigned a different letter, beginning with A on the first day, B on the second day, and so forth. Each day, the team walked a different survey route with one team member wearing a hip chain so that the distance walked could be measured. At every 200 meter interval along the survey route, a team member tied a piece of flagging tape to a nearby tree to indicate sampling locations to be used later by the botany and bird teams (see Chapters 3 and 4). At these points and the first and last points along each reconnaissance survey route, a team member obtained and recorded a GPS reading and an Estimated Position Error for the team's location using a Garmin II Plus GPS unit.

For each sighting, the time, GPS position, altitude, mammal species or type of human sign identified, method of identification (sight, sound, dung, or nest), number of individuals identified, and habitat type where the species or sign was detected were noted. Sight was the most common method of identifying some mammals, including many primates. Clearly, with shy mammals, such as owl-faced guenons or chimpanzees, or nocturnal mammals, such as bushpigs, however, sound, dung, tracks or nests were more common indicators of a species' presence

Human signs that were recorded whenever encountered included:

- snares and traps
- tree cutting
- bamboo cutting
- honey collection or beehives
- poacher sign
- huts
- camps
- gold mining
- cattle sign
- clearing
- agriculture
- burned areas
- troughs or pits

Poacher signs included all signs of poachers that did not fall into the categories of camps or snares and traps. Surveyors most often found snares and traps by following narrow human-made paths that led a short distance away (approximately 5-8 meters) from the reconnaissance route. Any traps or snares discovered were dismantled since trapping is illegal in Nyungwe Forest.

Surveyors classified the habitat type where each mammal or human sign was sighted as falling into one of the following nine categories:

Closed forest: 50% or more of the forest canopy is closed
Open forest: less than 50% of the forest canopy is closed
Clearing: open areas of at least 30 m long that are dominated by *Sericostachys*, *Mimulopsis*, and other secondary vegetation.
Fern: forest gaps dominated by ferns, often on open slopes
Human clearing: open areas that were cleared by humans through techniques other than fire
Marsh: areas dominated by waterlogged soil
Bamboo: areas dominated by bamboo
Savanna: areas dominated by grasslands that may or may not also include trees
Burned zones: regions of the forest that were recently burned and have yet to regenerate

Surveyors most often found snares and traps by following narrow human-made paths that led a short distance away from the reconnaissance route

Results

Survey routes

Surveys for mammal and human signs were conducted over a total of 346 km along 74 reconnaissance routes at 13 sites (Table 2.1). The mean distance walked along each route was 4673 m (S.D.=1252, range: 2003m - 8560m; n=74).

Table 2.1. The total distance walked, number of trails walked and average trail length for mammal and human signs surveys.

Dates	Site	No. of trails	Average trail length (m)	Total distance (m)
6/22-6/28	Uwinka	8	4488	35902
6/30-7/5	Busoro	5	4475	22376
6/30-7/6	Gisakura	7	5733	40131
7/7-7/13	Bweyeye	6	5169	31012
7/8-7/13	Nyabitimbo	5	4592	22960
7/21-7/24	Kivu	4	4113	16452
7/21-7/26	Nshili	6	4632	27790
7/29-8/3	Uwasenkoko	6	3833	23000
7/30-8/3	Nyabihu	5	4519	22593
8/13-8/17	Rubyiro	5	5432	27158
8/14-8/19	Ruzizi	6	4794	28761
8/20-8/24	Kagano	5	4315	21573
8/21-8/26	Muzimu	6	4344	26066
Total		74	4673	345774

Mammals

Species richness and endemism

Signs of at least 18 species of mammals were found during the surveys. Fifteen of these mammals could be identified to species, 1 to genus and 2 to general categories (large and small duikers). Species richness was highest at Uwinka and Gisakura (both western sites) where at least 11 species were found to be present at each site (Figure 2.1). Species richness was lowest in the north of the park at Kagano and Muzimu.

One Albertine Rift endemic (Ruwenzori sun squirrel) and one near endemic (lhoesti's monkey) were detected during surveys. At least one of the two species was found at all 13 sites: 6 sites had both species and 7 had 1 species (Figure 2.1). A third species (owl-faced guenon) known to exist at one site (Nshili) was not detected during surveys.

Species richness was highest at Uwinka and Gisakura (both western sites) where at least 11 species were found to be present at each site

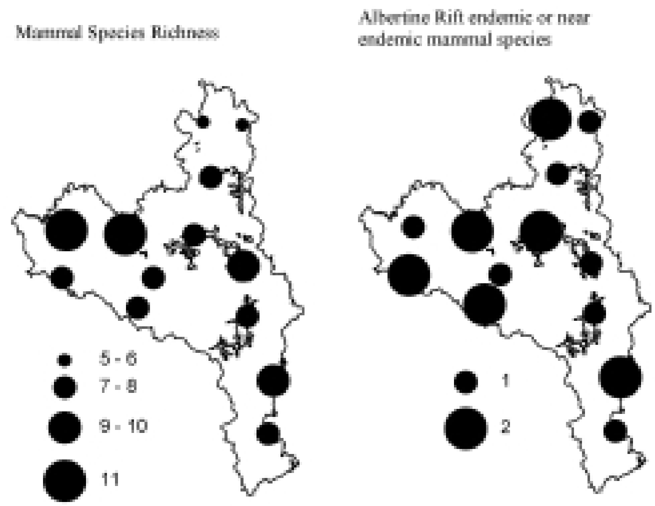


Figure 2.1. Mammal species richness and number of Albertine Rift endemic or near endemic mammal species at the 13 survey sites.

Encounter rates

Primates

Primates were detected by sight, sound, dung, tracks and, in the case of chimpanzees (*Pan troglodytes*), nests. The rates of encounters with all primates combined (excluding chimp nests) are presented in Figure 2.2. Primate signs were most common at sites in the west, center and southeast of the forest.

Signs of blue monkeys (*Cercopithecus mitis*) and l'hoesti's monkeys (*Cercopithecus lhoesti*) were found across much of the reserve, while signs of colobus monkeys (*Colobus angolensis*) were found only in the west and near the northern tip of the reserve (Figure 2.3). Mangabeys (*Lophocebus albigena*) were found primarily in the west, though they were sighted in the south as well, while baboons (*Papio anubis*) were found only at one site in the west and at one site in the south. Three other species of diurnal monkey (redtail monkeys: *Cercopithecus ascanius*, mona monkeys: *Cercopithecus mona*, and owl-faced guenons: *Cercopithecus hamlyni*) known to exist at Nyungwe were not detected or identified during the surveys. Signs of chimpanzees (excluding nests) were found at all 13 sites, most often in the western portion of the reserve.

Chimpanzee nests were also found at 12 of the 13 survey sites and were particularly common (≥2 nests/km) at sites in the west and near the northern tip of the reserve.

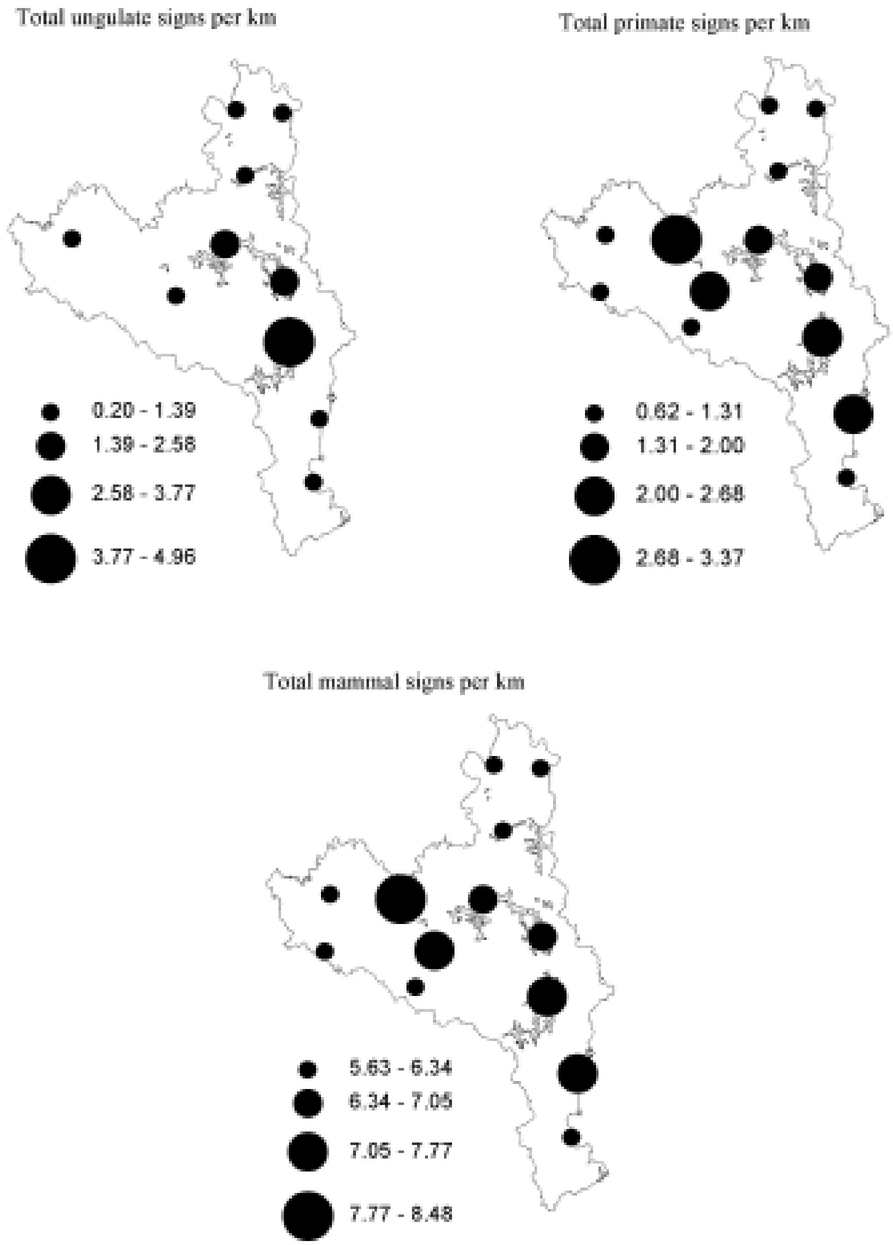


Figure 2.2. Encounter rates with signs of ungulates, primates, and all mammals combined per kilometer walked.

Ungulates and Elephants

Signs of at least one species of ungulate were found at most survey sites (Figure 2.2). Signs of bushpigs (*Potamochoerus larvatus*) were found at all of the sites in the higher elevation eastern part of the reserve from the northern tip at Muzimu and Kagano to the southern tip at Nshili (Figure 2.4). Their signs were particularly common at Nyabihu. Bushpigs were also the ungulate most often detected at 8 of the 10 sites where signs of ungulates were found. Signs of duikers of any species (*Sylvicapra* sp. or *Cephalophus* sp.) were found primarily in the eastern part of the reserve, and as with bushpigs, most commonly at

Signs of chimpanzees were found at all 13 sites, most often in the western portion of the reserve

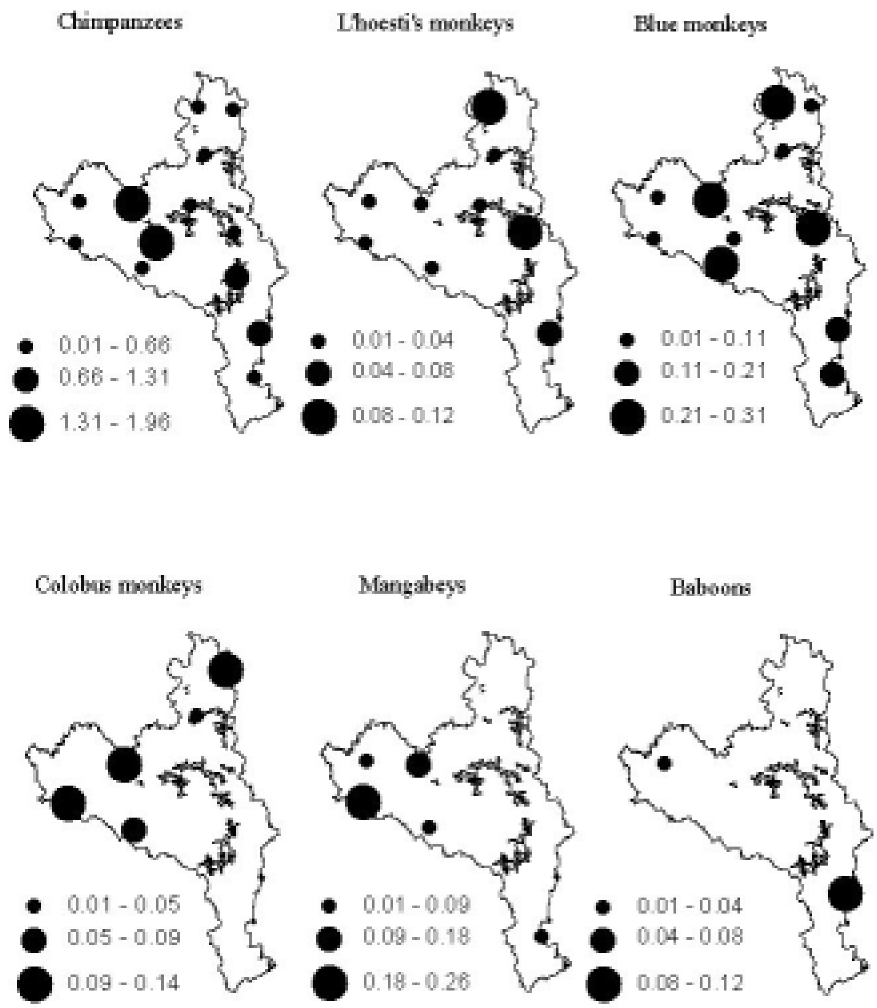


Figure 2.3. Encounter rates (signs/km) with signs of six primate species at Nyungwe. (note: chimpanzee identifications based on nests are not included in this figure)

Nyabihu. Encounter rates with signs of all ungulates combined were much higher at Nyabihu than at any other site (Figure 2.2). The tracks and dung of at least one elephant (*Loxodonta africana*) were found in the west near Kamiranzovu marsh, though this elephant is believed to have been poached soon thereafter (Figure 2.4).

Carnivores

Carnivores were most often detected by their dung. The only carnivore observed directly was a serval (*Felis serval*) at Uwasenkoko. Carnivores for which dung or tracks were believed to have been found included servals, genets (*Genetta* sp.), otters (Herpestidae), and mongooses (Lutrinae), though these identifications could not be made with complete certainty. Since carnivores are often difficult to distinguish from one another by their dung, or even by their tracks, they have been lumped together here under the general category of carnivores.

Evidence of carnivores was found at 8 sites (Figure 2.4). Rates of encounter with carnivore signs were highest at Gisakura, though even there, only 0.175 carnivore signs were found per kilometer walked.

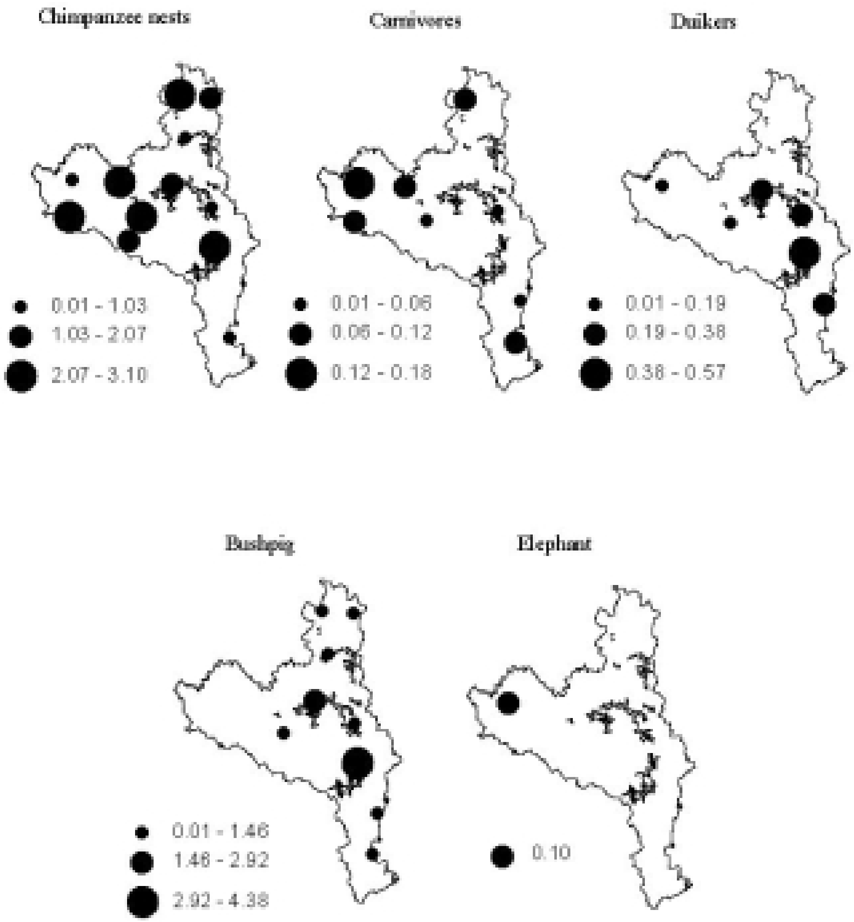


Figure 2.4. Encounters rates with chimp nexts (nests/km), signs of carnivores (signs/km), and signs of three taxa of ungulates (signs/km). (note: the elephants signs found at Gisakura are believed to be from the last elephant at Nyungwe which is believed to have been poached several months after the surveys ended)

Rodents

Most evidence of rodents came from dung or tracks. Gambian rats were detected at only 3 sites, all in the east (Figure 2.5). They were also encountered in traps or snares at 4 additional sites, Muzimu, Nyabitimbo, Ruzizi, and Uwinka. Tracks of porcupines (*Hystrix* sp.) were found at only 2 sites, Uwinka and Gisakura. Porcupines were also encountered in traps at Uwinka.

Squirrel (Sciuridae) sightings were not recorded by the mammal team, though team members did note that squirrels were found in traps or snares at Busoro and Uwasenkoko. The bird team, however, noted and identified squirrels on an opportunistic basis during their surveys for birds. Three species of squirrels were recorded by the bird team during surveys, Boehm's squirrel (*Paraxerus boehmi*), the fire-footed rope squirrel (*Funisciurus pyrropus*), and the Ruwenzori sun squirrel (*Heliosciurus ruwenzori*). The latter species is endemic to the Albetine Rift and was observed at most sites across the reserve (Figure 2.5).

Boehm's squirrel and the fire-footed rope squirrel were sighted at fewer sites, most of which were in the west of the reserve. Three sites in the west (Bweyeye, Busoro, and Uwinka) were the only sites where all 3 species of squirrel were observed. Two species of squirrel were observed at 3 sites and 1 species of squirrel was observed at 6 sites. No squirrels were directly observed by the bird team at Uwasenkoko, though the mammal team found a squirrel in a trap there that they did not identify to species.

Human signs were encountered at the highest rates in the extreme north and south of the reserve

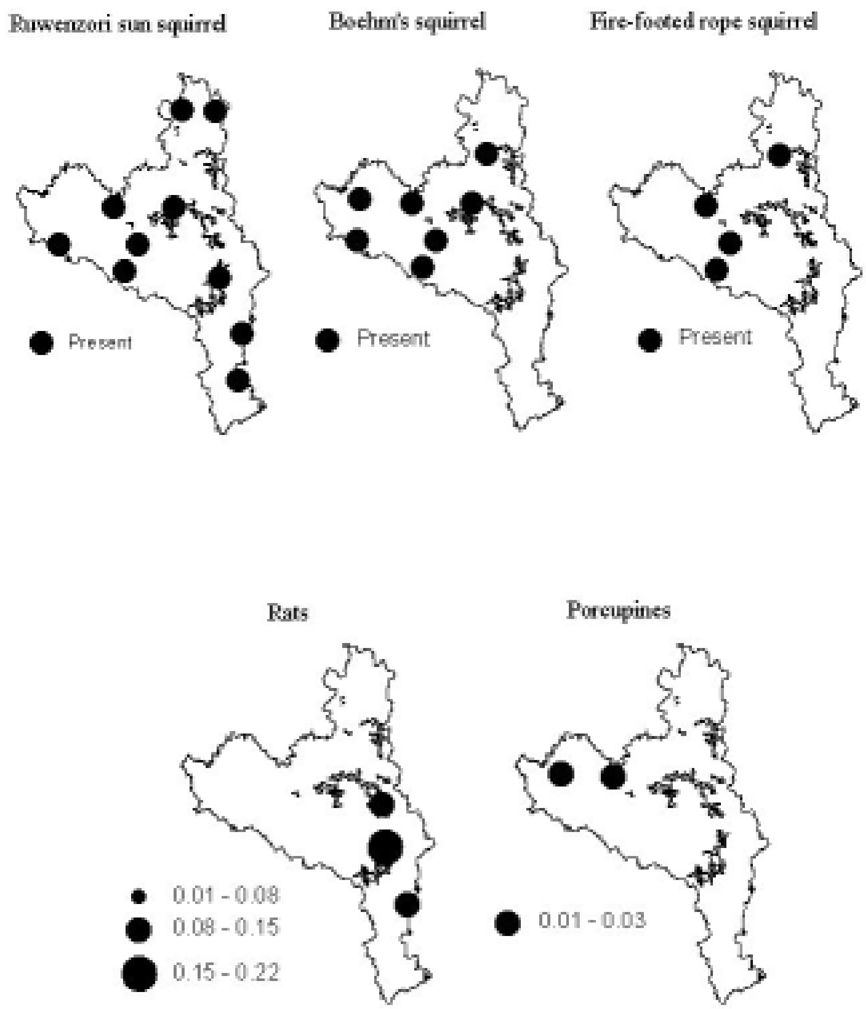


Figure 2.5. Locations where 3 species of squirrels were sighted and encounter rates (signs/km) with rats and porcupines.

All mammals

Encounter rates with all mammal taxa combined varied widely between sites (Figure 2.2). Mammals were most often encountered in the west, center and southeast of the reserve.

Human signs

Rates of encounters with human signs ranged from 1.4 - 5.0 signs/km (Mean=2.9 signs/km, S.D.=1.2, n=13) at the various sites (Appendix 2.2). Human signs were encountered at the highest rates in the extreme north and south of the reserve at Muzimu and Nshili, respectively. Rates were lowest at Uwinka and Rubyiro. Snares and traps were found at all sites and were the most frequently encountered type of human sign at most sites. Snares and traps were most often encountered at Kivu (2.0 snares and traps/km), though they were also commonly encountered ($\geq$1.0 snares and traps/km) at Muzima, Uwasenkoko, Busoro, and Nyabitimbo. A total of 27 animals were found trapped in the 317 snares and traps discovered during these surveys at Nyungwe. Animals found in traps included blue monkeys, duikers, bushpigs, porcupines, squirrels, Gambian rats, francolins, and one monkey that was not identified to species.

Other forms of human disturbance found at more than half of the 13 sites included felled trees, burned areas, signs of poachers, signs of honey collection, and camps. Evidence of gold mining was encountered at 6 sites, 5 of which were in the western part of the reserve. Agricultural fields were encountered at 4 sites, most often at Nshili and Bweyeye. These fields included at least one of the following crops: beans, cabbages, sweet potatoes, or tobacco. Evidence of cattle entering the reserve was discovered at only 3 sites, most often at Nshili. Signs of bamboo cutting were found only at Nshili, the site where bamboo was most abundant. Clearings were encountered on only 2 occasions, both at Nyabihu. Finally, huts were found in the reserve on only 1 occasion (at Bweyeye).

A relatively large and viable population living at one of the highest altitudes yet recorded for chimpanzees

Relationship between human signs and mammal signs

Spearman rank correlations were used to investigate the relationship between signs of human disturbance and signs of large mammals (Table 2.2). There were no significant correlations between signs of snares or traps, camps, tree cutting or honey collection with signs of any of the large mammals. There were significant negative correlations ($p<.05$) between poacher signs and signs of chimpanzees, mangabeys, and all large mammals combined. There were also significant negative correlations ($p<.01$) between signs of gold mining and bushpigs, and between signs of gold mining and signs of all ungulates combined. Finally, there was a significant positive correlation ($p<.01$) between signs of gold mining and signs of mangabeys.

Table 2.2. Spearman rank correlation coefficients (r_S) for the relationships between signs of human disturbance and of large mammals at 13 sites. Correlation coefficients in **bold** have $p<.05$.

	Total human disturbance	Snares or traps	Poacher signs	Camps	Tree cutting	Honey collection	Gold mining
Chimp nest	0.022	0.011	-0.429	0.268	0.516	0.055	0.233
Chimp[1]	-0.444	-0.209	**-0.637**	-0.241	-0.121	-0.358	0.293
Baboon	0.061	0.157	0.236	-0.255	-0.280	-0.105	0.028
Blue	0.302	0.242	-0.025	-0.122	0.360	0.003	0.311
Colobus	-0.297	-0.323	-0.166	-0.368	0.075	-0.019	0.375
L'hoesti	0.351	0.426	0.267	0.303	0.128	0.078	-0.270
Mangabey	-0.113	-0.304	**-0.573**	-0.325	0.351	-0.256	**0.821**
Total Primates[1]	-0.185	0.027	-0.560	-0.232	0.022	-0.223	0.054
Duiker	-0.090	0.179	-0.030	-0.045	-0.340	-0.302	-0.383
Bushpig	0.042	0.089	0.460	0.168	-0.340	0.361	**-0.878**
Total Ungulates	-0.022	0.099	0.519	0.175	-0.409	0.324	**-0.901**
Carnivores	-0.502	-0.480	-0.254	-0.196	-0.463	-0.291	0.086
Porcupine	-0.552	-0.515	-0.253	-0.255	-0.218	-0.472	0.560
Rat	0.089	0.327	0.108	-0.365	-0.208	-0.143	-0.473
Grand Total[1]	-0.215	-0.011	**-0.593**	-0.260	0.000	-0.393	0.167

[1] not including chimpanzee nests

It should be noted that it would be careless to disregard the possibility that some or all of the small number of significant correlations produced by the above analysis might be spurious. Whenever a large number of correlations are run on a dataset, a small percentage can be expected to have resulted by chance alone and have no biological meaning. In the case of the above analysis, 105 correlations were run with only 6 significant results at the $p<.05$ level and only 3 significant results at the $p<.01$ level. A more thorough long-term investigation of the relationship between human disturbance and mammal distribution and abundance is presented in Chapter 5 for one region of the forest.

The region of Nyungwe most deserving of further primate surveys is Nshili

Discussion

Mammals

Primates

The fact that Angolan colobus monkeys were detected at only 5 sites during the surveys was both surprising and alarming. This result suggests that the large groups of Angolan colobus monkeys for which Nyungwe is well-known are not widely distributed across the reserve. Since Nyungwe is the only forest in Africa where colobus monkeys form extremely large super-groups (as many as 350 animals), it is essential that the groups that remain are protected. The colobus super-groups have considerable potential for attracting tourists to Nyungwe as Rwanda's socio-political climate becomes more favorable to tourism.

Although the survey results for colobus monkeys were not particularly encouraging, our surveys provided a more optimistic picture for chimpanzees. We found that chimpanzees were widespread across the reserve, occurring at all 13 survey sites. As what appears to be a relatively large and viable population living at one of the highest altitudes yet recorded for chimpanzees (McGrew et al., 1996), the chimpanzees at Nyungwe provide valuable opportunities for both conservation and research into their behavioral ecology at high altitudes. With one troop already semi-habituated near Uwinka, the excellent possibilities for chimpanzee viewing should also attract an increasing number of tourists to Nyungwe.

Nyungwe represents an important location for the conservation of l'hoest's monkeys, a species whose range is restricted to the Albertine Rift and a region of lowland forest in eastern D.R. Congo. Nyungwe is the only location where these typically elusive monkeys have been habituated and studied intensively (Kaplin and Moermond, 1998, 2000). Our 1999 surveys recorded them as present at 9 of 13 sites, and Fashing recorded them at a tenth site during surveys for owl-faced guenons at Nshili in May, 2000. Therefore, as a large forest where l'hoesti's monkeys are widely distributed, Nyungwe represents a key location for their conservation.

Redtail monkeys were one of three species of diurnal primate known to exist at Nyungwe that were not detected during the surveys. They have long been reported to be very rare at Nyungwe, primarily inhabiting forested areas at relatively low elevations within the reserve, though in 1992 Kaplin (pers. observ.) observed two redtails living in a blue monkey group near Uwinka at an elevation of 2500 m. Despite their rarity at Nyungwe, redtails are known to be widely distributed across many of the lowland forests of East and Central Africa. Mona monkeys are also believed to be quite rare at Nyungwe and we failed to detect them at all 13 survey sites, though they are known to still exist in the Bururi area about 10 km from Uwinka (Fashing, pers. observ.), and were observed regularly around Uwinka in the early 1990s (Kaplin, pers. observ.). Like redtails, mona monkeys are widely distributed, though mostly across Central and West Africa.

The region of Nyungwe most deserving of further primate surveys is Nshili. The bamboo forest in this area is home to the owl-faced guenon, a notoriously shy and elusive primate not detected during our 1999 surveys. Owl-faced guenons are near endemics to the Albertine Rift and are listed as vulnerable by IUCN (1996). Furthermore, almost nothing is known about owl-faced guenon ecology and conservation status throughout their limited range in central Africa. Fashing and several PCFN staff members spent 3 full days searching for them in the Nshili area during May 2000, but neither heard nor saw any sign of them. Local informants said that sightings of these monkeys are very rare except when the monkeys raid their cornfields. A more thorough survey for owl-faced guenons combining listening for their early morning vocalizations with quietly searching for the monkeys would likely shed more light on their distribution and status in the southern sector of Nyungwe. Unfortunately, the threat of insecurity along the Burundi border makes such an extensive survey inadvisable at present.

Three species of squirrels were identified during the surveys, including one, the Ruwenzori sun squirrel, that is endemic to the Albertine Rift

Ungulates and Elephants

Rates of encounter with signs of ungulates in general, and bushbucks and duikers in particular, were much higher at Nyabihu than at any other site. Though rates of encounter are very gross indicators of relative abundance between sites, the relatively high rate of encounters with signs of ungulates at Nyabihu suggest that this site may be an area of relatively high ungulate density at Nyungwe. Not surprisingly, this site had one of the lower rates of encounters with snares and traps as well as with overall human disturbance. The low encounter rates with human disturbance at Nyabihu can probably be attributed to the fact that it is a relatively inaccessible site a long distance from the nearest village.

The tracks and feces of what is believed to be the last elephant at Nyungwe were found near the Kamiranzovu Marsh at the Gisakura survey site during our survey. Several months later, the remains of a poached elephant were found in the same area. It therefore appears that elephants have now been extirpated at Nyungwe. Buffalo had already been extirpated long before our surveys and Vedder (1988) noted that terrestrial mammals were already relatively scarce by the late 1980s. Therefore, human activities appear to have had particularly adverse effects on large ungulate populations at Nyungwe. These adverse effects are documented in greater detail in Chapter 5.

Rodents

Three species of squirrels were identified during the surveys, including one, the Ruwenzori sun squirrel, that is endemic to the Albertine Rift. Fortunately, the Ruwenzori sun squirrel was found to be widely distributed across the reserve, though no data are available on its relative abundance at different sites. Despite the limited geographical range of the Ruwenzori sun squirrel, none of the three squirrel species identified during our surveys are listed as threatened

(IUCN, 1996).

To date, no surveys of small mammal populations have been conducted at Nyungwe. Since many of the mammal species believed to be endemic to the Albertine Rift are small mammals (Burgess et al., in prep.), future surveys on these mammals would be of considerable conservation importance.

Human signs

Because PCFN staff spend most of their time in the western part of the reserve, it is not surprising that two of the lowest overall rates of human disturbance were found near the ranger stations at Uwinka and Gisakura, while the two highest rates of human disturbance were found at the extreme northern and southern ends of the reserve at Muzimu and Nshili. PCFN presence therefore appears to be reducing human activities in the forest near the permanent ranger stations in the west, while the extreme northern and southern corners of the park remain more susceptible to human encroachment. The high level of human encroachment at Nshili combined with the uniqueness of its stands of bamboo forest and the owl-faced guenons that live there, make it a prime candidate for the location of a ranger station.

The relationship between signs of human use and signs of mammals

Only a handful of the many correlations calculated between signs of human use and signs of mammals at various sites produced statistically significant relationships. Some of these significant correlations are unlikely to be of any biological significance. For example, there was a significant correlation between signs of mangabeys and signs of gold mining. This positive correlation is almost certainly more related to the fact that mangabeys tend to be a species that lives at the low altitudes where gold mining generally occurs at Nyungwe, than to any affinity for the gold mining itself.

Human activities, particularly poaching, can be assumed to have deleterious effects on mammal populations. During our 1999 surveys, however, we were simply able to identify those areas where human disturbance is most frequent at Nyungwe and make rough comparisons with rates of mammal detection in those areas. A more quantitative long-term study would be necessary to thoroughly investigate the effects of human disturbance on mammal populations. The preliminary results from such a study showing that bushpigs, duikers, porcupines and Gambian rats have all declined since 1995 due to human disturbance are presented in Chapter 5.

Grauer's swamp warbler
(*Bradypterus graueri*)

INVENTORY OF BIRDS AT NYUNGWE

Introduction

At least 150 species of birds are known to be endemic to the Afromontane region (Dowsett, 1990), a region that includes the Albertine Rift as well as a number of other mountainous areas in sub-Saharan Africa. The Albertine Rift is home to 80 of these Afromontane endemics (Dowsett, 1990) and includes 37 species found only in the Albertine Rift itself (Stattersfield et al., 1998). Nyungwe is one of several forests in the Albertine Rift that are well-known for their rich bird life, and is of considerable importance for the conservation of a number of endemic bird species. At least 20 species and 5 races endemic to the Albertine Rift are known to inhabit the Nyungwe Forest making it the second richest forest for Albertine Rift endemics after the Itombwe Massif in D.R. Congo (Dowsett 1990).

In 1989 and 1990, Dowsett (1990) conducted an 18-week survey of the birds at Nyungwe Forest. During our survey of Nyungwe in 1999, we aimed to build upon Dowsett's earlier work by collecting data on the geographical locations of all birds recorded. These data would allow us to determine species distributions and enable us to map the relative importance of different sites within the forest for the conservation of Afromontane birds.

Methods

Total bird counts

The same 13 campsites visited by the mammal survey teams were also used as bases by two ornithological teams. Each team of ornithologists included two people who had received training in bird identification in 1993 and 1994 and participated in a bird monitoring program since mid-1995. These team members could identify the calls of most birds in the forest. In addition, two people with experience in mist netting of birds were associated with each team. Each ornithology team divided into two sub-teams, one sub-team that focused on point counts of birds and another that focused on mist netting. Both sub-teams recorded all species of birds seen or heard during their time at each camp site or its environs, including any opportunistic sightings/calls outside their work times and at night. A list of all birds seen or heard at each of the 13 sites in the forest was compiled using these data.

Total species lists were compiled for each of the 13 sites and the relative abundance of bird species at each site was calculated from the point count data and mist netting data

Point counts

The sub-team focusing on point counts of birds visited the same points as the botanical team which were established at 200 meter intervals along the reconnaissance routes initially followed by the mammal and human signs team. Point counts of birds were made the day after a reconnaissance route was walked by the mammalogists and botanists to reduce the possible deleterious effects any noise and movements made by these other teams would have on observations of birds. At each point the two observers would wait for a couple of minutes for the birds to settle down and then record all birds seen or heard during a period of 5 minutes. They would then move on to the next point and repeat this process. Point counts were usually conducted at 20-30 locations along most reconnaissance routes. Counts were made between dawn and 11am and again between 4pm and dusk. The data were used to measure relative encounter rates per point for each of the 13 sites but were not used to estimate bird density because the point locations were biased by the reconnaissance trails.

Mist netting

The sub-team focusing on mist netting birds put up their nets on the day of arrival at a camp site, having scouted around the various habitat types in the vicinity of the camp and selected one that was relatively common. Seven 12-14 meter nets were placed in areas to maximize the variation within that habitat type. Nets were opened at dawn on the following day and closed at dusk. They were then opened at dawn on the 3rd day and closed at midday and moved to a new habitat type. Nets were then opened in the same manner as before for one full day and one half day and moved to a third habitat type for the final full and half day. Therefore, by the end of a 7-day period at a camp site, each of three different habitat types (often one associated with a ridge, one with a slope, and one with a valley) would have been trapped in for one full day and one half day. Nets were checked at every half hour interval while they were open and any birds caught placed in bags to keep them calm.

Analyses

Total species lists were compiled for each of the 13 sites and the relative abundance of bird species at each site was calculated from the point count data and mist netting data. Shannon-Wiener diversity values were calculated for the point count data, respectively. Species accumulation curves were plotted and a first order jackknife estimate of total species richness calculated for each site and for the forest as a whole. These species accumulation curves and jackknife estimates were calculated based on 612 randomly selected individual birds seen at point counts at each site since 612 was the minimum number of individuals seen at any site. In addition, the numbers of Albertine Rift endemics, threatened species, and endangered species were calculated for each site.

Similarity indices were calculated and dendrograms created using Bray-Curtis linked cluster analysis on (1) the bird point count data and (2) total species lists based on presence/absence data for each site. A Detrended Correspondence Analysis (DCA) was also carried out on the presence/absence data.

Finally the distribution of Albertine Rift endemics, total species richness, and species diversity were plotted on maps of the forest so that relative differences between sites could be examined in a spatial context.

Results

Species numbers

A total of 151 bird species were recorded during the point counts and 92 species captured in mist nets. This gave a total of 163 known species with five unidentified species. If team members did not know the species, they attempted to identify it using common bird books. However, in those cases where team members were in doubt, or in those instances where identifications were judged to be suspect, the birds in question were analyzed as unidentified species. An additional 32 species were recorded opportunistically by sight or sound, bringing the total to at least 195 species heard or seen during this survey. However some of these birds were not forest species but were species that were flying over the forest (e.g. Wahlberg's eagle). A total list of species found at each site is provided in Appendix 3.1.

Species richness varied between sites from 53 to 90 for point counts and from 22 to 35 for mist netted birds (Table 3.1; Figure 3.1). The Jackknife estimates of species richness vary between 63 and 117 species at a site (Figure 3.1; Table 3.2).

The distribution of Albertine Rift endemics, total species richness, and species diversity were plotted on maps of the forest so that relative differences between sites could be examined in a spatial context

Table 3.1 The number of birds seen/heard (point counts) or caught (mist nets), number of points or meter net hours and number of species for each of the 13 sites.

	Point Count data			Mist net data	
Site	Number Seen/heard	No. of points	Species	Number caught	Species
Busoro	712	111	74	108	35
Bweyeye	772	141	90	113	34
Gisakura	863	174	84	136	33
Kagano	644	108	53	66	24
Kivu	729	108	63	107	35
Rubyiro	780	151	73	108	28
Muzimu	702	120	58	98	28
Nshili	788	122	87	109	25
Nyabihu	880	117	53	55	24
Nyabitimbo	612	108	70	144	32
Ruzizi	872	138	63	156	32
Uwasenkoko	821	109	67	83	25
Uwinka	1,143	130	80	83	22
Total	10,318	1,637	151	1,366	91

Diversity and rarity

A Shannon Wiener Index of diversity was calculated for each site based on 612 randomly selected birds observed during point counts. The most diverse site was Bweyeye followed by Gisakura (Table 3.2; Figure 3.1). This result is not particularly surprising as these two sites are at relatively lower altitudes compared to the other sites (see Chapter 1). Similarly, the first order jackknife estimates of species richness show that, in general, sites in the western portion of Nyungwe tend to be more species rich (Table 3.2; Figure 3.1).

In general, sites in the western portion of Nyungwe tend to be more species rich

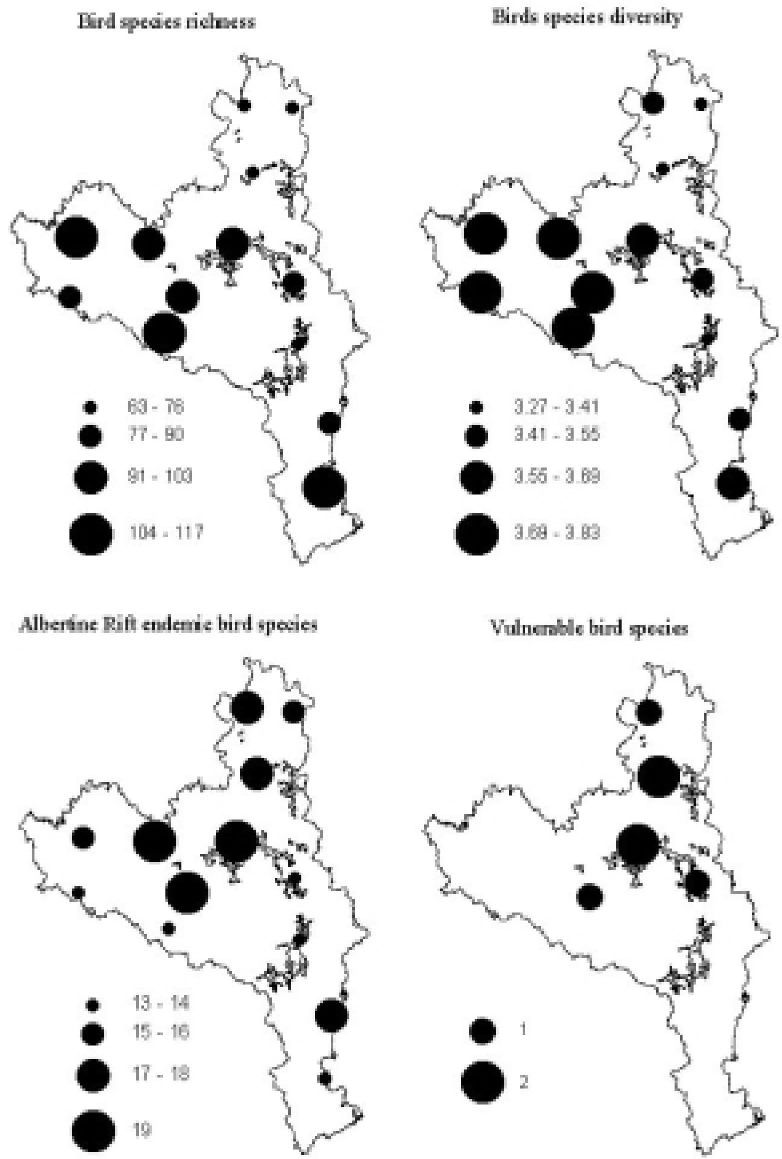


Figure 3.1 Bird species richness, bird species diversity (Shannon-Wiener indices), Albertine Rift endemie bird species, and vulnerable bird species at 13 sites.

Table 3.2. The Shannon-Wiener Diversity values, an estimate of total species richness using the first order jackknife estimate (Krebs 1989), the number of Albertine Rift endemic species and the number of species that are threatened or endangered globally, for each site.

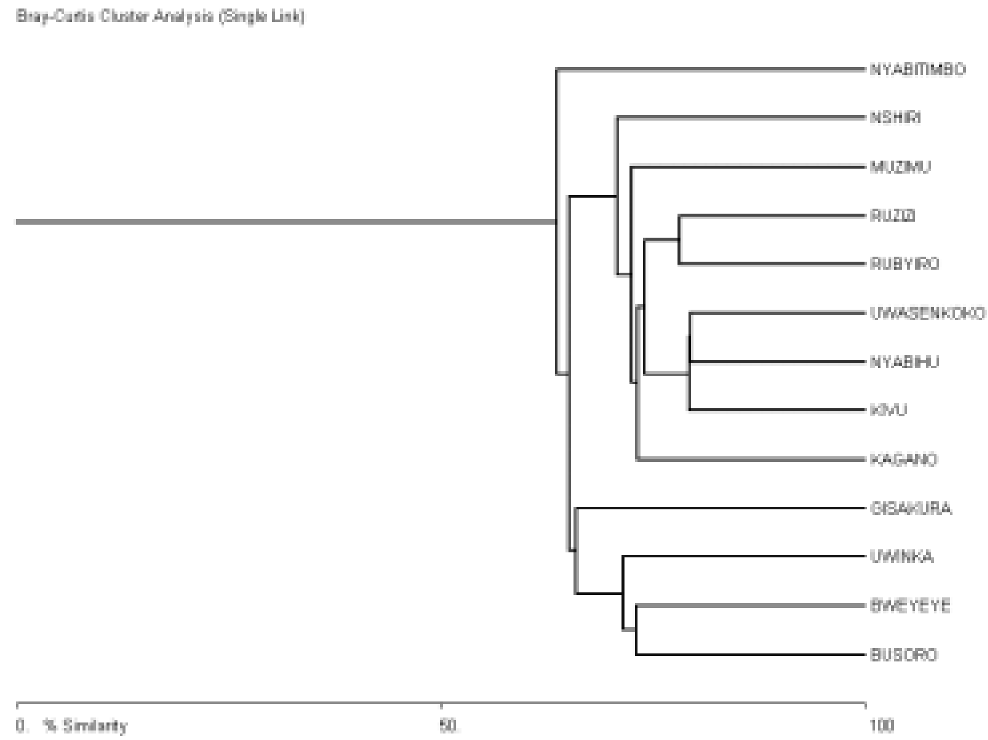
	Point Count data		Point count and mistnet data	
Site	**Shannon Wiener**	**Jackknife**	**Albertine Rift Endemics**	**Threatened or endangered**
Busoro	3.71	91	19	1
Bweyeye	3.83	117	13	0
Gisakura	3.77	106	16	0
Kagano	3.27	63	16	0
Kivu	3.55	78	17	0
Rubyiro	3.56	91	19	2
Muzimu	3.50	69	18	1
Nshili	3.57	114	14	0
Nyabihu	3.41	64	13	0
Nyabitimbo	3.74	86	14	0
Ruzizi	3.38	76	18	2
Uwasenkoko	3.51	85	14	1
Uwinka	3.74	94	19	0
Total		**178**	**22**	**3**

Similarity between bird communities

The similarity between bird communities was calculated for the bird point count data and for the data on all birds seen, trapped or heard (Appendix 3.1). The two similarity dendrograms from these two data sets do not differ substantially (Fig. 3.2), and where they do differ, the difference is usually between sites that have a close similarity value.

A Detrended Correspondence Analysis of the bird point count data and the presence/absence data set established two main axes of variation that separated the western and eastern sites on DCA axis 1 and then further separated the western sites on DCA axis 2 (Fig. 3.3).

Figure 3.2 The similarity dendrograms computed from a) bird point count data (numbers recorded) and b) all birds seen/heard/trapped (presence/absence data).



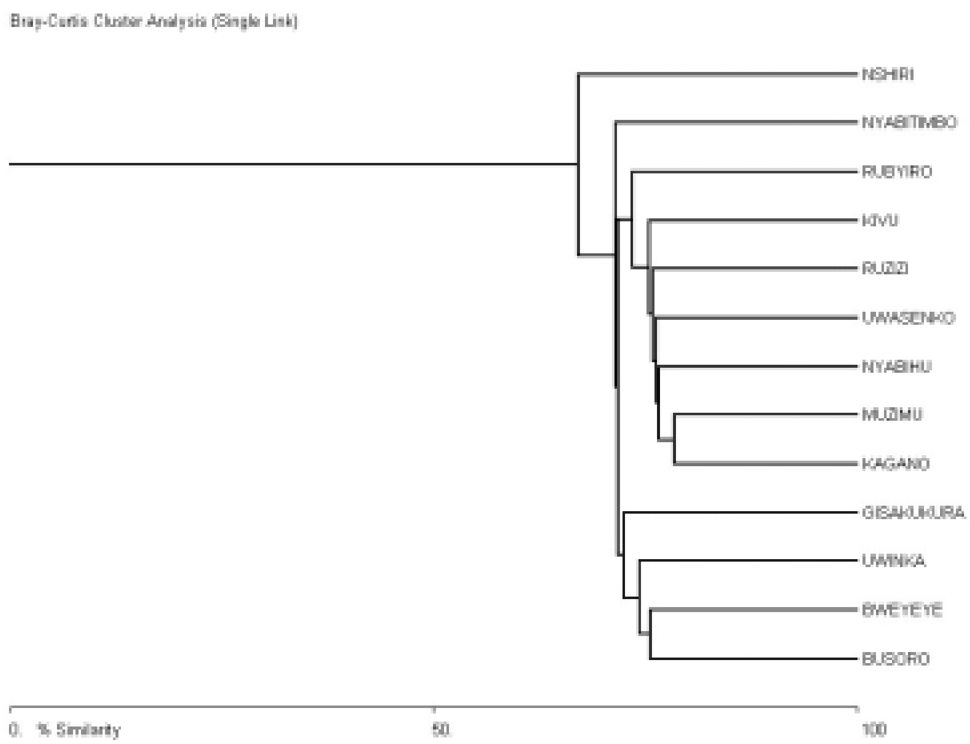
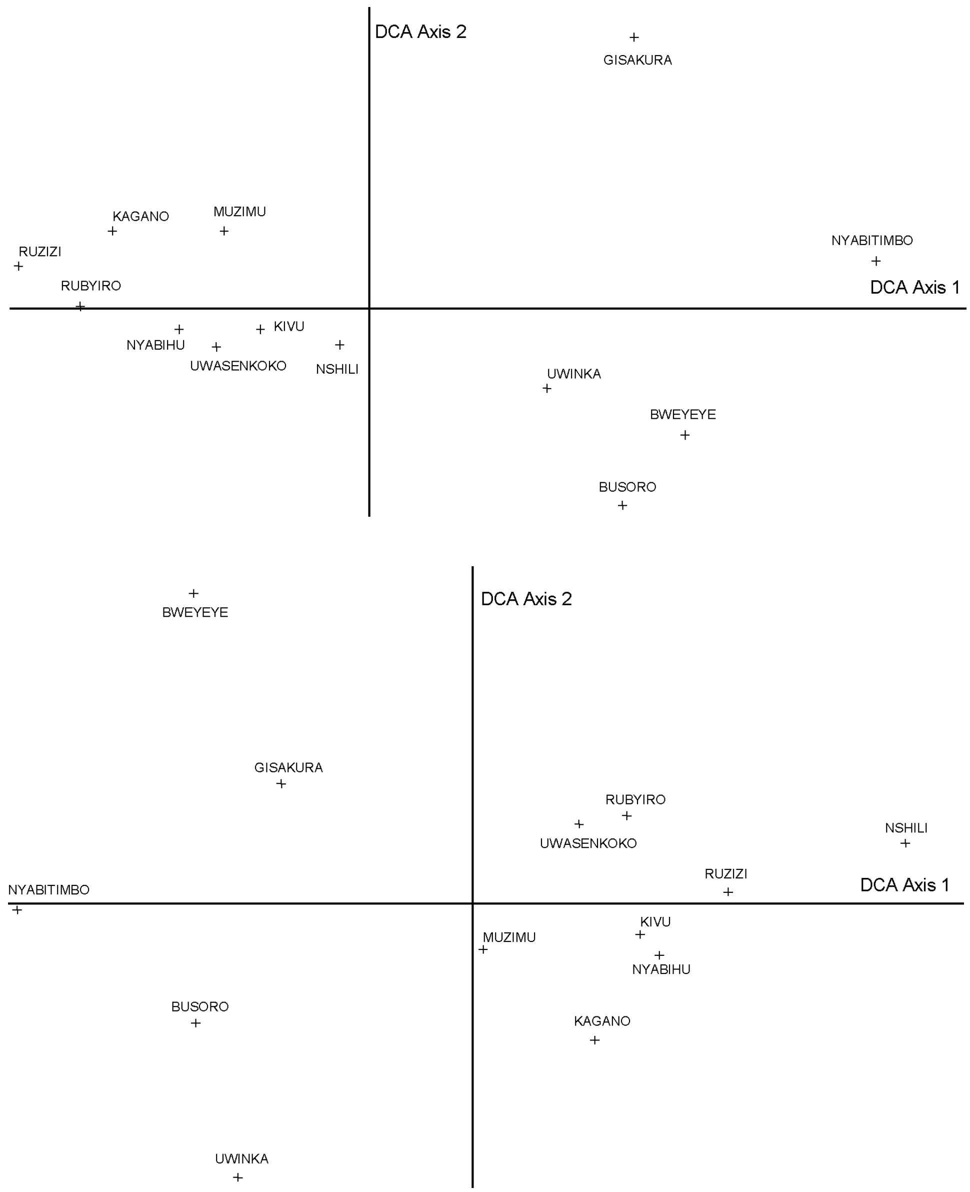


Figure 3.3 Detrended Correspondence Analyses of a) the bird point count data set where counts of individuals were used and b) presence/absence data for all species seen, trapped or heard.



Both analyses produced similar results (although the plots have reversed the direction of axis 1). Birds associated with the western half of the forest (Bweyeye, Gisakura, Uwinka, Nyabitimbo and Busoro) included *Andropadus gracilirostris, Apalis cinerea, Apaloderma vittatum, Bathmocercus cerveniventris, Chrysococcyx caprius, C. cupreus, Cuculus clamosus, Gymnobucco bonapartei, Nigrita caniacapilla, Platysteria concreta, Ploceus insignis, Smithornis capensis* and *Trochocercus cyanomelas*. Birds associated with the other sites included *Batis molitor, Bradypterus graueri, Centropus senegalensis, Nectarinia preussi, Phylloscopus umbrovirens, Psittacus erithacus* and *Sheppardia aequatorialis.*

Spatial distribution of birds

The species richness of the 13 sites was plotted in a GIS system (ARCVIEW) to analyze the spatial distribution of species richness (Figure 3.1). It was clear that high bird species richness occurs in the western half of Nyungwe. However this does not necessarily mean that the western half of Nyungwe is the most important for conservation. We also examined the distribution of birds considered to be of conservation importance, the Albertine Rift endemic species. This study recorded 22 Albertine Rift endemics of which three are vulnerable under the IUCN criteria (IUCN/SSC 1994; Collar *et al.* 1994; Stattersfield *et al.* 1998), which means that there is a 10% probability that the species will be extinct within 100 years. The relative encounter rates of each of the Albertine Rift endemics that were observed were plotted to analyze their spatial distribution (Appendix 3.2). Despite the higher overall species richness in the western part of the reserve, Albertine Rift endemics (Figure 3.1) are most species rich along the Zaire-Nile divide (a chain of mountains running down the eastern part of the reserve). Neither species diversity nor species richness were correlated with the number of Albertine Rift endemics (Species diversity: R^2=-0.042, p=n.s.; Species richness: R^2=-0.065, p=n.s.) (Note: data for these correlations are based on the number of species recorded during point counts and mist net captures).

Despite the higher overall species richness in the western part of the reserve, Albertine Rift endemics are most species rich along the Zaire-Nile divide

The three vulnerable species, the Kungwe Apalis (*Apalis argentea*), Grauer's Swamp Warbler (*Bradypterus graueri*) and Shelley's Crimson-wing (*Cryptospiza shelleyi*) occurred at few sites (Figure 3.1). Two other species observed are near-threatened species, Red-collared mountain babbler (*Kupeornis rufosinctus*) and Kivu Ground-thrush (*Zoothera tanganjicae*) but these occurred at many of the sites (Appendix 3.1).

Discussion

In 1988/89 Dowsett (1990) recorded a total of 175 bird species for Nyungwe but the total species list numbers 275 (Dowsett *et al.* 1990). Many of these additional 100 species were rare visitors to the forest and do not spend all their life here. This study recorded 196 species. It is likely that more species could have been recorded had tapes of bird calls been used to encourage species to respond as Dowsett did. However a good proportion of the total species list was observed and it is likely that the majority of the permanent forest residents were recorded so that we feel comfortable comparing the different sites within the forest for species richness and rarity.

Comparisons were made between Nyungwe and other forests in the Albertine Rift in Uganda where similar detailed surveys have been made (Table 3.3). These show that the number of species recorded from Nyungwe is relatively rich, but not very high, although the number of Albertine Rift endemic species is high, second only to the Itombwe massif in eastern Democratic Republic of Congo (Omari *et al.* 2000).

Table 3.3 Comparison of bird species numbers between forests in the Albertine Rift. The total number of species recorded for the forest, number of Albertine Rift endemics and number of Threatened (Vulnerable, Endangered or Critical) species are given.

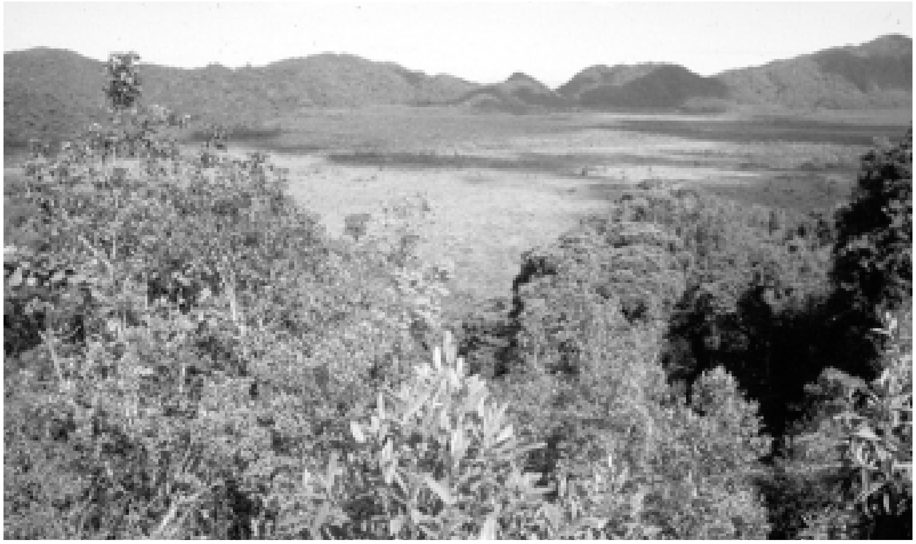
Forest	Number of species	Albertine Rift Endemics	Threatened
Democratic Republic of Congo			
Itombwe Mountains	588	35	8
Burundi			
Kibira National Park	207	17	4
Rwanda			
Nyungwe Forest	275	25	4
Virunga Volcanoes	178	20	4
Uganda			
Echuya Forest	85	8	1
Bwindi Impenetrable National Park	348	24	4
Kalinzu Forest	374	2	0
Kasyoha-Kitomi Forest	276	0	0
Ruwenzori National Park	195	19	1
Kibale National Park	325	3	0
Itwara Forest	183	0	0
Bugoma Forest	221	0	1
Budongo Forest	359	0	1

References: Omari et al. 1999; Howard et al. 2000; INECN (Undated); ORTPN 1985; Stattersfield et al. 1998.

These results confirmed that Nyungwe Forest has a global importance for the conservation of bird species

There was a high similarity (>60%) in bird species composition between sites within the forest, with the greatest split between sites in the west of the forest and those on the Zaire-Nile ridge that runs down the eastern side. The western side is generally at a lower altitude and was more species rich and diverse for birds (Figure 3.1) as it is also for trees (see chapter 4). However species richness and diversity did not equate necessarily with conservation importance. The distribution of 22 Albertine Rift Endemic species and particularly the three that are vulnerable to extinction, was much more skewed towards the Zaire-Nile ridge. Therefore, conservation actions should not just focus on the species rich sites within the forest.

These results confirmed that Nyungwe Forest has a global importance for the conservation of bird species. Conservation actions should aim to preserve the rich diversity of species at lower altitudes in the west of the forest whilst at the same time aim to protect the Albertine Rift endemic species which were more abundant in the east of the forest.



View over the canopy of Nyungwe Forest with the Kamiranzovu marsh behind

TREE DISTRIBUTIONS AND DIVERSITY

Methods

Introduction

The Nyungwe Forest is undoubtedly the most floristically rich forest remaining in Rwanda. With two (Gishwati and Makura) of the three other major forests in Rwanda having been almost entirely cleared in recent years (Masozera and Fashing, pers. observ.), many of the plant species at Nyungwe probably no longer exist anywhere else in Rwanda. Therefore, one of the most important goals of our surveys was to document the distribution and abundance of plant species, particularly those that are Albertine Rift endemics, to help devise a conservation strategy for plant life at Nyungwe.

Data collection

Botanical data were collected along the reconnaissance route surveyed earlier that day by the mammals and human signs team. However, because of the time required to collect and identify plants, the botanical team was generally unable to survey the entire length of the reconnaissance route on a given day. Two different methods were used for collecting botanical data: the first method, Method 1, was adopted at the first five sites surveyed (Uwinka, Busoro, Gisakura, Bweyeye, and Nyabitimbo), while the second, Method 2, was employed at the last eight sites surveyed (Kivu, Nshili, Nyabihu, Uwansenkoko, Rubyiro, Muzimu, Kagano, and Ruzizi). This difference in methods is unfortunate since it makes it difficult to compare much of the botanical data collected early in the surveys with those collected later. The two different methods were as follows:

Method 1: First five sites

A circular plot of 20 meters in radius was established every 200 meters along the reconnaissance route. A team member stood in the center of the plot and recorded the altitude and GPS position at this location. The topographic category of this location was also noted as being one of the following: valley, slope, summit or ridge. The "habitat type" of the plot was also designated using the same categories as those used by the other teams: Closed forest, Open forest, Clearing, Fern, Human clearing, Marsh, Bamboo, Savanna, Burned zone. Canopy coverage above the plot was classified as 0 (*open canopy* covering ≤25% of the plot), 1 (*moderately dense canopy* covering 26-50% of the plot), 2 (*very dense canopy* covering 51-75% of the plot) and 3 (*closed canopy* covering 76-100% of the plot). All woody plants ≥10 cm DBH in the plot were identified to species if possible and all species found to be present in the plot were recorded on the data sheet. The number of individuals of each species was not recorded, however, since counting individuals was originally judged to be too time consuming. The botany team also recorded the species identity of the tree ≥30 cm DBH found nearest to the center of the plot in the Northeast, Southeast, Southwest, and Northwest quarters of the plot. If the nearest tree was more than 10 m from the center of the plot in any particular quarter, no tree was designated as being present for that quarter. If a tree could not be confidently identified to species, or was believed to be a rare species, specimens were collected for later identification at the Rwandan National Herbarium in Butare. Duplicate specimens were deposited in the newly established herbarium at the PCFN headquarters in Gisakura as well.

Method 2: Final eight sites

Method 2 was first employed at the sixth survey site, Kivu, in an effort to gather data of a more quantitative nature than those collected with Method 1. In Method 2, circular plots of only 10 meters in radius were established every 200 meters along the reconnaissance route. From the center of these 10 meter plots, altitude, GPS position, topographic category, habitat type and canopy coverage were all determined as in Method 1. The most common, or dominant, species in the undergrowth layer of the plot was identified if possible and recorded. The tree ≥30 cm DBH nearest to the center of the plot in each quarter of the plot was also identified and recorded as in Method 1. In addition, all species of woody plants ≥10 cm DBH were identified, but unlike in Method 1, each individual woody plant within the plot was also counted to quantify the frequency and relative density of each species. Botany team members also stopped at every 50 meter interval between the circular plots (e.g. 50 m, 100 m, 150 m, etc.) to identify and record the tree ≥30 cm DBH nearest to where they were standing in each of the four quarters of an imaginary circle 10 m in radius surrounding their stopping point. As in Method 1, specimens from trees that were rare or that could not be identified were collected for later identification and preservation at the herbariums in Butare and Gisakura.

Data analysis

A number of formulae were used to analyze the botanical data from Nyungwe to determine the frequency, diversity, density, relative dominance, and indices of habitat preference of woody plant species at the various sites in the reserve. When conducting these analyses, we only compared data collected in the same manner. The formulae used to analyze the botanical data are as follows:

$$\text{Density} = \frac{\text{Number of individuals of species or family } x}{\text{Area surveyed}}$$

$$\text{Relative Density} = 100 \text{ X } \frac{\text{Number of individuals of species or family } x}{\text{Total number of individuals of all species or families}}$$

$$\text{Relative Family Diversity} = 100 \text{ X } \frac{\text{Number of species in family } x}{\text{Total number of all species}}$$

Alpha-diversity (Huston, 1994) of plant species was also calculated for each site to provide a measure of the number of species within an area of given size.

A Shannon-Wiener index of diversity, H', (Shannon and Weaver, 1949) was also calculated for the plants at each survey site. The formula for calculating diversity is:

$$H' = -\sum_{i=1}^{s} p_i \log p_i$$

where s is the number of species and p_i is the proportion of the total number of individuals represented by the *i*th species. To facilitate comparisons between sites, the plot area on which H' calculations were based was held constant across sites. At the five sites where plots of 10 m in radius were evaluated, data from 108 plots were used to calculate H', while at the eight sites where plots of 20 m in radius were evaluated, data from 27 plots were used to calculate H'.

Alpha-diversity (Huston, 1994) of plant species was also calculated for each site to provide a measure of the number of species within an area of given size. In addition, since the total area surveyed varied between sites, the rarefaction method (Sanders, 1968; Simberloff, 1972, 1978) was employed to facilitate comparison of plant species richness between sites.

Results

Survey routes

The botanical team surveyed a total of 361 km of reconnaissance trails at the 13 sites (Table 4.1). They evaluated 1637 circular botanical plots covering a total surface area of 116.4 hectares.

Table 4.1. Distance walked (km), number of circular plots evaluated every 200 m, and total surface area (ha) of the circular plots evaluated during plant surveys at 13 sites.

Site	Distance walked (km)	Number of plots	Surface area of plots (ha)
Busoro	22.4	111	14.4
Bweyeye	31.0	141	18.3
Gisakura	40.1	173	22.5
Kagano	21.6	108	3.4
Kivu	23.8	109	3.4
Muzimu	26.1	120	3.7
Nshili	27.8	122	3.8
Nyabihu	22.6	117	3.6
Nyabitimbo	23.0	108	14.0
Rubyiro	29.7	151	4.7
Ruzizi	28.8	138	4.3
Uwasenkoko	23.0	109	3.4
Uwinka	41.0	130	16.9
Total	360.9	1637	116.4

Burned zones occurred at all sites except Uwinka

Survey site habitat types

The results of habitat type assessments for 1637 plots along the reconnaissance routes at 13 survey sites are presented in Table 4.2. Nyabitimbo was the site with the highest percentage of plots (62%) classified as closed forest. Open forest was most common (56%) at Muzimu. Bamboo forest occurred at only Nshili and Nyabihu, and was most prevalent (20%) at the former site. Eight sites contained at least some plots characterized as savanna, though only Rubyiro contained a substantial portion (15%) of this habitat. Plots characterized as marshes were found at 11 sites with marshland being most prevalent (24%) at Gisakura. Plots classified as clearings were also found at 11 sites, though they were not particularly common at any one site. Even at the site where they were most abundant, Kagano, clearings only comprised 9% of the total habitat type records. Plots characterized as being dominated by ferns were also uncommon, yet were present at all sites, most commonly (7%) at Nyabihu. Plots classified as human clearings were present, but relatively uncommon, at all sites except Bweyeye where they comprised more than half (52%) of the habitat type records. Burned zones occurred at all sites except Uwinka. Rubyiro was the site with the highest frequency (37%) of burned zones.

Table 4.2. Number of records and percent of total habitat records accounted for by each habitat type. (Based on circular plots every 200 meters.)

Site	Altitude (m)	Closed Forest		Open Forest		Bamboo		Savanna		Marsh		Clearing		Fern		Human Clearing		Burned Zone		Total
		Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number
Uwinka[1]	1840 - 2500	51	39.23	59	45.38	0	0.00	0	0.00	7	5.38	8	6.15	1	0.77	4	3.08	0	0.00	130
Gisakura[1]	1750 - 2150	59	34.10	43	24.86	0	0.00	2	1.16	41	23.70	4	2.31	3	1.73	8	4.62	13	7.51	173
Busoro[1]	1720 - 2370	43	38.74	48	43.24	0	0.00	0	0.00		0.00	0	0.00	3	2.70	1	0.90	16	14.41	111
Bweyeye[1]	1590 - 2190	21	14.89	22	15.60	0	0.00	0	0.00	11	7.80	1	0.71	1	0.71	74	52.48	11	7.80	141
Nyabitimbo[1]	1700 - 2150	67	62.04	19	17.59	0	0.00	0	0.00		0.00	1	0.93	0	0.00	7	6.48	14	12.96	108
Kivu[2]	2200 - 2480	15	13.76	53	48.62	0	0.00	2	1.83	13	11.93	8	7.34	5	4.59	5	4.59	8	7.34	109
Nshili[2]	2180 - 2555	7	5.74	44	36.07	24	19.67	6	4.92	2	1.64	0	0.00	2	1.64	7	5.74	30	24.59	122
Nyabihu[2]	2225 - 2480	22	18.80	41	35.04	9	7.69	6	5.13	10	8.55	3	2.56	8	6.84	1	0.85	17	14.53	117
Uwasenkoko[2]	2370 - 2690	4	3.67	59	54.13	0	0.00	2	1.83	9	8.26	7	6.42	5	4.59	3	2.75	20	18.35	109
Rubyiro[2]	2110 - 2500	16	10.60	31	20.53	0	0.00	23	15.23	13	8.61	4	2.65	7	4.64	1	0.66	56	37.09	151
Muzimu[2]	2180 - 2570	12	10.00	67	55.83	0	0.00	0	0.00	5	4.17	3	2.50	2	1.67	7	5.83	24	20.00	120
Kagano[2]	2260 - 2450	53	49.07	35	32.41	0	0.00	1	0.93	2	1.85	10	9.26	1	0.93	5	4.63	1	0.93	108
Ruzizi[2]	2305 - 2500	6	4.35	54	39.13	0	0.00	1	0.72	20	14.49	8	5.80	6	4.35	21	15.22	22	15.94	138
Total		376		575		33		43		133		57		44		144		232		1637

[1] Circular plots of 20 m in radius assessed every 200 m for habitat type

[2] Circular plots of 10 m in radius assessed every 200 m for habitat type

Overall plant family, genus and species richness

A total of 242 species of vascular plants from at least 57 families were recorded at the 13 survey sites. 235 of these plants could be identified to genus and 226 to species. Twelve species were recorded that were previously unknown to exist at Nyungwe (Table 4.3). Some of the 7 species that could not be identified to genus may represent new species, and this possibility is currently under review by a plant taxonomist.

Table 4.3. Species recorded during the 1999 survey that were previously unknown to exist at Nyungwe.

1 *Acanthus montanus* (Acanthaceae)
2 *Antidesma venosum* (Euphorbiaceae)
3 *Baissea* sp. (Apocynaceae)
4 *Begonia ampla* (Begoniaceae)
5 *Calycosiphonia spathicalyx* (Rubiaceae)
6 *Casearia englerii* (Flacourtiaceae)
7 *Chionanthus africanus* (Oleaceae)
8 *Discoclaoxylon hexandru*m (Euphorbiaceae)
9 *Isolona lebrunii* (Annonaceae)
10 *Leplaea mayombensis* (Meliaceae)
11 *Macaranga aff. Monandra* (Euphorbiaceae)
12 *Trilepisium madagascariense* (Moraceae)

A total of 242 species of vascular plants from at least 57 families were recorded at the 13 survey sites

The two most common species (*Syzygium guineense* and *Macaranga kilimandscharica*) accounted for 35.7% of the large (≥30cm DBH) trees sampled using the 4-tree sampling regime at 200 m intervals (Table 4.4). The next most common tree species, *Carapa grandiflora*, accounted for only 6.6% of the large trees sampled. Although only 2 species each accounted for at least 10% of the relative density, 19 species each accounted for at least 1% of the relative density.

Table 4.4. Number of individuals and relative density of the top 20 species of large trees (>30 cm DBH) at Nyungwe. [From data collected on the tree in each direction (NE, SE, SW, NW) nearest the center of a circular plot every 200 meters at all 13 sites.)

Rank	Species	Number	Relative Density
1	*Syzygium guineense* (Myrtaceae)	939	18.2
2	*Macaranga kilimandscharica* (Euphorbiaceae)	904	17.5
3	*Carapa grandiflora* (Meliaceae)	341	6.6
4	*Strombosia scheffleri* (Olacaceae)	235	4.5
5	*Hagenia abyssinica* (Rosaceae)	217	4.2
6	*Cleistanthus polystachyus* (Euphorbiaceae)	200	3.9
7	*Parinari excelsa* (Chrysobalanaceae)	171	3.3
8	*Neoboutonia macrocalyx* (Euphorbiaceae)	116	2.2
8	*Podocarpus latifolius* (Podocarpaceae)	116	2.2
10	*Ilex mitis* (Aquifoliaceae)	110	2.1
11	*Symphonia globulifera* (Clusiaceae)	69	1.3
12	*Maesa lanceolata* (Myrsinaceae)	67	1.3
13	*Polyscias fulva* (Araliaceae)	65	1.3
14	*Harungana montana* (Clusiaceae)	62	1.2
15	*Agauria salicifolia* (Ericaceae)	59	1.1
16	*Chrysophylum gorungosanum* (Sapotaceae)	56	1.1
17	*Rapanea melanophloeos* (Myrsinaceae)	55	1.1
18	*Pentadesma reyndersii* (Clusiaceae)	52	1.0
19	*Entandrophragma excelsum* (Meliaceae)	50	1.0
20	*Newtonia buchananii* (Mimosaceae)	49	0.9

The most common tree family at Nyungwe, Euphorbiaceae, accounted for 26.1% of the large (≥30cm DBH) trees surveyed at Nyungwe (Table 4.5). The second most common tree family was the Myrtaceae which included 18.2% of the large trees. The top 3 families combined (Euphorbiaceae, Myrtaceae, and Meliaceae) accounted for more than 50% of all large trees surveyed.

Table 4.5. Number of individuals and relative density of the top 20 families of large trees (>30 cm DBH) at Nyungwe. From data collected on the tree in each section (NE, SE, SW, NW) nearest the center of a circular plot every 200 meters at all 13 sites.)

Rank	Family	No. species	No. individuals	Relative Density
1	Euphorbiaceae	10	1348	26.1
2	Myrtaceae	1	939	18.2
3	Meliaceae	4	402	7.8
4	Olacaceae	2	236	4.6
5	Clusiaceae	5	233	4.5
6	Rosaceae	2	229	4.4
7	Chrysobalanaceae	2	191	3.7
8	Myrsinaceae	2	122	2.4
9	Podocarpaceae	2	120	2.3
10	Aquifoliaceae	1	110	2.1
11	Rubiaceae	16	109	2.1
12	Sapotaceae	3	73	1.4
13	Theaceae	2	66	1.3
14	Araliaceae	1	65	1.3
14	Ericaceae	3	65	1.3
16	Mimosaceae	2	63	1.2
17	Rhizophoraceae	4	54	1.0
18	Moraceae	3	48	0.9
19	Oliniaceae	1	46	0.9
20	Lauraceae	2	43	0.8

Species richness was significantly higher at the 5 western sites than at the 8 eastern sites

Species richness and species diversity across sites

Patterns of plant species richness as estimated by the rarefaction method for the 13 sites at Nyungwe are presented in Figure 4.1. Estimated values for species richness ranged from 25.7 at Ruzizi to 70.4 at Bweyeye (Mean=42.3, S.D.=14.9, n=13). Species richness was significantly higher at the 5 western sites than at the 8 eastern sites (Mann-Whitney U Test: Z=-2.93, p=.003, n=13).

Patterns of variation in Shannon-Wiener indices of plant species diversity (H') between sites are also presented in Figure 4.1. H' ranged from 2.38 at Ruzizi to 4.11 at Bweyeye (Mean=3.25, S.D.=0.50, n=13). As with species richness, H' was significantly higher at the 5 western sites than at the 8 eastern sites (Mann-Whitney U Test: Z=-2.93, p=.003, n=13).

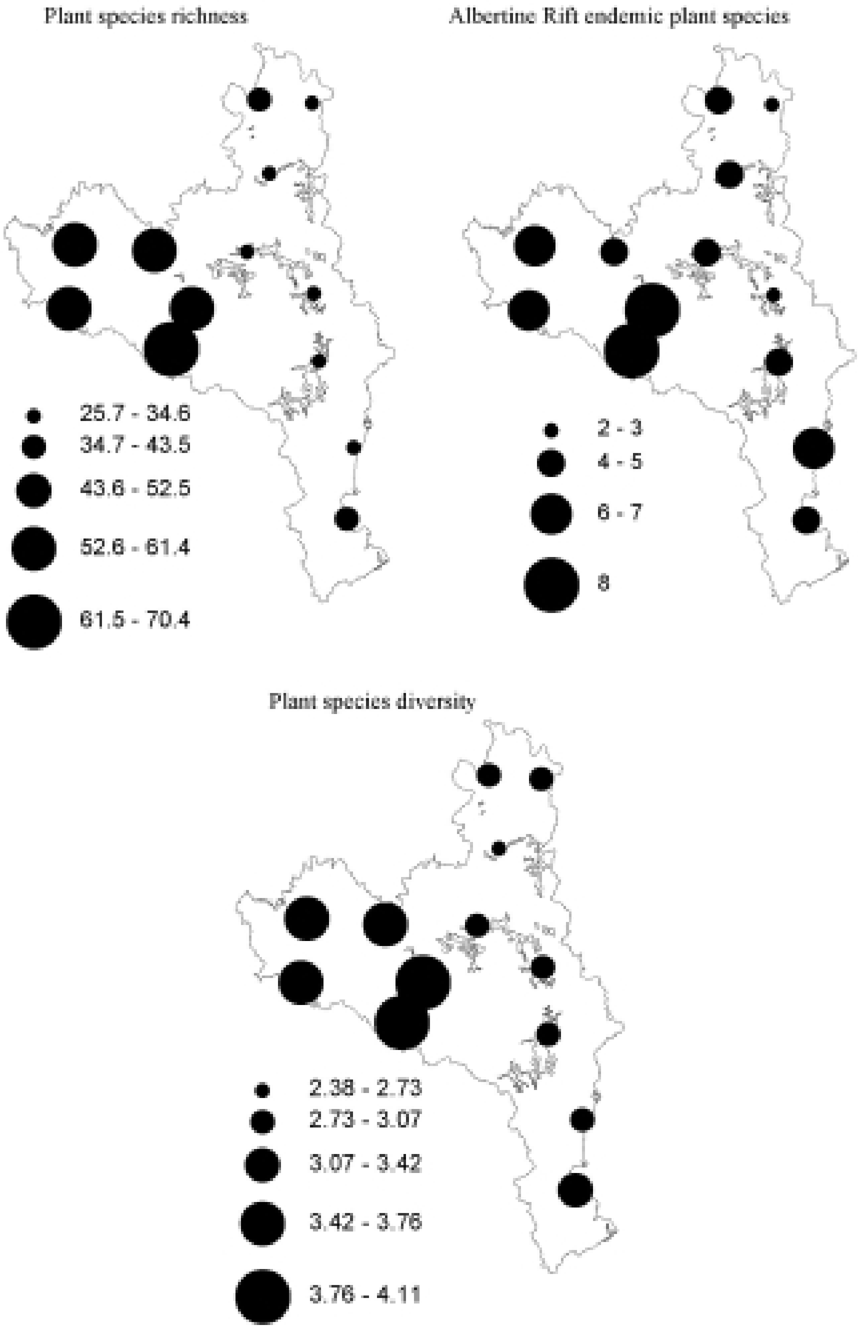


Figure 4.1. Estimated plant species richness, number of Albertine Rift endemic plant species, and Shannon-Wiener indices of plant species diversity at the 13 survey sites.

Albertine Rift endemics

Twenty-one of the 24 plant species believed to be Albertine Rift endemics and known to exist at Nyungwe were recorded during the 1999 surveys. The distribution of these species across the reserve is presented in Table 4.6. Four of these 19 species were found at only one site each (*Lovoa brownii*, *Pavetta pierlotii*, *Pittosporum mildbraedii*, *Tricalysia kivuensis*) while 2 species were found at all 13 sites (*Harungana madagascariense*, *Mimulopsis excellens*), though it should be noted that smaller overall surface areas were sampled at the 8 eastern sites.

Table 4.6. Distribution of Albertine Rift endemics recorded during the 1999 survey at Nyungwe.

Known Endemics	Busoro	Bweyeye	Gisakura	Kagano	Kivu	Muzimu	Nshili	Nyabihu	Nyabitimbo	Rubyiro	Ruzizi	Uwasenkoko	Uwinka
Beilschmiedia michelsonii (Lauraceae)	x	x	x	x	-	x	x	-	x	-	-	-	x
Cassipourea ndando (Rhizophoraceae)	-	-	x	-	-	-	-	-	x	-	-	-	x
Harungana montana (Clusiaceae)	x	x	x	x	x	x	x	x	x	x	x	x	x
Lobelia petiolata (Lobeliaceae)	-	-	-	-	x	-	-	-	-	x	-	-	-
Oricia renieri (Rutaceae)	x	x	x	-	-	-	-	-	x	-	-	-	x
Peddiea rapaneoides (Thymelaeaceae)	-	-	-	x	x	-	-	x	-	x	x	-	-
Pentadesma reyndersii (Clusiaceae)	-	x	x	-	-	-	-	-	x	-	-	-	-
Pittosporum mildbraedii (Pittosporaceae)	-	-	-	-	-	-	x	-	-	-	-	-	-
Rubus runssorensis (Rosaceae)	Found during the 1999 survey but its distribution across the reserve was not assessed.												
Tarenna rwandensis (Rubiaceae)	x	x	x	-	-	-	-	-	x	-	-	-	-
Probable Endemics													
Ixora burundensis (Rubiaceae)	x	x	x	-	-	-	-	-	x	-	-	-	x
Lobelia stuhlmanii (Lobeliaceae)	Not found during the 1999 surveys.												
Lovoa brownii (Meliaceae)	Not found during the 1999 surveys.												
Mimulopsis excellens (Acanthaceae)	Found during the 1999 survey but its distribution across the reserve was not assessed.												
Pavetta pierlotii (Rubiaceae)	-	-	-	-	x	-	-	-	-	-	-	-	-
Peddiea orophila (Thymelaeaceae)	Not found during the 1999 surveys.												
Philippia johnstonii (Ericaceae)	-	-	-	-	x	-	-	x	-	x	-	-	-
Psychotria palustris (Rubiaceae)	x	x	-	-	x	x	x	-	-	-	x	-	x
Pycnostrachys goetzenii (Lamiaceae)	Found during the 1999 survey but its distribution across the reserve was not assessed.												
Rytigynia kigeziensis (Rubiaceae)	x	x	-	x	x	x	x	x	-	x	x	x	x
Tricalysia kivuensis (Rubiaceae)	-	-	-	-	-	-	-	-	x	-	-	-	-
Vernonia kirungae (Asteraceae)	Found during the 1999 survey but its distribution across the reserve was not assessed.												
Warneckea walikalensis (Melastomataceae)	x	x	x	-	-	-	-	-	x	-	-	-	x
Zeyherelle rwandense (Sapotaceae)	x	x	x	-	-	-	-	-	x	-	-	-	x

To control for the fact that different sized areas were sampled at different sites, we also analyzed woody plant ($\geq$10 cm DBH) distribution data from a random sample of plots totaling ~33,930 m^2 in surface area for each site. Based on this analysis, Albertine Rift endemic species richness was highest in the western portion of Nyungwe (Figure 4.1). Busoro and Bweyeye had the most endemic species with 8, followed by Gisakura with 7, Nyabitimbo with 6, and Uwinka with 4. The mean number of Albertine Rift endemics at western sites was 6.6 (S.D.=1.7). Each site in the eastern portion of the forest had between 2 and 7 Albertine Rift endemics (Kivu: 7, Nshili: 5, Muzimu: 4, Nyabihu: 4, Rubyiro: 4, Ruzizi: 4, Kagano: 3, Uwasenkoko: 2) with a mean of 4.1 (S.D.=1.5). This difference in number of endemics between the western and eastern parts of the forest is significant (Mann-Whitney U Test: Z=-2.19, p=.029, n=13).

Similarity between plant communities

The similarity between plant communities was calculated with a Bray-Curtis Cluster Analysis, using plant data from equal sized surface areas at each site (~33,930 m^2). Figure 4.2 shows that the 13 sites can be lumped into two distinct groups. The 8 higher elevation sites in the east form one group, while the 5 lower elevation sites in the west form another group. A Detrended Correspondence Analysis, also based on equal-sized survey areas from each site, demonstrates that there is a clear differentiation between sites in the east and west of the reserve (Figure 4.3). Axis 1 separated the 8 sites in the east from the 5 in the west, while Axis 2 separated the western sites from each other.

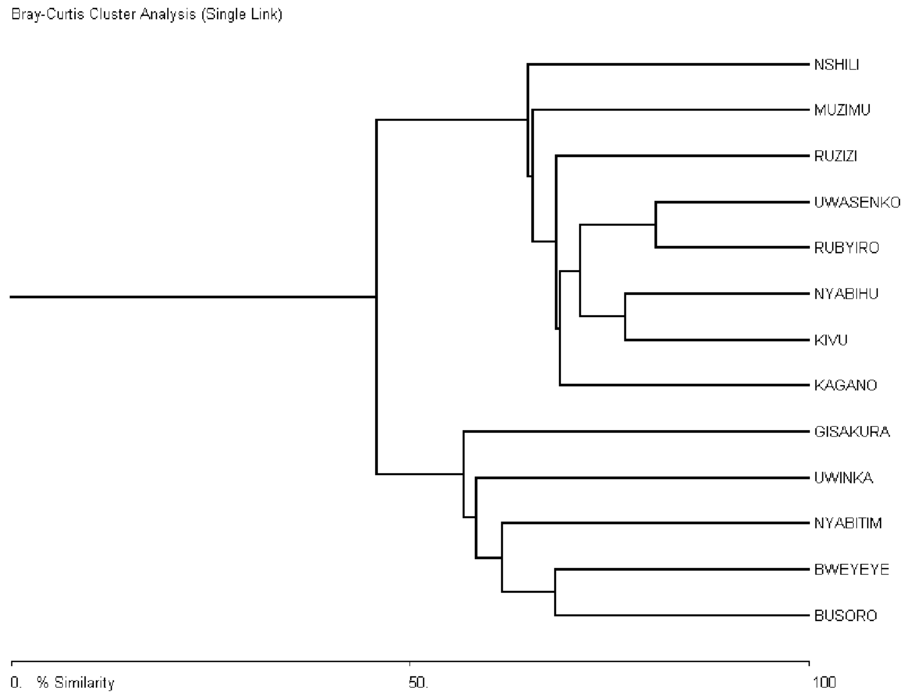


Figure 4.2. Similarity matrix for tree species in sites of total area 33,929m^2.

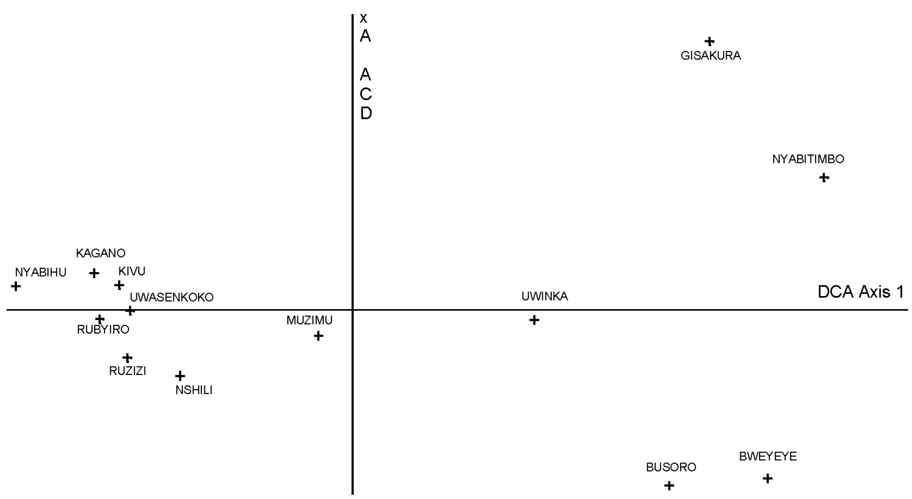


Figure 4.3. Tree DCA using percentage of species in each site for an area surveyed of 33,929m^2.

Herbaceous layer

The most dominant herbaceous species in vegetation plots varied considerably between habitat types (Appendix 4.2). The herbaceous layer was most often dominated by one species of fern (*Pteridium aquilinum*) in plots characterized as Burned Zones (43%), Savannas (26%), Human Clearings (20%), and Ferns (45%). *Sericostachys scandens* was the species that most often dominated Clearings (18%). Plots characterized as Closed Forest (24%) and Open Forest (14%) were most often dominated by *Mimulopsis excellens*. Finally, *Hypericum revolutum* was the species that most often dominated plots classified as Marshes (32%).

Discussion

Habitat variation across sites

Our surveys documented considerable habitat type variation between sites at Nyungwe. Two sites, Nshili and Gisakura, had particularly unique habitat type profiles. Nshili was the only site with a large proportion of bamboo-dominated habitats, while Gisakura was the only site with a substantial portion of marshland. The distinctiveness of the habitat type profiles at these two sites suggests that they are important sites for the conservation of habitat type heterogeneity across Nyungwe.

Our surveys documented considerable habitat type variation between sites at Nyungwe

Overall species and family richness

At 971 km^2, Nyungwe is by far the largest rainforest remaining in Rwanda (Weber, 1989). The second largest forest, located in the Virunga mountains, covers only about 140 km^2 and is believed to be relatively species poor in terms of woody plants (Plumptre, pers. observ.). Two even smaller forests between Nyungwe and the Virungas, Gishwati and Makura, have been almost entirely cleared over the past several years (Fashing and Masozera, pers. observ.). Therefore, with more than 240 vascular plant species from at least 57 families, Nyungwe probably includes most of the rainforest plant species that remain in Rwanda. The total number of species at Nyungwe is lower than that at several other montane and mid-elevation forests in the Albertine Rift, including Bwindi (324 species), Budongo (465 species), and Kibale (351 species, Howard and Davenport, 1996).

Species richness, species diversity and patterns of occurrence of Albertine Rift endemics across sites

Both plant species richness and plant species diversity were significantly higher at the 5 western sites than at the 8 eastern sites at Nyungwe. These differences between west and east may be attributable to the fact that the sites in the west are at lower average elevations than those in the east. Plant species richness and diversity are both known to exhibit an inverse relationship with increasing altitude at other locations (e.g. Andohahela, Madagascar: Rakotomalaza and Messmer, 1999).

The number of Albertine Rift endemic plants was also significantly larger at the western sites than at the eastern sites at Nyungwe. Detrended Correspondence Analysis showed that sites in the west tended to exhibit more variation than sites in the east because species richness was high. Because species richness, species diversity, number of Albertine Rift endemics, and between-site differences were all higher in the western part of the reserve, we suggest that the western sector is of primary importance for woody plant conservation at Nyungwe.

L'Hoest's monkey,
(*Cerocopithecus lhoesti*)

CHANGES IN BIRD AND MAMMAL POPULATIONS OVER TIME

Introduction

One potential critique of the survey reported here is that it is a snap shot in time and that it is possible the bird and mammal populations move around and change in abundance both seasonally and over several years. This is a problem of most short surveys that are undertaken and it is important to try to evaluate how representative the survey is.

The Projet Conservation de la Forêt de Nyungwe (PCFN) has been monitoring bird and mammal populations at Uwinka since mid 1995 and at Gisakura since mid 1996. The data have been entered into a computer up to December 1998 and we used these data to examine any changes in these animal communities over time.

Methods

Mammals

Seven transects were re-established near Uwinka base camp, the site of the PCFN field station in early 1995. These transects had been used prior to the genocide in 1994 but the data that had been collected were lost during the turmoil and looting of the field station. Transect length ranged from 1.2 to 4.5 kilometers in length for these seven transects and they were located at random intervals along the Gikongoro-Cyangugu road that passes through the forest. Data from these transects were analyzed between January 1996 - December 1998. Total transect length was 19.2 km. In early 1996 a further three transects were established at a second site near Gisakura. Each of these was 2 km long making a total transect length of 6 km (Fig. 5.1). Data from these transects were analyzed between Aug 1996-Dec 1998.

Experienced Field Assistants walked each transect once each month recording all sightings and calls of mammals, making a note of whether it was a sighting or call. These were the same Field Assistants that participated in the Nyungwe Survey described in chapter 2. All primates, bushpigs (*Potamochoerus larvatus*), duikers (*Cephalophus* spp.), Gambian rats (*Cricetomys gambianus*), and African brush-tailed porcupines (*Atherurus africanus*) were recorded. Smaller squirrels were recorded on the lines but also from the point counts that the ornithologists made. Perpendicular distance from the transect to the animal was estimated by eye but we felt that the accuracy was not reliable so that in the analyses presented here we look only at encounter rate per kilometer walked.

Experienced Field Assistants walked each transect once each month recording all sightings and calls of mammals, making a note of whether it was a sighting or call

Birds

At every 200 meters along each of the same transects as used for the mammal monitoring a point count was made. A team of two ornithologists worked together, one listening and looking for birds and one recording. These were the same ornithologists that participated in the point counts on the Nyungwe survey described in chapter 3. At each point they would wait 2 minutes to let the birds settle down and then record all sightings and calls of birds and squirrels for a period of five minutes before moving on another 200 meters. Counts were made whilst walking out and back at the same points along the transect and the total summed for each point. To some extent this helped take account of variations between times of day in bird activity. Data were analyzed for birds between May 1995-Dec 1998 for the 7 lines at Uwinka and between Aug 1996-Dec1998 for the three lines at Gisakura.

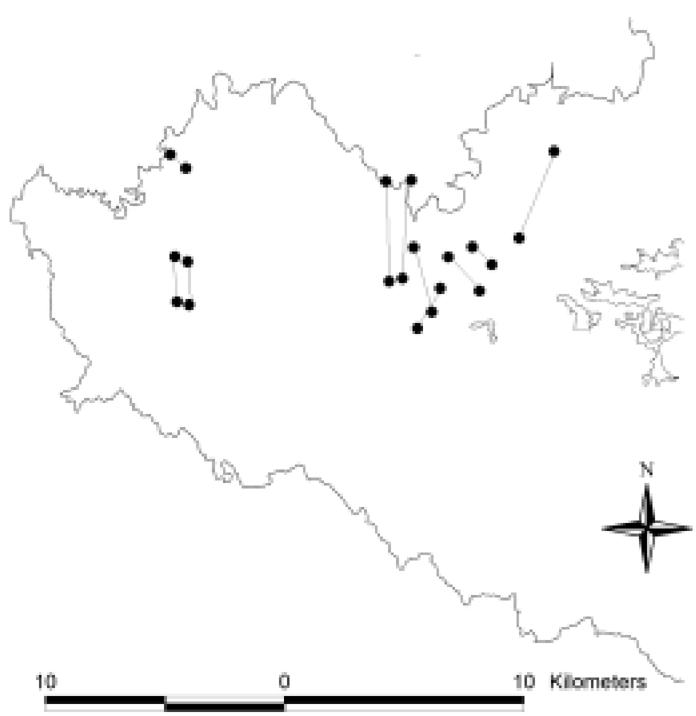


Figure 5.1. Locations of 10 transects in the northwest of the forest that were monitored between 1996-1998.

Analyses

The analysis of the data initially looked at total species richness recorded for mammals and birds at the two sites (Uwinka – 7 lines; Gisakura – 3 lines) over time and for the birds the variation in number of Albertine Rift endemics was also analyzed. Subsequently analyses were made of individual species. Spearman rank correlations were used to identify significant increases or decreases with time. Plots were made of individual species to identify those that showed any seasonality.

Results

Variation in total species richness with time

The only site to show any significant change in species richness was at Uwinka where mammal species richness significantly declined between January 1996-December 1998 (Table 5.1; Fig. 5.2a). An analysis of individual species of mammals showed significant declines in Bushpigs, black-fronted duikers (*Cephalophus nigrifrons*), brush-tailed porcupine, and Gambian rat (Table 5.2). Each of these animals has been hunted with wire snares over this period by the local people living around the forest. A very large number of snares has been collected in Nyungwe since 1995 (Figures 5.3 and 5.4) because few rangers were employed to patrol the forest and keep poachers out.

The only site to show any significant change in species richness was at Uwinka where mammal species richness significantly declined between January 1996-December 1998

Analysis of changes in the number of Albertine Rift Endemics birds showed that at Gisakura there was a significant increase in the number encountered between August1996 and December 1998. Examination of Figure 5.5 shows that it was in the first 6-7 months that there were fewer endemics species recorded. It is not certain if this increase is real or whether the Field Assistants were uncertain about some identifications early on at the start of the monitoring of these lines and that they learnt some new species from lower altitudes once they started to work there.

Table 5.1. Spearman rank correlations between total species richness, number of Albertine Rift endemics (for birds) and time since monitoring commenced. **=P<0.01

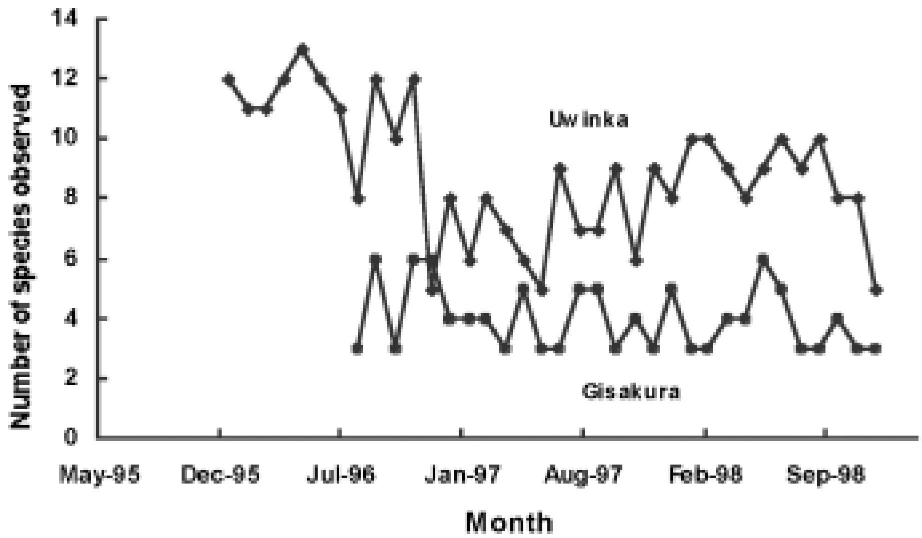
	Site	Spearman rank r-value	Probability
Mammals			
Total species richness	Uwinka	-0.428	0.009**
Total species richness	Gisakura	-0.235	0.221
Birds			
Total species richness	Uwinka	0.014	0.931
Albertine Rift endemics	Uwinka	0.254	0.101
Total species richness	Gisakura	0.265	0.165
Albertine Rift endemics	Gisakura	0.496	0.006**

Variation in individual species with time

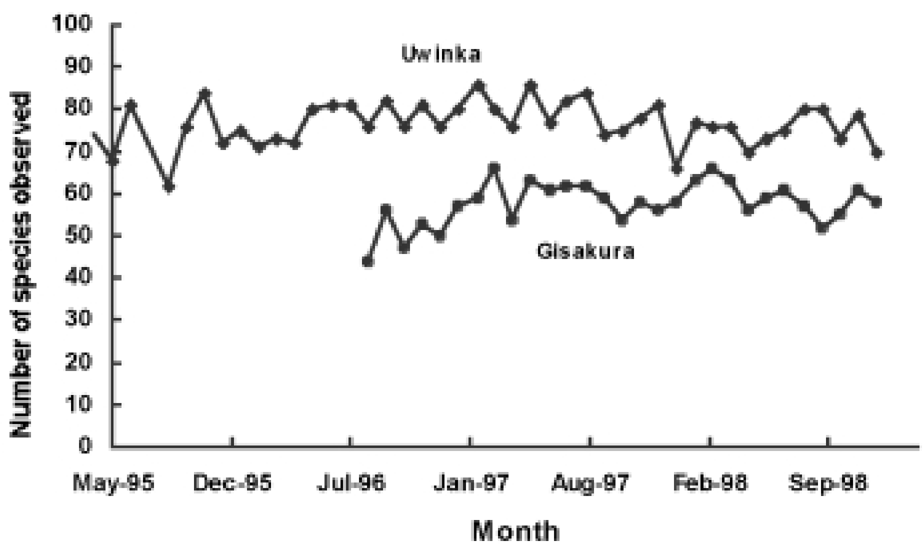
A total of 183 species of birds and 21 species of mammals were recorded during at least one month of this monitoring. Table 5.2 gives the results of Spearman rank correlations for individual species at each of the sites where they were significant. Fewer significant changes in encounter rates over time occurred at Gisakura but this may be partly a fact of smaller sample sizes. At

Uwinka 13 bird species were declining in abundance and 16 were increasing in abundance. None of the species declining or increasing were Albertine Rift Endemics. At Gisakura 5 bird species were declining and 5 species increasing. One Albertine Rift endemic, *Cossypha archeri* (Archer's Robinchat) was declining over time.

Figure 5.2. Variation in species number at two sites between May 1995 and December 1998 for a) mammals and b) birds.



a. Mammal species number



b. Bird species number

Figure 5.3. The number of snares collected over time in Nyungwe Forest.

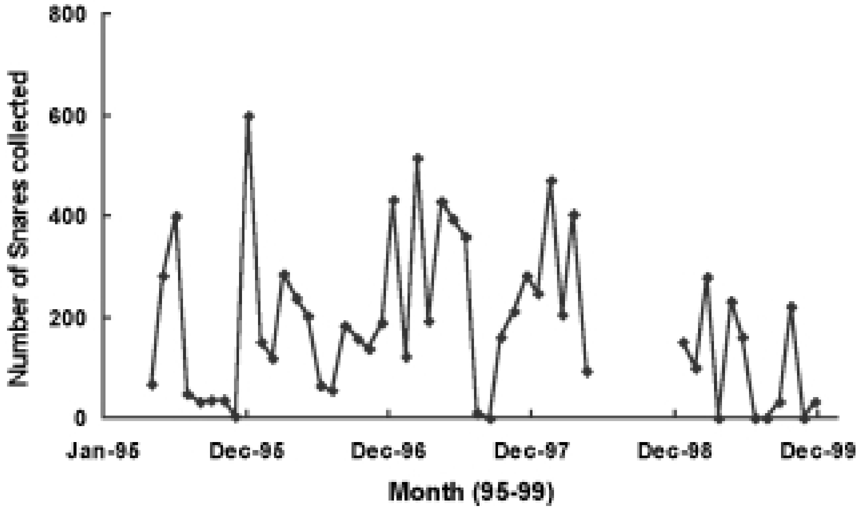


Figure 5.4. Snares collected per man day per month.

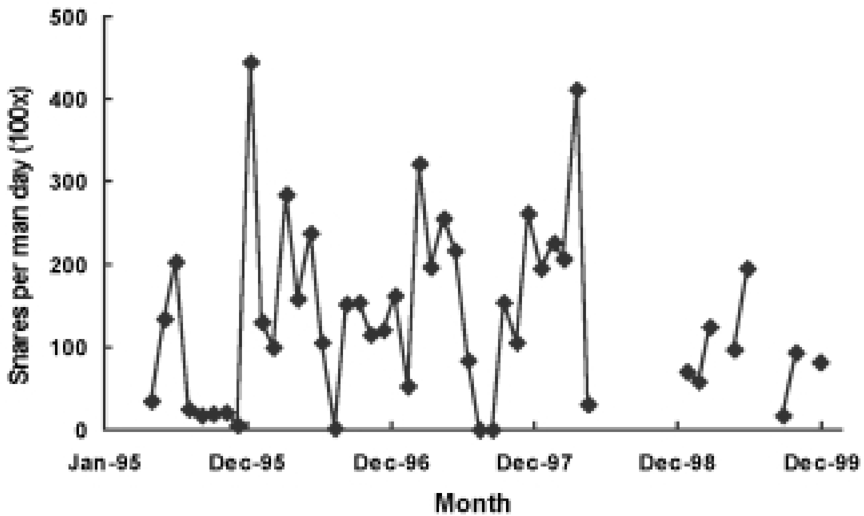
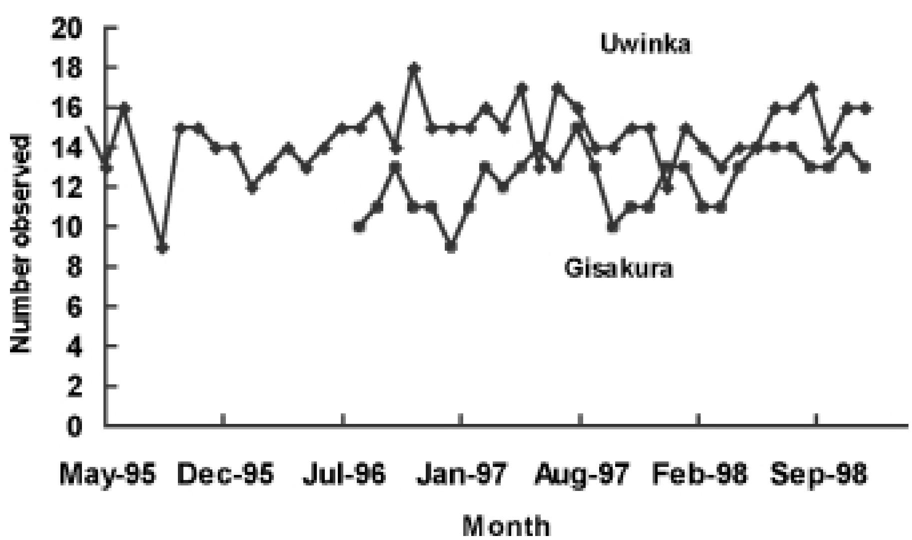


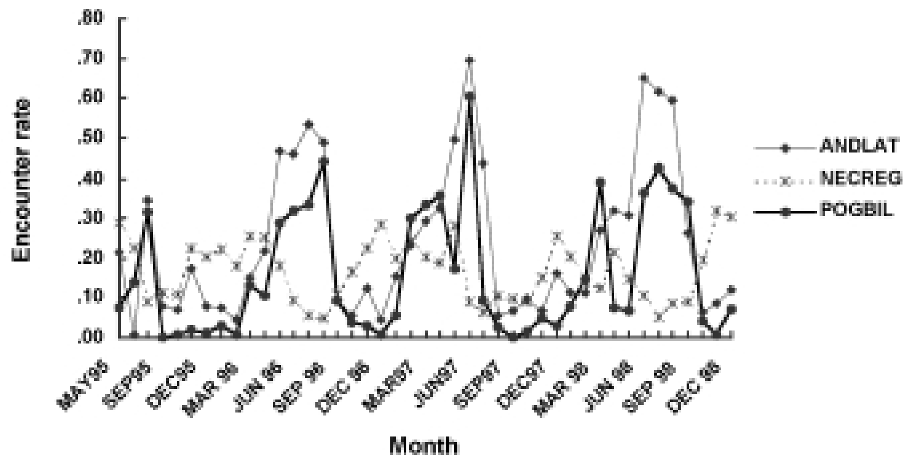
Figure 5.5. The variation in the number of Albertine Rift endemic birds observed in each month between May 1995 and December 1998 for the two sites.



Seasonality in observations of species

Few bird species exhibited seasonality in detection. Seasonality was defined as a regular increase and decrease in encounter rates as time increased. Not surprisingly *Merops apiaster*, the Eurasian beeater, was seasonal at Uwinka and Gisakura as it migrates to the north between April-September each year. The only other species that was seasonal at Gisakura was the Rameron Pigeon (*Columba arquatrix*). At Uwinka these two species and a further four species exhibited seasonality (Fig. 5.6): *Andropadus latirostris* (yellow-whiskered greenbul), *Bycanistes subcylindricus* (Black and white casqued hornbill), *Nectarinia regia* (Regal sunbird- an Albertine Rift endemic) and *Pogoniulus bilineatus* (yellow-rumped tinkerbird).

Figure 5.6. Plots of the five resident bird species that exhibited seasonality at Uwinka. All exhibit a marked decline in detectability from November-February. ANDLAT= *Andropadus latirostris*; NECREG= *Nectarinia regia*; POGBIL= *Pogoniulus bilineatus*; BYCSUB= *Bycanistes subcylindricus*; COLARQ= *Columba arquatrix*



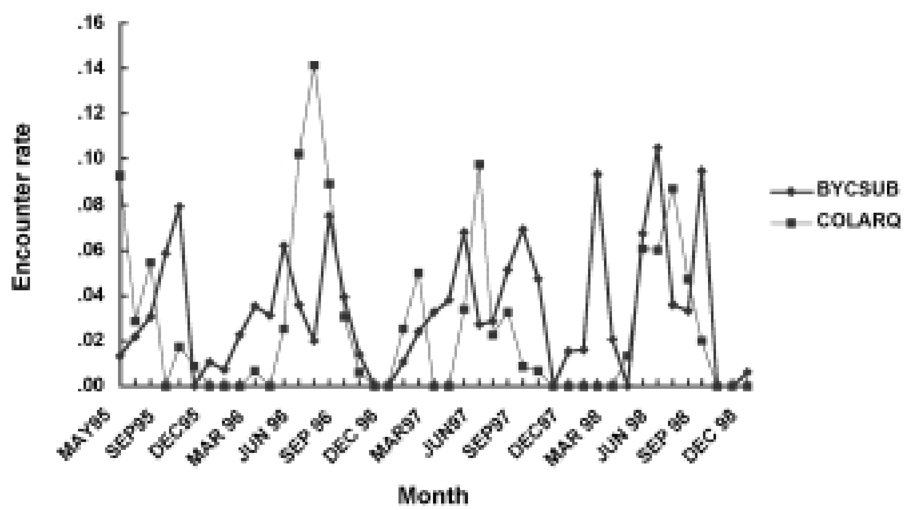


Table 5.2. Spearman rank correlations between species encounter rate (mammals/km walked; birds/point count) and time since the start of monitoring. Only significant results are reported.

Species	Uwinka	Gisakura
Mammals		
Potamochoerus larvatus	-0.514 p=0.001	ns
Cephalophus nigrifrons	-0.421 p=0.010	ns
Atherurus africanus	-0.769 p<0.001	ns
Cricetomys gambianus	-0.590 p<0.001	ns
Paraxerus boehmi	-0.443 p=0.007	ns
Cercopithecus mitis	ns	-0.397 p=0.033
Birds		
Andropadus curvirostris	-0.345 p=0.024	ns
A. masukuensis	-0.443 p=0.003	ns
Aquila wahlbergi	-0.437 p=0.003	ns
Buteo oreophilus	ns	-0.536 p=0.003
Chloropeta natalensis	-0.558 p<0.001	ns
Cossypha archeri	ns	-0.404 p=0.030
Indicator variegatus	-0.406 p=0.007	-0.424 p=0.022
Nectarinia afra	-0.464 p=0.002	ns
Onychognathus tenuirostris	-0.317 p=0.039	ns
Phyllastrephus flavostriatus	ns	-0.453 p=0.014
Ploceus alienus	-0.323 p=0.034	ns
Pogonocichla stellata	-0.624 p<0.001	ns
Prinia leocopogon	-0.473 p=0.001	ns
P. subflava	-0.420 p=0.005	-0.498 p=0.006
Psalidoprocne holomelaena	-0.488 p=0.001	ns
Tockus alboterminatus	-0.318 p=0.038	ns
Andropadus gracilis	0.405 p=0.007	ns
A. latirostris	ns	0.388 p=0.038
A. tephrolaemus	0.455 p=0.002	ns
Anthreptes collaris	0.601 p<0.001	ns
Apalis binotata	0.498 p=0.001	ns
A. porphyrolaema	0.447 p=0.003	ns
Bathmocercus cerveniventris	0.447 p=0.003	ns
Camaroptera brevicaudata	0.479 p=0.001	ns
Chloropeta similis	0.516 p<0.001	ns
Cisticola chubbi	0.461 p=0.001	0.426 p=0.021
Malaconotus dohertyi	0.406 p=0.007	ns
Merops oreobates	ns	0.373 p=0.046
Nectarinia olivacea	ns	0.469 p=0.010
N. purpureiventris	ns	0.376 p=0.044
Nigrita canicapilla	0.468 p=0.002	ns
Phylloscopus umbrovirens	0.464 p=0.002	ns
Prinia bairdii	0.540 p<0.001	ns
Sylvietta leucophrys	0.314 p=0.041	ns

A higher proportion of mammals were observed to be declining (23%) at Uwinka, probably due to the very high levels of poaching using snares that has occurred in this forest following the civil war and genocide

Discussion

A total of 183 species of bird were recorded during this monitoring and 21 species of mammal. Relatively few birds (16% at Uwinka and 5% at Gisakura) showed any trends in their populations over this period of time and only one trend was observed for an Albertine Rift endemic. Archer's Robinchat was observed to be declining at Gisakura and was not recorded at Uwinka and this species should become the focus of a more detailed study to determine why it is declining at Gisakura.

A higher proportion of mammals were observed to be declining (23%) at Uwinka, probably due to the very high levels of poaching using snares that has occurred in this forest following the civil war and genocide. Since 1994 the National Parks organization (ORTPN) has been very strapped for money as few tourists were visiting the mountain gorillas in the Parc National des Volcans in the north of the country. This was historically where most of ORTPN's operating budget came from. Tourism has started to increase in 1999 and 2000 and recently 90 additional forest guards were employed by ORTPN in Nyungwe. It is hoped that this additional manpower will reduce the poaching levels and allow the mammal numbers to come back.

Only 6 species of bird and no mammal species had any evidence of seasonality in their abundance or detectability. Consequently, there should not be any great concern over the time of year when the Nyungwe survey took place. In fact, for all of the seasonal species it was the ideal time of year to undertake the surveys as detectability was high for each of them.

A PCFN planning meeting at the Uwinka site, Nyungwe Forest

CONSERVATION PLANNING FOR NYUNGWE FOREST

Introduction

The results of the analyses of mammal data, bird data and tree data give us a good idea of which sites tend to be more important for total species richness and endemics. The aim of this chapter is to examine all of these results and synthesize an overall conservation ranking for each of the surveyed sites within the forest. This type of synthesis has been undertaken between forests (Margules *et al.*, 1988, 1994; Lombard *et al.*, 1995; Howard *et al.*, 2000) but to our knowledge has not been applied to sites within a protected area. There are a variety of methods for building networks of protected areas (Lomolino 1994) and consequently there are just as many ways of analysing multi-taxa data to identify the most important conservation sites within a reserve. Here we used three methods that examined total species richness, abundance of species of particular conservation importance (measured as Albertine Rift endemics) and complementarity analysis (Margules *et al.* 1988, 1994; Lombard *et al.* 1995).

Methods

Total Species Richness

The three taxa, mammals, birds and trees were ranked from 13 - 1 in order of their total actual and projected species richness. Projected species richness was calculated for trees and birds using the first order jackknife estimate. The scores for each taxa were then summed across sites to provide a 'ranking of total species'. These scores were then mapped.

Species of Conservation Concern

Likewise the three taxa were ranked from 13 - 1 in order of the number of Albertine Rift endemics that were encountered during the surveys. Where zero records were encountered the rank was zero rather than 1-13. The rankings were summed for each site to produce an overall 'ranking of conservation concern'. These scores were mapped.

Complementarity Analysis

Complementarity analysis proceeds in the following way. For each taxa the site which had the most species is identified and the percentage contribution of species found at that site compared to all species in the taxa calculated. The second step is then to select the site which adds the most number of 'new' species that were not encountered at the first site and calculate the percentage of all the species that are added. This process continues until all species have been accounted for at least once at a site. Each site is given a rank from 1 to 13 and once all species are accounted for all other sites receive a rank of zero. The rank position for each taxa were plotted on the map of Nyungwe.

All 13 sites are required to protect all species of plant, mammal and bird but only 8 sites are required to protect all Albertine Rift Endemics

Two methods of complementarity were used:

Complementarity analysis was calculated on total species richness and number of Albertine Rift Endemics and proceeded as described above.

Complementarity analysis proceeded first on the Albertine Rift endemics before moving to species richness once all the sites with endemics had been selected (i.e. choose the site with most endemic species and record the total number of species accounted for. Then select the site that contributes the most 'new' endemics – if there is a tie choose the site with most total species to add).

The data were then combined by summing the rank values across taxa for each site to provide an overall 'complementarity rank'.

Results

Method 1.

The rankings for mammals, birds and woody plants were plotted on the map of Nyungwe for both total species richness and the Albertine Rift Endemics (Fig. 6.1; Appendix 6.1). All mammal species can be accounted for in only three sites, all plant species in 9 sites but all 13 sites were required to protect all bird species. However if the focus of conservation is on the rarer endemic species then many fewer sites are needed to protect these: 3 for mammals, 3 for birds and 4 for plants.

How well does a selection of sites based on one taxa 'capture' the sites for other taxa? Table 6.1 gives the Spearman Rank Correlations between the rankings of the three taxa for both species richness and Albertine Rift endemics. It can be seen that focusing on one of these taxa does not capture the important sites for other taxa.

The sum of the site rank scores were summed for mammals, birds and plants to give a composite score for species richness and for Albertine Rift Endemics (Fig. 6.2). All 13 sites are required to protect all species of plant, mammal and bird but only 8 sites are required to protect all Albertine Rift Endemics. The most important sites for both analyses are in the west of the forest and Uwinka and Gisakura rank highest.

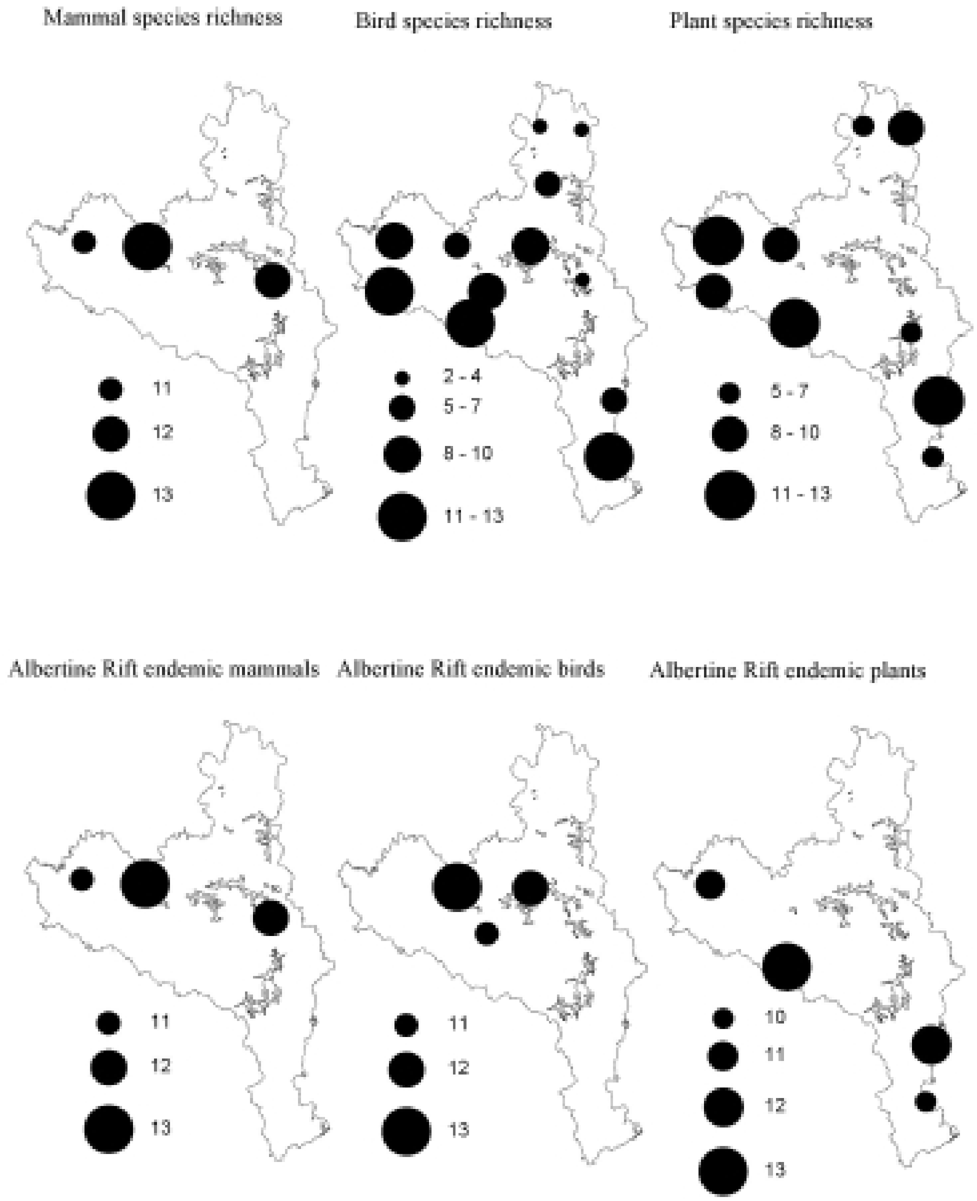


Figure 6.1. Complementarity rankings for each site for mammals, birds and plants. Ranks of '0' are not pictured.

Table 6.1. Spearman rank correlations between complementarity scores for mammal, bird and plant species richness (SR) and Albertine Rift endemism (ARE). Values in **bold** are significant at the p<.05 level.

	Mammal SR	Bird SR	Plant SR	Mammal ARE	Bird ARE	Plant ARE
Mammal SR	---	-0.009 n.s.	0.328 n.s.	**1.000 p<.001**	.390 n.s.	.107 n.s.
Bird SR	---	---	0.215 n.s.	-.009 n.s.	.171 n.s.	.436 n.s.
Plant SR	---	---	---	.328 n.s.	-0.350 n.s.	**.687 p=.017**
Mammal ARE	---	---	---	---	.390 n.s.	.107 n.s.
Bird ARE	---	---	---	---	---	-.354 n.s.
Plant ARE	---	---	---	---	---	---

Method 2.

Method 2 tries to combine the focus on Albertine Rift Endemics with total species richness by effectively weighting the sites for conservation of Albertine Rift Endemics so that all of these are protected before other species are included. Only three sites are needed to protect all mammals, the same sites as for species richness and for Albertine Rift Endemics alone (Fig. 6.3). However, 13 sites are needed to conserve all birds with higher scores for the sites in the west and center of the forest. Plants, however require a focus on sites in the west and south (Fig. 6.3). The scores for the three taxa and the summed total score are given in Table 6.2. The Spearman Rank correlation between scores for mammals, birds and plants are low: Mammals–birds: r_S=.134, p=.643; Mammals-Plants: r_S=-.111, p=.700; Birds-Plants: r_S=-.050, p=.8621.

The summed rank scores for the three taxa using this method are plotted in Figure 6.4. This indicates that the most important sites for conservation in Nyungwe for all taxa combined and weighting for Albertine Rift Endemic species are Uwinka and Gisakura, with Nshili and Bweyeye as the next most important.

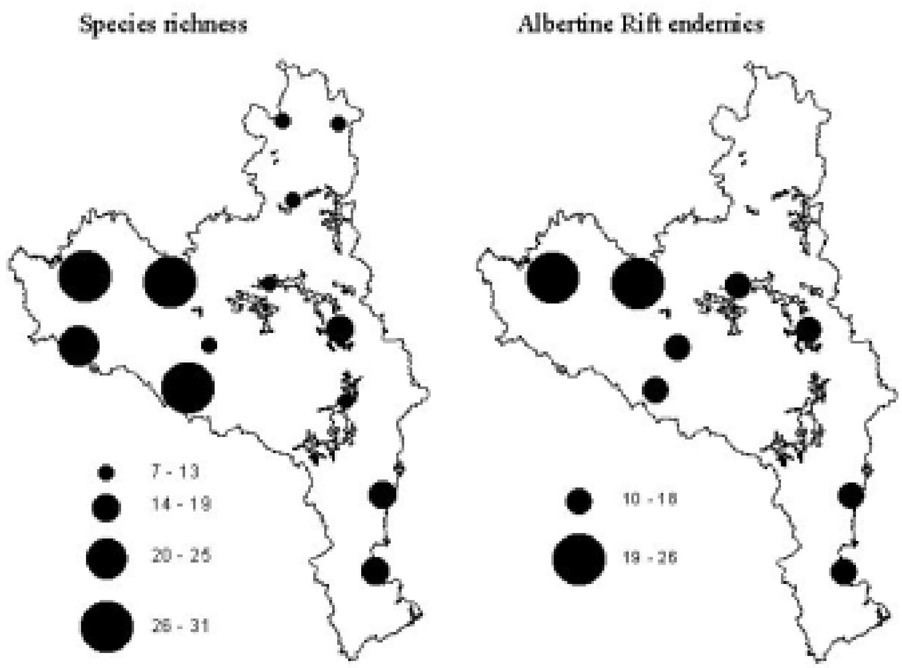


Figure 6.2. Summed complementarity rankings for species richness and Albertine Rift endemics for each site at Nyungume. Summed ranks of ‘0’ are not pictured.

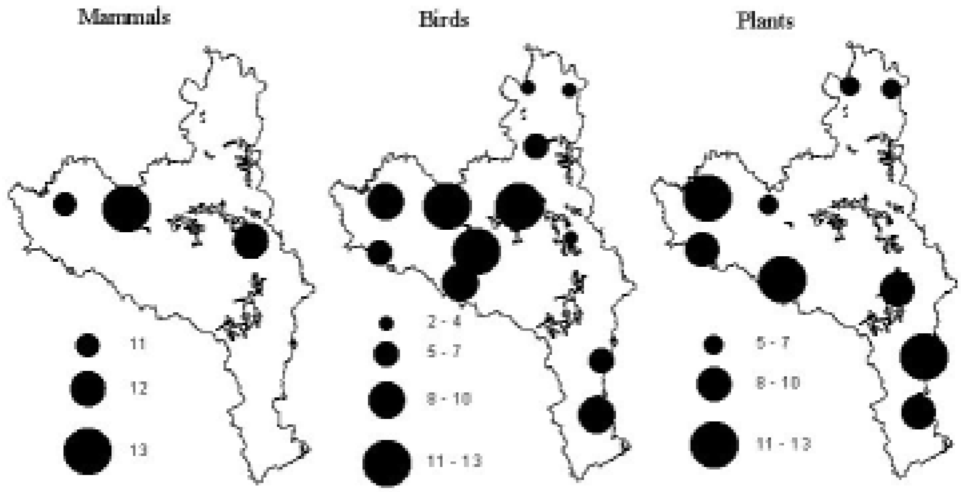


Figure 6.3. Complementarity rankings for mammals, birds, and plants based primarily on Albertine Rift endemics and secondarily on total species richness at each site (see text for details). Ranks of '0' are not pictured.

Table 6.2. Complementarity scores calculated with Method 2 in which Albertine Rift endemism (ARE) is given top priority and species richness (SR) second priority in mammals, birds and plants at the 13 survey sites.

Site	Mammals	Birds	Plants	Total
Busoro	0	11	0	11
Bweyeye	0	9	13	22
Gisakura	11	8	11	30
Kagano	0	4	7	11
Kivu	0	5	12	17
Muzimu	0	3	5	8
Nshili	0	10	10	20
Nyabihu	0	0	8	8
Nyabitimbo	0	6	9	15
Rubyiro	0	12	0	12
Ruzizi	0	7	0	7
Uwasenkoko	12	2	0	14
Uwinka	13	13	6	32

Discussion

A problem with the several methods used here is how to decide which result to accept and use. Conservation operates at various scales and managers need to decide at what scale they will focus. Any conservation manager will want to conserve as much of the biodiversity that exists in their protected area as possible and so focusing on species richness might be the most useful measure for identifying the priority areas for conservation in Nyungwe. However there are considerations of a larger scale than that of the protected area. If we analyze the situation at the global scale then we should focus on the Albertine Rift Endemics which are known to be globally restricted and therefore more likely to suffer extinction than more widely ranging species. Therefore the analysis that focuses on Albertine Rift endemics alone would be the better one to select.

We hope though that by studying three very different taxa we will capture the sites of conservation importance for most of the unstudied taxa

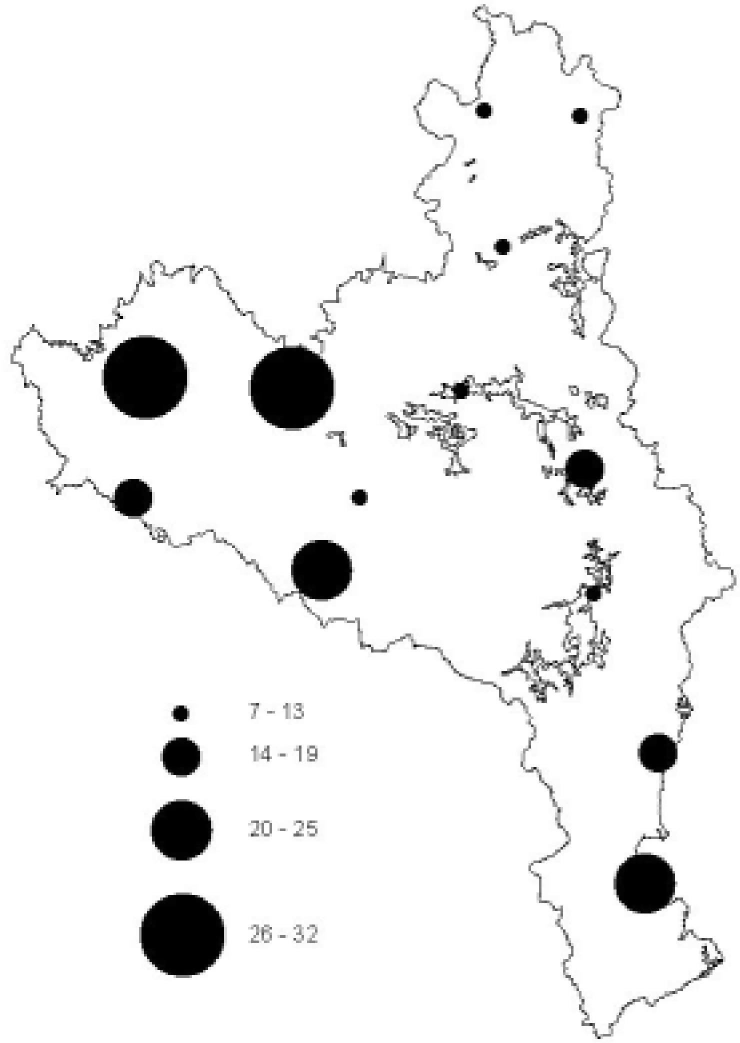


Figure 6.4. Summed complementarity rankings based primarily on Albertine Rift endemics and secondarily on total species richness at each site (see text for details).

The second method used in the analyses above tries to combine both of these into one measure that weights sites for conservation of Albertine Rift Endemics but does not neglect the other biodiversity in the forest. Consequently we would advocate the results displayed in Figure 6.4 as the better model to use when designing conservation actions for Nyungwe.

The Spearman Rank Correlations between rankings for each taxa comparisons were low indicating that no one taxa could be used as a surrogate for the other taxa. It is therefore possible that unstudied taxa (e.g. insects, reptiles, amphibians, etc.) may come out completely differently as well. We hope though that by studying three very different taxa we will capture the sites of conservation importance for most of the unstudied taxa.

Uwinka and Gisakura have the highest overall conservation ranking which is encouraging for the management of Nyungwe as these two sites are already better protected then the other sites because of the permanent presence of the tourism site at Uwinka and the ORTPN headquarters at Gisakura. However, the fact that tourism takes place at one of the areas of highest conservation ranking is of some concern. Ideally the sites of highest conservation value would remain as little disturbed as possible and tourism would be managed in sites of intermediate conservation value (where enough animals of interest occur but where it is less important if tourists have a negative impact on the environment). It would be very difficult to shift the tourism site at Uwinka but these results indicate that the impacts of tourists should be carefully monitored here. It may also be sensible to look at other potential sites such as at Rubyiro as a second tourism site if tourist numbers ever build up to a level where they start to have a negative impact at Uwinka.

These analyses show that Nshili and Bweyeye are also of reasonably high conservation value. Nshili is an unusual habitat type with a lot of bamboo whilst Bweyeye is important because it contains some relatively low altitude forest that is very diverse (Fig. 4.1). Both are sites that are being heavily impacted by human activities (Chapter 2). Nshili had the second highest encounter rate of human signs and Bweyeye had 52% of vegetation sites having been cleared by man (Chapter 4). Therefore guard patrols should concentrate in these two areas to ensure their protection and survival.

Bweyeye, Gisakura, Nshili, and Uwinka combined include 89% of the mammals, 78% of the birds, and 66% of the woody plants detected during our surveys at Nyungwe. Management of Nyungwe should give priority to these four sites to minimize human impacts. However, this does not mean that the rest of the forest is not valuable. Each site protects at least one species in the forest that was not found at the other sites and efforts should be made to keep the boundaries of the forest intact. However, if some forms of human use of the forest are ever considered in future, these should be located at the edge of the forest near the sites that are of lower conservation value.

As one of the few remaining lower montane rainforests in Africa, Nyungwe represents an important location for future biological research

Priorities for future biological research at Nyungwe

As one of the few remaining lower montane rainforests in Africa, Nyungwe represents an important location for future biological research. Perhaps the most important botanical research that could be conducted at Nyungwe would be to monitor and study the process of regeneration within the forest after the recent fires. Determining those plant taxa that are most adversely affected by fire (e.g. poor fire resistance; poor regeneration) is important for future fire management in the reserve. The effects of these fires on bird communities at Nyungwe also deserve investigation. It would also be useful to investigate the habitat requirements of vulnerable bird species within the reserve to devise conservation strategies to better protect these species. Furthermore, Archer's robinchat has been declining in number at Gisakura and an investigation into the reasons for this decline would of considerable conservation importance.

Among the large mammals, primates are both the most abundant and the easiest to study. Some priorities for future primate research were discussed in the chapter on mammals. These included further research on the behavioral ecology of the semi-habituated chimpanzee troop near Uwinka, the ultimate causes of supergroup formation among the Angolan colobus monkeys, and the basic natural history and conservation status of the owl-faced guenons. One other area of future primate research not discussed in the mammals section that is of importance is a survey to identify the species of nocturnal primates existing at Nyungwe as well as their distribution and relative abundance. At present, virtually nothing is known about the nocturnal primates at Nyungwe.

The steep terrain makes the intensive study of other large mammals rather difficult at Nyungwe. However, surveys for small mammals are of considerable importance since we know little about the small mammal communities at Nyungwe, despite the fact that the majority of Albertine Rift endemic mammals are small mammals. Determining the distribution of Albertine Rift endemic small mammals at Nyungwe is therefore of substantial conservation concern.

In conclusion, there are clearly a variety of interesting and important possibilities for biological research at Nyungwe. We hope that much of this research will be undertaken in the future and that the results will be taken into consideration when future conservation decisions are made regarding the Nyungwe Forest.

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APPENDICES

Appendix 2.1. Encounter rates of mammals per km of all forms of detection combined (sight, sound, dung and tracks).
(Note: chimpanzees detected by their nests are in a separate column from chimpanzees detected by sight, sound or tracks.

Site	Chimpanzee nest	Chimpanzee	Baboon	Blue	Colobus	L'hoesti	Mangabey	Unidentified monkey	Total Primates[1]	Elephant[2]	Duiker	Bushpig	Ungulates	Carnivores	Porcupine	Rat	Total Mammals
Busoro	2.813	1.964	0.000	0.045	0.000	0.000	0.000	0.402	2.411	0.000	0.179	0.134	0.313	0.045	0.000	0.000	7.456
Bweyeye	1.903	0.323	0.000	0.258	0.065	0.032	0.032	0.161	0.871	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.871
Gisakura	0.299	0.249	0.025	0.075	0.000	0.025	0.025	0.224	0.623	0.100	0.100	0.000	0.200	0.175	0.025	0.000	5.823
Kagano	1.481	0.231	0.000	0.046	0.139	0.000	0.000	0.231	0.647	0.000	0.000	0.556	0.556	0.000	0.000	0.000	5.647
Kivu	0.000	0.909	0.121	0.121	0.000	0.061	0.000	0.848	2.060	0.000	0.242	0.303	0.545	0.061	0.000	0.121	7.242
Muzima	3.103	0.153	0.000	0.268	0.000	0.115	0.000	0.230	0.766	0.000	0.000	0.690	0.690	0.000	0.000	0.000	5.766
Nshili	0.971	0.144	0.000	0.144	0.000	0.000	0.036	0.899	1.223	0.000	0.000	0.432	0.432	0.072	0.000	0.000	6.295
Nyabihu	2.124	0.973	0.000	0.000	0.000	0.000	0.000	1.150	2.123	0.000	0.575	4.381	4.956	0.088	0.000	0.221	7.432
Nyabitimbo	2.348	0.478	0.000	0.087	0.130	0.043	0.261	0.261	1.260	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6.260
Rubyiro	1.581	0.515	0.000	0.000	0.000	0.037	0.000	0.846	1.398	0.000	0.221	2.022	2.243	0.111	0.000	0.000	6.509
Ruzizi	0.313	0.069	0.000	0.104	0.035	0.035	0.000	0.382	0.625	0.000	0.000	1.146	1.146	0.000	0.000	0.000	5.625
Uwasenkoko	0.348	0.217	0.000	0.217	0.000	0.087	0.000	0.826	1.347	0.000	0.217	1.261	1.478	0.043	0.000	0.130	6.520
Uwinka	2.228	1.337	0.000	0.306	0.139	0.028	0.139	1.421	3.370	0.000	0.000	0.000	0.000	0.084	0.028	0.000	8.482

[1] not including chimpanzee nests
[2] the elephant detected at Gisakura is believed to have been poached several months later

Encounter rates of animals seen per km along reconnaissance transects

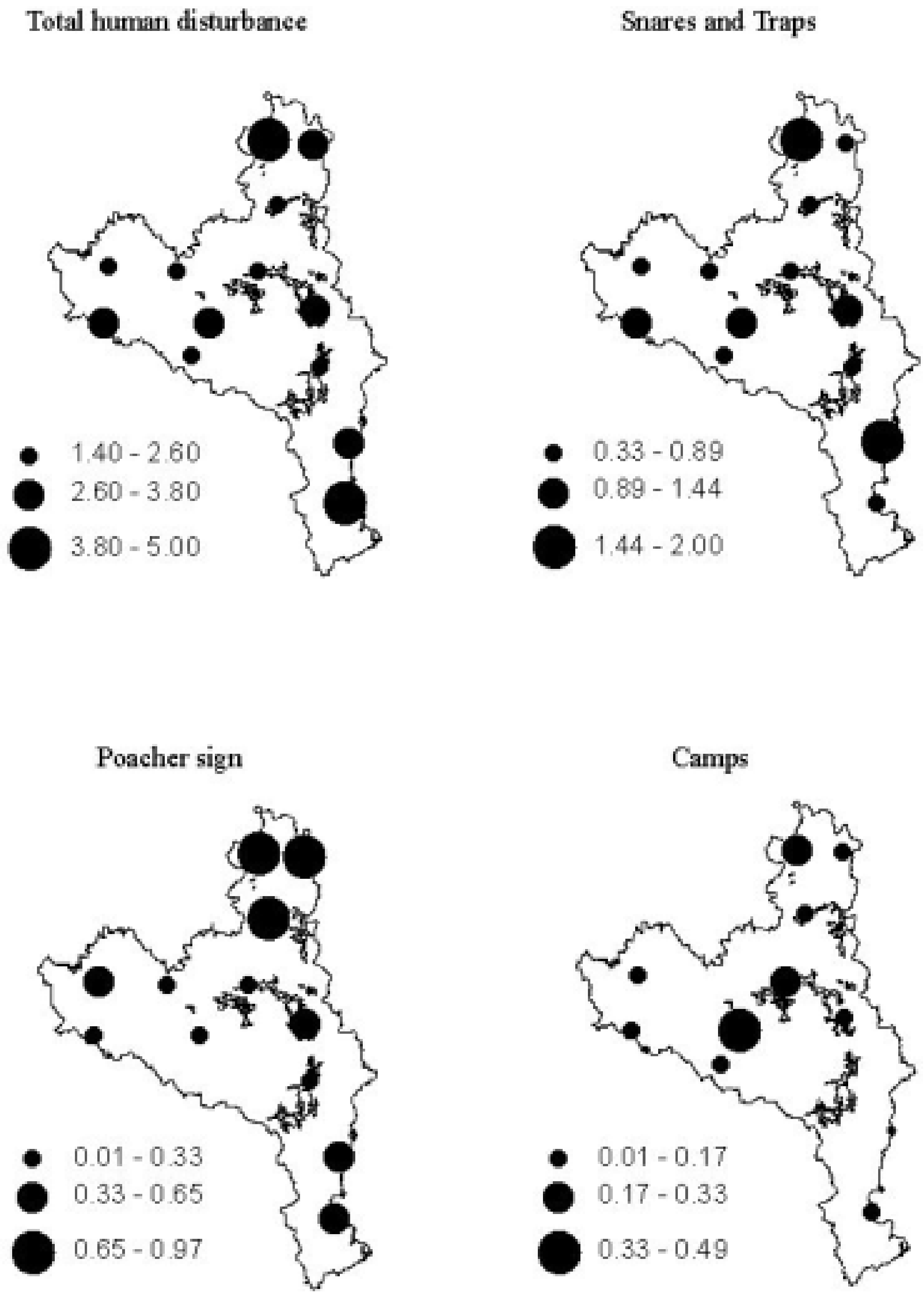
Site	Blue	L'hoesti	Mangabey	Colobus	Duiker	Bushpig	Serval	Rat	Total
Busoro	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bweyeye	0.097	0.032	0.000	0.032	0.000	0.000	0.000	0.000	0.161
Gisakura	0.025	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.050
Kagano	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Kivu	0.121	0.061	0.000	0.000	0.061	0.000	0.000	0.000	0.242
Muzima	0.192	0.115	0.000	0.000	0.000	0.000	0.000	0.000	0.307
Nshili	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nyabihu	0.000	0.000	0.000	0.000	0.088	0.000	0.000	0.000	0.088
Nyabitimbo	0.043	0.043	0.087	0.043	0.000	0.000	0.000	0.000	0.217
Rubyiro	0.000	0.037	0.000	0.000	0.000	0.000	0.000	0.000	0.037
Ruzizi	0.035	0.035	0.000	0.035	0.000	0.000	0.000	0.000	0.104
Uwasenkoko	0.043	0.087	0.000	0.000	0.043	0.043	0.043	0.087	0.348
Uwinka	0.084	0.028	0.028	0.000	0.000	0.000	0.000	0.000	0.139

Encounter rates of dung per km.

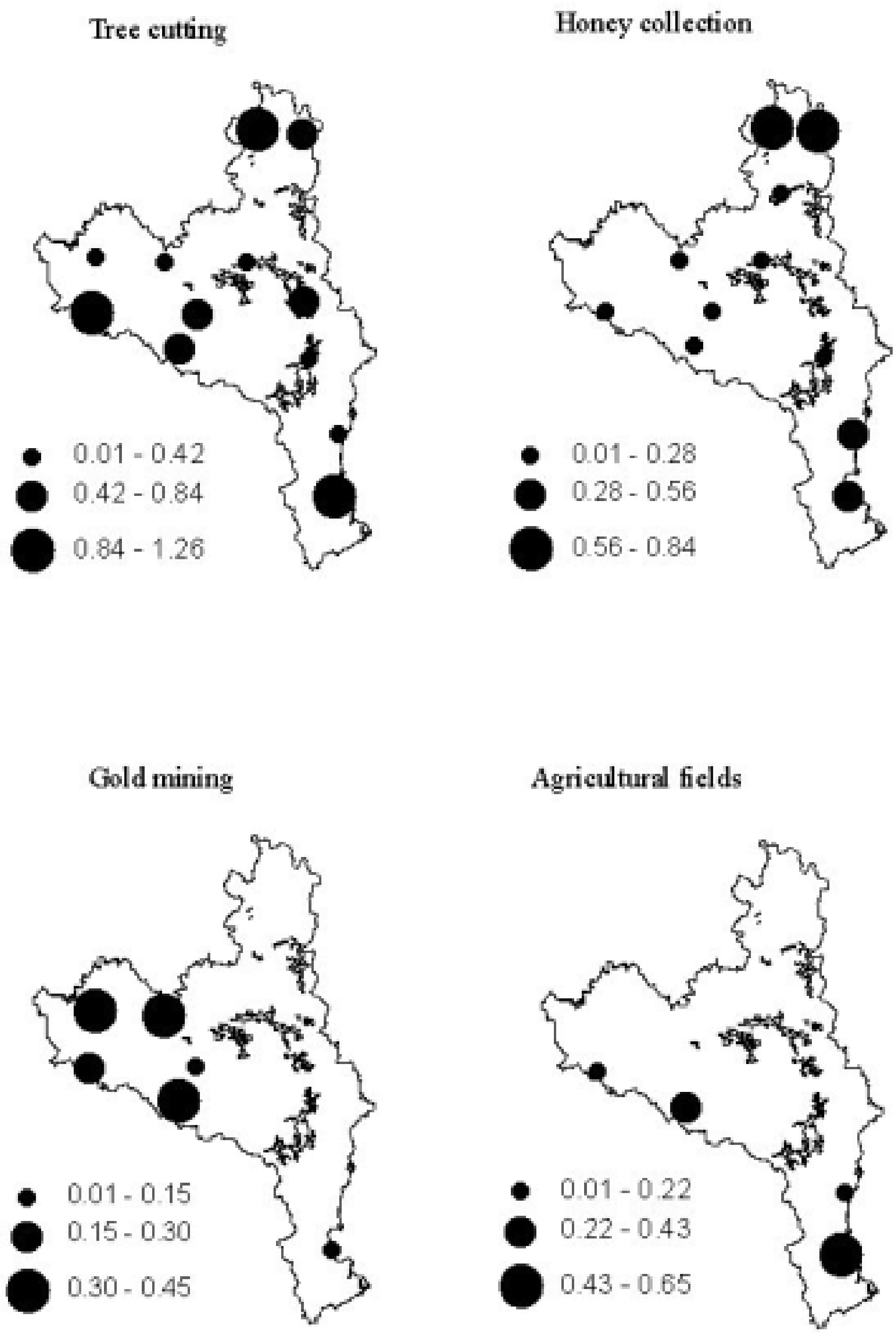
Site	Chimpanzee	Baboon	Monkey	Carnivore	Duiker	Bushpig	Rat	Total
Busoro	1.250	0.000	0.313	0.045	0.179	0.089	0.000	1.875
Bweyeye	0.258	0.000	0.032	0.000	0.000	0.000	0.000	0.290
Gisakura	0.075	0.025	0.200	0.150	0.100	0.000	0.000	0.549
Kagano	0.185	0.000	0.185	0.000	0.000	0.231	0.000	0.602
Kivu	0.545	0.061	0.788	0.061	0.061	0.182	0.061	1.758
Muzima	0.077	0.000	0.230	0.000	0.000	0.268	0.000	0.575
Nshili	0.072	0.000	0.719	0.072	0.000	0.108	0.000	0.971
Nyabihu	0.796	0.000	0.973	0.088	0.442	3.053	0.177	5.530
Nyabitimbo	0.217	0.000	0.217	0.000	0.000	0.000	0.000	0.435
Rubyiro	0.184	0.000	0.735	0.110	0.037	1.140	0.000	2.206
Ruzizi	0.000	0.000	0.278	0.000	0.000	0.556	0.000	0.833
Uwasenkoko	0.130	0.000	0.609	0.000	0.043	0.565	0.043	1.391
Uwinka	1.142	0.000	1.421	0.084	0.000	0.000	0.000	2.647

Appendix 2.2. Relative encounter rates (number per km censused) of all human signs for each site sampled.

Site	Snares/ Traps	Poacher sign	Camps	Tree cutting	Bamboo cutting	Honey collection	Gold mining	Burned areas	Clearing	Agriculture	Cattle sign	Troughs	Huts	Total human disturbance
Busoro	1.384	0.089	0.491	0.804	0.000	0.045	0.134	0.134	0.000	0.000	0.000	0.000	0.000	3.100
Bweyeye	0.645	0.000	0.097	0.452	0.000	0.129	0.452	0.194	0.000	0.355	0.000	0.000	0.032	2.200
Gisakura	0.549	0.474	0.150	0.175	0.000	0.000	0.324	0.025	0.000	0.000	0.000	0.000	0.000	1.700
Kagano	0.787	0.972	0.046	0.463	0.000	0.648	0.000	0.046	0.000	0.000	0.046	0.000	0.000	3.000
Kivu	2.000	0.545	0.000	0.182	0.000	0.303	0.000	0.424	0.000	0.061	0.000	0.000	0.000	3.500
Muzimu	1.686	0.881	0.307	1.111	0.000	0.843	0.000	0.153	0.000	0.000	0.000	0.000	0.000	5.000
Nshili	0.827	0.432	0.072	0.935	0.540	0.324	0.108	0.468	0.000	0.647	0.396	0.072	0.000	4.800
Nyabihu	0.752	0.221	0.000	0.133	0.000	0.133	0.000	0.265	0.088	0.000	0.044	0.044	0.000	1.700
Nyabitimbo	1.217	0.130	0.130	1.261	0.000	0.130	0.174	0.174	0.000	0.130	0.000	0.000	0.000	3.300
Rubyiro	0.331	0.294	0.221	0.074	0.000	0.147	0.000	0.478	0.000	0.000	0.000	0.000	0.000	1.500
Ruzizi	0.799	0.868	0.174	0.000	0.000	0.139	0.000	0.660	0.000	0.000	0.000	0.000	0.000	2.600
Uwasenkoko	1.391	0.522	0.174	0.696	0.000	0.000	0.000	0.478	0.000	0.000	0.000	0.000	0.000	3.300
Uwinka	0.501	0.056	0.000	0.362	0.000	0.056	0.446	0.028	0.000	0.000	0.000	0.000	0.000	1.400



Appendix 2.3. Encounter rates (signs/km) with snares or traps, poacher sign, camps and all human disturbance combined.



Appendix 2.3 (continued). Encounter rates (signs/km) with tree cutting, honey collection, gold mining, and agricultural fields.

Appendix 3.1 Birds identified during the 1999 surveys. Species with **E** next to their name are Albertine Rift endemics.

SPECIES	BUSORO	BWEYEYE	GISAKURA	KAGANO	KIVU	RUBYIRO	MUZIMU	NSHILI	NYABIHU	NYABITIMBO	RUZIZI	UWASENKOKO	UWINKA
Accipiter melanoleucus										*X*			
Accipiter rufiventris													*X*
Accipiter tachiro	*X*	*X*	*X*			*X*		*X*		*X*			
Alcippe abyssinica	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Alethe poliophrys **E**	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*		*X*	*X*
Amaurornis flavirostris								*X*					
Anas sparsa	*X*												
Anas undulata			*X*					*X*				*X*	
Andropadus curvirostris		*X*											*X*
Andropadus gracilirostris			*X*							*X*			*X*
Andropadus latirostris	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Andropadus nigriceps		*X*	*X*		*X*				*X*	*X*			*X*
Andropadus tephrolaemus	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Anthreptes collaris	*X*		*X*	*X*		*X*	*X*	*X*	*X*	*X*			*X*
Anthreptes fraseri					*X*								
Anthreptes rectirostris											*X*		
Anthus trivialis			*X*					*X*					
Apalis argentea **E**	*X*												
Apalis binotata	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Apalis cinerea	*X*	*X*	*X*							*X*			*X*
Apalis jacksoni	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Apalis porphyrolaema	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Apalis ruwenzorii **E**	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*

SPECIES	BUSORO	BWEYEYE	GISAKURA	KAGANO	KIVU	RUBYIRO	MUZIMU	NSHILI	NYABIHU	NYABITIMBO	RUZIZI	UWASENKOKO	UWINKA
Apaloderma narina			*X*	*X*	*X*		*X*	*X*	*X*	*X*	*X*	*X*	*X*
Apaloderma vittatum	*X*	*X*	*X*							*X*			*X*
Aplopelia larvata	*X*	*X*						*X*				*X*	*X*
Aquila wahlbergi	*X*												*X*
Ardea melanocephala								*X*				*X*	
Ardeola ralloides			*X*										
Balearica regulorum								*X*					
Bathmocercus cerveniventris	*X*	*X*	*X*							*X*			*X*
Batis diops **E**	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Batis molitor					*X*		*X*	*X*	*X*		*X*		
Bostrichia hagedash			*X*	*X*		*X*		*X*	*X*		*X*		
Bradypterus baboecala						*X*		*X*	*X*	*X*			
Bradypterus carpalis								*X*					
Bradypterus cinnamomeus	*X*		*X*	*X*	*X*	*X*	*X*	*X*	*X*		*X*	*X*	*X*
Bradypterus graueri **E**						*X*	*X*				*X*	*X*	
Bubo lacteus				*X*									
Bubo poensis	*X*									*X*			
Buteo buteo			*X*	*X*		*X*		*X*				*X*	
Buteo oreophilus		*X*			*X*	*X*			*X*		*X*	*X*	*X*
Buteo rufofuscus		*X*						*X*					
Bycanistes subcylindricus	*X*	*X*	*X*				*X*			*X*			*X*
Camaroptera brevicaudata			*X*										
Campethera nivosa		*X*		*X*			*X*		*X*			*X*	
Campethera tullbergi	*X*												
Caprimulgus fossii											*X*		

SPECIES	BUSORO	BWEYEYE	GISAKURA	KAGANO	KIVU	RUBYIRO	MUZIMU	NSHILI	NYABIHU	NYABITIMBO	RUZIZI	UWASENKOKO	UWINKA
Caprimulgus ruwenzori **E**	*X*			*X*	*X*	*X*	*X*			*X*	*X*	*X*	*X*
Centropus monachus	*X*	*X*	*X*		*X*	*X*		*X*		*X*		*X*	
Centropus senegelensis				*X*				*X*			*X*		
Cercococcyx montanus	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Chloropeta natalensis		*X*			*X*	*X*		*X*	*X*		*X*	*X*	
Chloropeta similis	*X*			*X*	*X*	*X*	*X*	*X*	*X*		*X*	*X*	*X*
Chrysococcyx caprius			*X*							*X*			
Chrysococcyx cupreus	*X*	*X*											*X*
Chrysococcyx klaas		*X*											
Cinnyricinclus sharpii	*X*	*X*			*X*	*X*		*X*				*X*	*X*
Cisticola chubbi	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Colius striatus		*X*				*X*		*X*			*X*		*X*
Columba arquatrix	*X*	*X*	*X*		*X*		*X*	*X*		*X*		*X*	*X*
Columba unicincta											*X*		
Coracina caesia	*X*	*X*				*X*				*X*		*X*	*X*
Corvus albicollis	*X*	*X*			*X*	*X*							*X*
Corvus albus								*X*			*X*		
Corythaeola cristata	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Criniger chloronotus		*X*											
Cossypha caffra					*X*			*X*					
Cossypha heuglini							*X*						
Cossypha natelensis					*X*								
Cryptospiza jacksoni **E**	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*		*X*
Cryptospiza reichenovii	*X*	*X*		*X*	*X*			*X*		*X*	*X*		
Cryptospiza salvadorii								*X*					

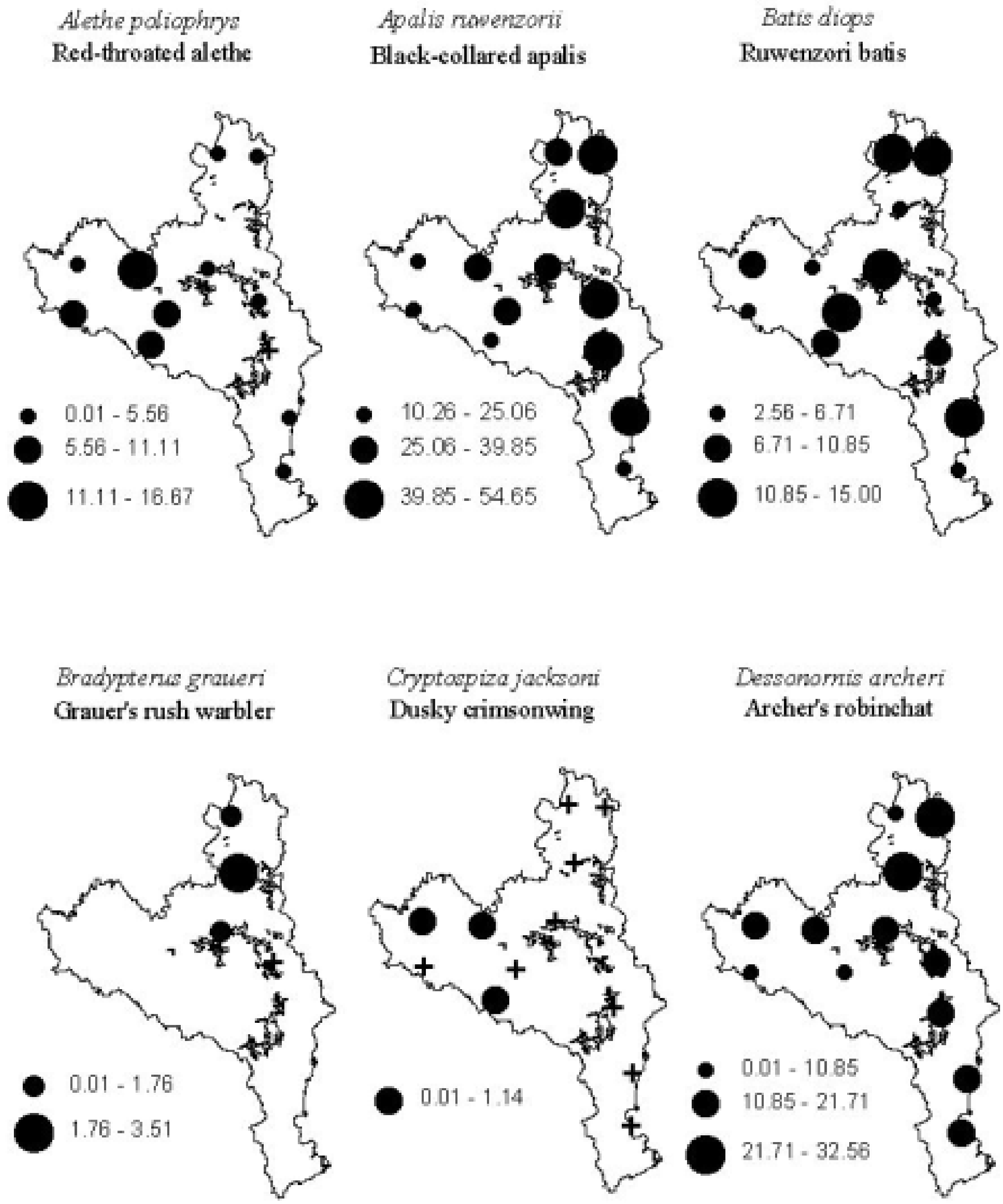
SPECIES	BUSORO	BWEYEYE	GISAKURA	KAGANO	KIVU	RUBYIRO	MUZIMU	NSHILI	NYABIHU	NYABITIMBO	RUZIZI	UWASENKOKO	UWINKA
Cryptospiza shelleyi **E**						*X*					*X*		
Cuculus clamosus	*X*	*X*	*X*							*X*			*X*
Cuculus solitarius	*X*	*X*		*X*			*X*		*X*	*X*	*X*	*X*	
Dendropicos elliotii		*X*											
Dendropicos fuscescens						*X*							
Cossypha archeri **E**	*X*		*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Dicrurus adsimilis		*X*								*X*			
Diopterus fischeri	*X*	*X*	*X*		*X*	*X*	*X*	*X*			*X*	*X*	*X*
Dryoscopus angolensis										*X*			
Dryoscopus gambensis			*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Elimina albonotata	*X*	*X*	*X*										
Elminia albicauda		*X*								*X*			
Elminia albiventris			*X*							*X*		*X*	
Emberiza flaviventris			*X*										
Eminia lepida		*X*											
Erannornis longicauda		*X*			*X*						*X*		
Estrilda atricapilla		*X*	*X*		*X*	*X*			*X*			*X*	
Estrilda melanotis								*X*					
Estrilda nonnula		*X*	*X*					*X*					
Estrilda paludicola								*X*					
Francolinus nobilis **E**	*X*				*X*	*X*			*X*		*X*		*X*
Francolinus squamatus												*X*	
Glaucidium perlatum						*X*							
Graueria vitata **E**	*X*	*X*	*X*	*X*	*X*	*X*	*X*			*X*	*X*	*X*	*X*
Gymnobucco bonapartei										*X*			*X*

SPECIES	BUSORO	BWEYEYE	GISAKURA	KAGANO	KIVU	RUBYIRO	MUZIMU	NSHILI	NYABIHU	NYABITIMBO	RUZIZI	UWASENKOKO	UWINKA
Hemitesia neumanni **E**	X	X	X			X		X		X			X
Indicator conirostris										X			
Indicator minor											X		
Ispidinia picta													X
Kakamega poliothorax	X		X	X	X	X	X	X		X		X	X
Kupeornis rufosinctus **E**	X	X	X	X	X	X	X	X	X		X	X	X
Lagonosticta senegala				X									
Laniarius luehderi	X	X	X			X				X			X
Laniarius poensis	X	X	X	X	X	X	X	X	X	X	X	X	X
Lanius collaris								X					
Lanius mackinnoni	X	X	X					X					
Linurgus olivaceus	X									X			
Lonchura poensis			X										
Lophoatus occipitalis		X				X							
Malaconotus dohertyi	X	X		X	X	X	X	X	X	X	X	X	X
Malaconotus lagdeni											X		
Melaenornis ardesiacus **E**	X	X	X				X	X		X			X
Merops oreobates	X	X		X			X	X		X		X	
Mesopicos griseocephalus		X	X	X		X	X		X	X	X	X	X
Milvus migrans								X					
Motacilla aguimp		X											
Motacilla capensis								X					
Motacilla clara	X	X	X			X				X			
Muscicapa adusta	X	X	X	X	X	X	X	X	X		X	X	X
Muscicapa striata						X							

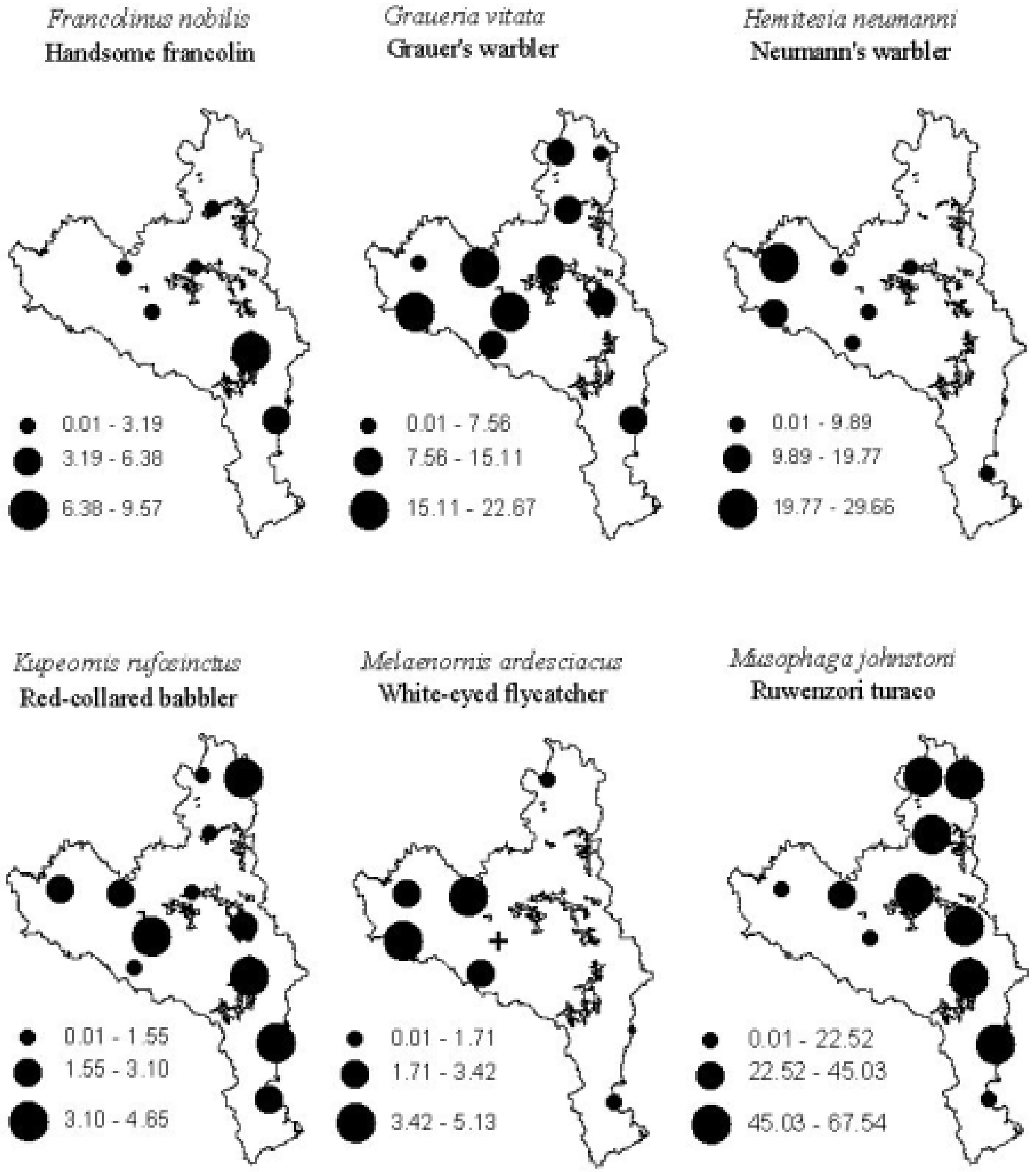
SPECIES	BUSORO	BWEYEYE	GISAKURA	KAGANO	KIVU	RUBYIRO	MUZIMU	NSHILI	NYABIHU	NYABITIMBO	RUZIZI	UWASENKOKO	UWINKA
Musophaga johnstoni **E**	X		X	X	X	X	X	X	X		X	X	X
Nectarinia afra	X	X	X			X	X	X		X	X		
Nectarinia alinae **E**	X	X	X	X	X	X	X	X	X	X	X	X	X
Nectarinia cuprea													X
Nectarinia famosa								X					
Nectarinia kilimensis		X			X			X					
Nectarinia ludovicensis					X				X				
Nectarinia olivacea	X	X	X			X				X			
Nectarinia preussi						X						X	
Nectarinia purpureiventris **E**	X	X	X	X	X	X	X	X			X	X	X
Nectarinia regia **E**	X	X	X	X	X	X	X	X	X	X	X	X	X
Nectarinia spp						X							
Nectarinia venusta			X		X	X		X					X
Nectarinia verticalis		X											
Neocossyphus poensis		X	X	X						X			
Nigrita canicapilla	X	X								X			
Nycticorax nycticorax			X										
Onychognathus tenuirostris			X				X	X		X			X
Onychognathus walleri	X	X	X	X	X	X	X	X	X	X	X	X	X
Oriolus percivali	X	X	X	X	X	X	X	X	X	X	X	X	X
Parus fasciiventer **E**	X		X	X	X	X	X	X	X		X		X
Parus funereus				X						X			X
Phoeniculus bollei	X	X	X	X	X	X	X		X	X	X	X	X
Phoeniculus purpureus				X									
Phyllastrephus flavostriatus	X	X	X	X	X	X	X	X		X	X	X	X

SPECIES	BUSORO	BWEYEYE	GISAKURA	KAGANO	KIVU	RUBYIRO	MUZIMU	NSHILI	NYABIHU	NYABITIMBO	RUZIZI	UWASENKOKO	UWINKA
Phyllastrephus placidus										*X*			*X*
Phylloscopus laetus **E**	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Phylloscopus umbrovirens				*X*	*X*	*X*			*X*			*X*	
Platysteira concreta		*X*	*X*							*X*			*X*
Ploceus alienus E	*X*	*X*	*X*	*X*	*X*	*X*	*X*			*X*	*X*	*X*	*X*
Ploceus baglafecht	*X*	*X*				*X*		*X*			*X*	*X*	
Ploceus cucullatus	*X*	*X*	*X*								*X*	*X*	
Ploceus insignis	*X*												*X*
Ploceus melanogaster		*X*								*X*			
Pogoniulus bilineatus	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Pogoniulus coryphaeus		*X*					*X*						
Pogonocichla stellata	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*		*X*	*X*	*X*
Polyboroides typus								*X*					
Prinia bairdii	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Prinia spp													*X*
Psalidoprocne albiceps					*X*			*X*					
Psalidoprocne holomelaena	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Psittacus erithacus					*X*			*X*					
Pycnonotus barbatus	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Rallus caerulescens								*X*					
Riparia paludicola						*X*		*X*					
Sarothura rufus								*X*					
Saxicola torquatus		*X*	*X*	*X*	*X*			*X*	*X*		*X*	*X*	
Scopus umbretta						*X*		*X*	*X*				
Serinus burtoni	*X*	*X*	*X*		*X*	*X*	*X*			*X*		*X*	

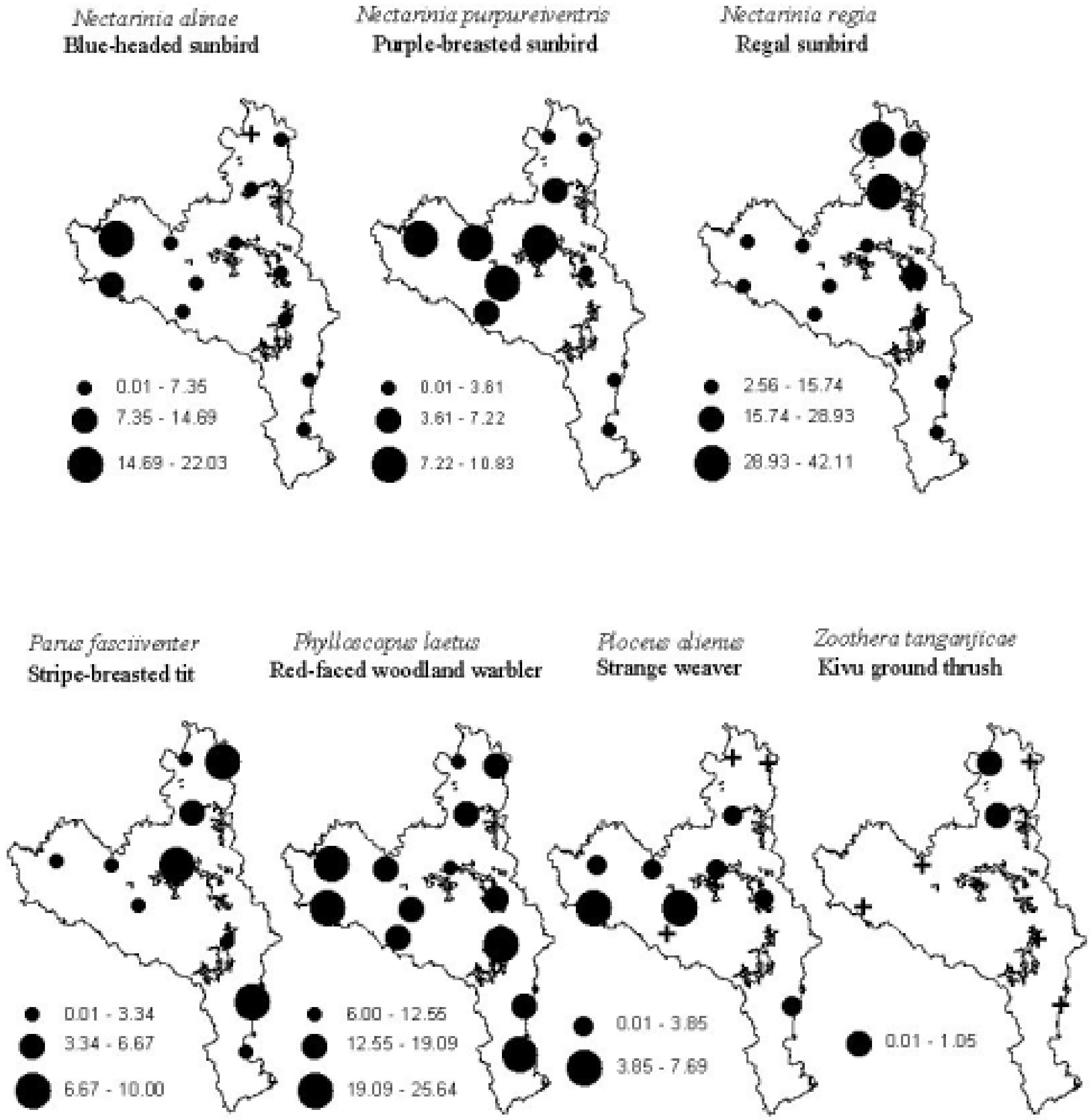
SPECIES	BUSORO	BWEYEYE	GISAKURA	KAGANO	KIVU	RUBYIRO	MUZIMU	NSHILI	NYABIHU	NYABITIMBO	RUZIZI	UWASENKOKO	UWINKA
Serinus citrinelloides	X	X			X	X		X	X		X	X	
Serinus striolatus		X	X	X	X	X	X	X	X		X	X	X
Sheppardia aequatorialis	X	X	X		X					X			X
Smithornis capensis	X	X	X							X			X
Stephanoaetus coronatus	X	X	X	X	X				X				X
Stiphrornis erythrothorax										X			
Streptopelia semitorquata		X	X		X			X	X			X	
Strix woodfordii									X	X		X	X
Sylvietta leucophrys	X	X	X	X	X	X		X		X	X	X	X
Tauraco schuetti	X	X	X				X	X		X			X
Tchagra australis					X	X							
Terpsiphone viridis	X	X	X		X		X	X		X	X	X	X
Tockus alboterminatus				X		X		X	X		X		X
Treron australis	X		X		X	X		X	X	X			
Trichastoma pyrrhopterum	X	X	X	X	X	X	X	X	X	X	X	X	X
Tringa glareola			X										
Trochocercus cyanomelas	X	X								X			X
Turdus olivaceus	X	X	X	X	X	X	X	X	X		X	X	X
Turtur tympanistria	X	X	X		X		X	X	X	X		X	X
Upupa epops	X												
Unknown spp	X				X								
Zoothera tanganjicae **E**				X	X		X		X	X	X		X
Zosterops senegalensis	X	X	X	X	X	X	X	X	X	X	X	X	X



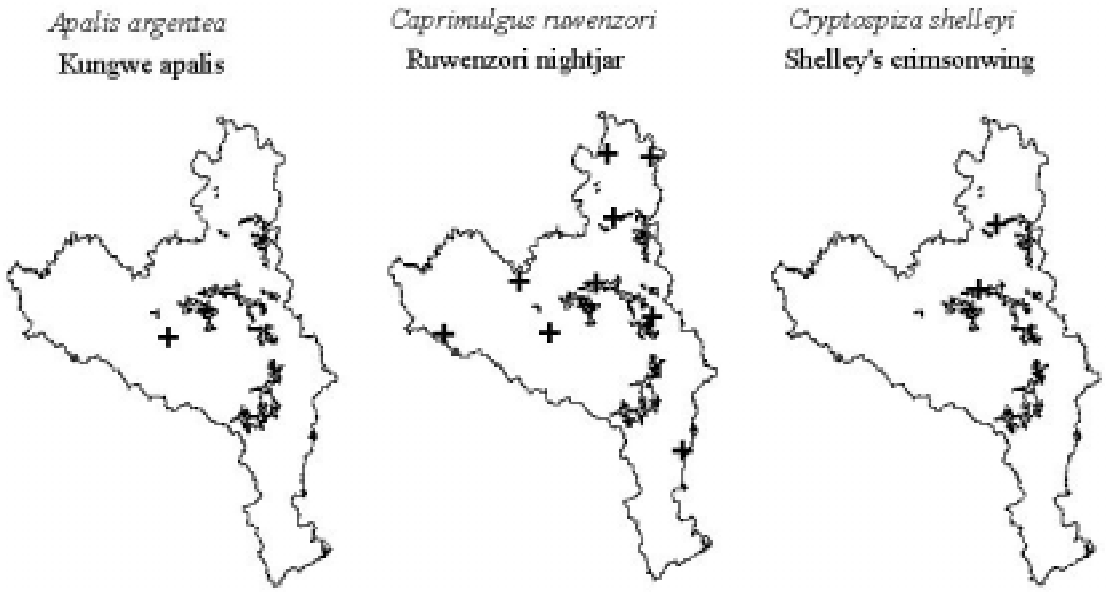
Appendix 3.2. Encounter rates [(mean number of birds/point count)∗100] of Albertine Rift endemic bird species at different sites. + denotes that a species was recorded at a site through mist netting or opportunistic observations outside of point counts



Appendix 3.2. (continued) Encounter rates [(mean number of birds/point count)100] of Albertine Rift endemic bird species at different sites. + denotes that a species was recorded at a site through mist netting or opportunistic observations outside of point counts



Appendix 3.2 (continued). Encounter rates [(mean number of birds/point count)*100] of Albertine Rift endemic bird species at different sites. + denotes that a species was recorded at a site through mist netting or opportunistic observations outside of point counts.



Appendix 3.2 (continued). Distributions of Albertine Rift endemic bird species recorded only during mist netting or opportunistic observations outside of point counts at Nyungwe.

Appendix 4.1. List of tree and shrub species and their distribution across the 13 survey sites at Nyungwe.

x = present in at least 1 circular plot at a site; - = absent from all circular plots at a site; * absent from all circular plots at 200 m intervals, but present among the trees enumerated at 50 m at those sites where Method 2 was employed.

	Family	Species	Altitude (Min-Max)	BUSORO	BWEYEYE	GISAKURA	KAGANO	KIVU	MUZIMU	NSHILI	NYABIHU	NYABITIMBO	RUBYIRO	RUZIZI	UWASENKOKO	UWINKA
1	Acanthaceae	*Mimulopsis arborescens* C.B. CLARKE	1610-2380	x	x	x	-	-	-	-	-	-	-	-	-	x
2	Acanthaceae	*Sclerochiton obtusisepalum*	1930-1940	-	-	-	-	-	x	-	-	-	-	-	-	-
3	Agavaceae	*Dracaena afromontana* MILDB.	2265-2395	-	-	-	-	x	x	x	-	-	-	-	-	-
4	Alangiaceae	*Alangium chinense* (L. f.) REDHER	1590-2330	x	x	-	-	-	-	x	-	x	-	-	-	x
5	Anacadiaceae	*Trichosypha ulugurensis* MILDBR. *submontana*	1910-1950	-	-	-	-	-	-	-	-	-	-	-	-	x
6	Annonaceae	*Isolona lebrunii* BOUTIQUE	1620-2070	x	x	-	-	-	-	-	-	-	-	-	-	x
7	Apocynaceae	*Pleiocarpa pycnantha* (SCHUMANN) STAPF	1600-2010	-	x	x	-	-	-	-	-	x	-	-	-	x
8	Apocynaceae	*Tabernaemontana stapifiana* BRITTEN	1610-2425	x	x	x	-	-	-	x	*	x	-	-	x	x
9	Aquifoliaceae	*Ilex mitis* (L.) RADLK.	1730-2575	x	x	x	x	x	x	x	x	x	x	x	x	x
10	Araliaceae	*Polyscias fulva* (HIERN) HARMS	1600-2555	x	x	x	x	x	x	x	x	x	x	x	x	x
11	Asteraceae	*Senecio mannii* HOOK. f.	1680-2340	x	x	x	-	-	-	-	-	-	-	-	-	x
12	Asteraceae	*Senecio stuhlmannii* KLATT	1610-2310	-	x	-	-	-	-	-	-	-	-	-	-	x
13	Asteraceae	*Vernonia amygdalina* DELILE	1630-1630	-	x	-	-	-	-	-	-	-	-	-	-	-
14	Asteraceae	*Vernonia conferta* BENTH.	1600-2010	-	x	x	-	-	-	-	-	-	-	-	-	x
15	Bignoniaceae	*Kigelia africana* (LAM.) BENTH.	1610-1910	x	x	-	-	-	-	-	-	-	-	-	-	-
16	Capparaceae	*Ritchiea albersii* GILG.	1610-2110	x	x	-	-	-	-	-	-	-	-	-	-	-
17	Celastraceae	*Maytenus acuminata* (L. f.) LOES	1780-2685	x	x	x	x	x	x	x	x	x	x	x	x	x
18	Celastraceae	*Maytenus arbutifolia*	1780-2685	-	-	-	-	-	-	x	-	-	x	-	-	-
19	Celastraceae	*Maytenus undata* (THUNB.) BLAKELOCK	2200-2410	-	-	-	x	-	x	-	x	-	x	*	x	-
20	Chrysobalanaceae	*Magnistipula butayei* DE WILD. subsp. *montana* (HAUMAN) F. WHITE	1590-2290	x	x	x	-	-	x	-	-	x	-	-	*	x
21	Chrysobalanaceae	*Parinari excelsa* SABINE	1600-2420	x	x	x	*	-	x	-	-	x	-	-	*	x
22	Clusiaceae	*Garcinia volkensii* ENGL.	1660-2130	x	x	x	-	-	-	-	-	x	-	-	-	x
23	Clusiaceae	*Harungana montana* SPIRLET	1590-2480	x	x	x	x	x	x	x	x	x	x	x	x	x
24	Clusiaceae	*Hypericum revolutum* VAHL	1590-2390	-	x	-	x	x	-	x	x	-	x	x	x	-
25	Clusiaceae	*Pentadesma reyndersii* SPIRLET	1730-2120	-	x	x	-	-	-	-	-	x	-	-	-	-
26	Clusiaceae	*Symphonia globulifera* L. f.	1600-2410	x	x	x	x	x	x	x	-	x	-	-	*	x
27	Cornaceae	*Afrocrania volkensii* (HARMS) HUTCH.	1920-2475	-	-	x	x	x	x	x	x	-	x	x	x	x
28	Cyatheaceae	*Cyathea manniana* HOOK.	1730-2270	x	x	x	-	-	-	-	-	x	-	-	-	x
29	Ebenaceae	*Diospyros gabonensis* GUERKE	1590-2260	x	x	x	-	-	*	-	-	x	-	-	-	x
30	Ericaceae	*Agauria salicifolia* (LAM.) HOOK. f.	1960-2665	-	x	-	x	x	x	x	x	-	x	x	x	x
31	Ericaceae	*Erica kingaensis* ENGL.	1980-2360	-	-	x	x	-	-	-	-	-	x	-	-	-
32	Ericaceae	*Philippia benguelensis* (ENGL.) ALM. et T.C.H.	2150-2665	-	-	-	x	x	-	-	x	-	x	-	x	-
33	Ericaceae	*Philippia johnstonii* ENGL.	2180-2440	-	-	-	-	x	-	-	x	-	x	-	-	-
34	Euphorbiaceae	*Alchornea hirtella* BENTH.	1620-2325	x	x	-	-	x	-	-	-	-	x	-	-	-

	Family	Species	Altitude (Min-Max)	BUSORO	BWEYEYE	GISAKURA	KAGANO	KIVU	MUZIMU	NSHILI	NYABIHU	NYABITIMBO	RUBYIRO	RUZIZI	UWASENKOKO	UWINKA
34	Euphorbiaceae	*Alchornea hirtella* BENTH.	1620-2325	x	x	-	-	x	-	-	-	-	x	-	-	-
35	Euphorbiaceae	*Antidesma venosum*	1730-1940	-	-	x	-	-	-	-	-	x	-	-	-	-
36	Euphorbiaceae	*Bridelia brideliifolia* (PAX) FEDDE	1590-2330	x	x	x	-	-	-	-	-	x	-	-	-	x
37	Euphorbiaceae	*Cleistanthus polystachyus* HOOK. f. ex PLANCHON	1590-2290	x	x	x	-	-	-	-	-	x	-	-	-	x
38	Euphorbiaceae	*Clutia abyssinica* JAUB. et SPACH.	1620-1650	-	x	-	-	-	-	-	-	-	-	-	-	-
39	Euphorbiaceae	*Croton macrostachyus* HOCHST. ex DELILE	1600-2280	x	x	-	-	-	-	-	x	-	-	-	-	x
40	Euphorbiaceae	*Croton megalocarpus* HUTCH.	1620-2170	x	x	-	-	-	-	-	-	-	-	-	-	-
41	Euphorbiaceae	*Discoclaoxylon hexandrum* (MUELL. ARG.) PAX & K. HOFFM.	1940-1940	-	-	-	-	-	-	-	-	x	-	-	-	-
42	Euphorbiaceae	*Drypetes gerrardii* HUTCH.	1600-2320	x	x	x	-	-	-	-	-	x	-	-	-	x
43	Euphorbiaceae	*Drypetes occidentalis* (MUELL. ARG.) HUTCH.	1700-2320	x	x	x	-	-	-	-	-	x	-	-	-	x
44	Euphorbiaceae	*Macaranga* aff. *monandra*	1770-1770	-	-	-	-	-	-	-	-	x	-	-	-	-
45	Euphorbiaceae	*Macaranga kilmandscharica*	1590-2675	x	x	x	x	x	x	x	x	x	x	x	x	x
46	Euphorbiaceae	*Neoboutonia macrocalyx* PAX	1610-2450	x	x	x	x	x	x	x	x	x	x	x	x	x
47	Euphorbiaceae	*Sapium ellipticum* (HOPCHST. ex KRAUSS) PAX	1590-2220	x	x	x	-	-	-	-	-	x	-	-	-	x
48	Fabaceae	*Erythrina abissinica* DC.	1800-1800	-	x	-	-	-	-	-	-	-	-	-	-	-
49	Fabaceae	*Millettia dura* DUNN	1870-1870	-	-	-	-	-	-	-	-	-	-	-	-	x
50	Fabaceae	*Milltia psilopetala* HARMS	1630-1740	-	x	-	-	-	-	-	-	-	-	-	-	-
51	Flacourtiaceae	*Casearia engleri* GILG	1590-2000	x	x	-	-	-	-	-	-	-	-	-	-	-
52	Flacourtiaceae	*Casearia runssorica* GILG	1590-2535	x	x	x	-	-	x	x	*	x	x	x	*	x
53	Flacourtiaceae	*Dasylepis racemosa* OLIVIER	1610-2290	x	x	-	-	-	-	-	-	-	-	-	-	x
54	Flacourtiaceae	*Dovyalis* cfr. Zenkeri GILG	2010-2010	-	-	x	-	-	-	-	-	-	-	-	-	-
55	Flacourtiaceae	*Lindackeria bukobensis* GILG	1620-2260	x	x	-	-	-	-	-	-	x	-	-	-	x
56	Icacinaceae	*Apodytes dimidiata* E. MEYER ex BERNH.	1610-2660	x	x	x	x	x	x	x	x	x	x	x	x	x
57	Lauraceae	*Beilschmiedia michelsonii* ROBYNS et WILCZEK	1650-2465	x	x	x	x	-	x	x	-	x	-	-	-	x
58	Lauraceae	*Ocotea kenyensis* (CHIOV.) ROBYNS et WILCZEK	1900-2545	-	x	x	x	x	x	-	-	-	*	-	x	x
59	Lauraceae	*Ocotea usambarensis* ROBYNS et WILCZEK	1600-2535	x	x	x	*	x	x	x	x	x	x	-	x	x
60	Lobeliaceae	*Lobelia giberroa* HEMSLEY	1610-2685	-	x	-	-	x	-	-	-	-	-	-	x	-
61	Lobeliaceae	*Lobelia mildbraedii* ENGL.	1980-1980	-	-	x	-	-	-	-	-	-	-	-	-	-
62	Lobeliaceae	*Lobelia petiolata* HAUMAN	2330-2450	-	-	-	-	x	-	-	-	-	x	-	-	-
63	Loganiaceae	*Anthocleista grandiflora* GILG	1590-2020	-	x	x	-	-	-	-	-	x	-	-	-	-
64	Loganiaceae	*Nuxia congesta* FRESEN	2225-2555	-	-	-	-	-	-	x	-	-	-	-	-	-
65	Loganiaceae	*Nuxia floribunda* BENTH.	1880-2675	-	x	-	+	x	-	x	x	-	x	*	x	-
66	Melastomataceae	*Dichaetanthera corymbosa* (COGN.) JACQUES_FELIX	1590-2340	x	x	x	-	-	-	-	-	x	-	-	-	x
67	Melastomataceae	*Memecylon myrianthum* GILG	1900-1900	-	-	x	-	-	-	-	-	-	-	-	-	-
68	Melastomataceae	*Memecylon walikalense* A. et R. FERNANDES	1660-2310	x	x	x	-	-	-	-	-	x	-	-	-	x
69	Meliaceae	*Carapa grandiflora* SPRAGUE	1590-2525	x	x	x	x	x	x	x	x	x	x	x	x	x
70	Meliaceae	*Carapa* sp.	1750-1750	-	-	-	-	-	-	-	-	x	-	-	-	-
71	Meliaceae	*Ekebergia capensis* SPARRMAN	1800-2535	x	x	-	*	-	x	x	x	-	*	-	x	x
72	Meliaceae	*Entandrophragma excelsum* (DAWE et SPRAGUR) SPRAGUE	1640-2330	x	x	-	-	-	-	-	-	x	-	-	-	x
73	Meliaceae	*Lepidotrichilia volkensii* (GUERKE) LEROY	1620-2520	x	x	-	-	-	-	x	-	-	-	-	-	-
74	Meliaceae	*Leplaea mayombensis* (Pellegr.) Staner	1750-1810	-	-	-	-	-	-	-	-	x	-	-	-	-
75	Meliaceae	*Lovoa trichilioides* SPRAGUE	1960-1960	-	-	-	-	-	-	-	-	x	-	-	-	-
76	Melianthaceae	*Bersama abyssinica* FRESEN.	1640-2505	x	x	x	x	x	x	x	-	-	x	*	x	x
77	Mimosaceae	*Albizia gummifera* (J. GMELIN) C.A. SMITH	1590-2150	x	x	x	-	-	-	-	-	x	-	-	-	x
78	Mimosaceae	*Newtonia buchananii* (BAKER) GILBERT et BOUTIQUE	1600-2380	x	x	x	-	-	-	-	-	x	-	-	-	x
79	Monimiaceae	*Xymalos monospora* (HARVEY) BAILLON ex WARBURG	1740-2575	x	x	x	x	x	x	x	x	x	x	x	x	-

	Family	Species	Altitude (Min-Max)	BUSORO	BWEYEYE	GISAKURA	KAGANO	KIVU	MUZIMU	NSHILI	NYABIHU	NYABITIMBO	RUBYIRO	RUZIZI	UWASENKOKO	UWINKA
80	Moraceae	*Ficus mucuso*	1960-1960	-	-	-	-	-	-	-	-	x	-	-	-	-
81	Moraceae	*Ficus oreodryadum* MILDBR. et BURRET	2370-2535	-	-	-	x	-	-	*	-	-	-	-	x	-
82	Moraceae	*Ficus* sp	1790-1790	-	-	-	-	-	-	-	-	x	-	-	-	-
83	Moraceae	*Ficus sur* FORSSKAL	1630-1980	-	x	-	-	-	-	-	-	x	-	-	-	-
84	Moraceae	*Ficus vallis-choudae* DELILE	1610-1670	-	x	-	-	-	-	-	-	-	-	-	-	-
85	Moraceae	*Musanga leo-errerae*	1590-2100	x	x	x	-	-	-	-	-	x	-	-	-	x
86	Moraceae	*Myrianthus holstii* ENGL.	1590-2410	x	x	x	-	-	x	x	-	x	-	-	-	x
87	Moraceae	*Trilepisium madagascariense* De CANDOLLE	1790-1810	-	-	-	-	-	-	-	-	x	-	-	-	-
88	Myricaceae	*Myrica mildbraedii* ENGL.	2170-2170	-	-	-	-	-	-	-	-	-	x	-	-	-
89	Myricaceae	*Myrica humilis* CHAM. Et SCHLECHTD.	1590-2570	-	x	x	-	-	x	-	-	-	x	-	-	-
90	Myrsinaceae	*Maesa lanceolata* FORSSKAL	1590-2685	x	x	x	x	x	x	x	x	x	x	x	x	x
91	Myrsinaceae	*Rapanea melanophloeios* (L.) MEZ	1830-2685	x	x	x	x	x	x	x	x	-	x	x	x	x
92	Myrtaceae	*Syzygium guinense* (WILLD.) DC. *afromontanum*	1590-2370	-	x	x	-	+	-	-	-	x	-	-	-	x
93	Myrtaceae	*Syzygium guinense* (WILLD.) DC. *parvifolium* (ENGL.) MILDBR.	1590-2685	x	x	x	x	x	x	x	x	x	x	x	x	x
94	Myrtaceae	*Syzygium rowlandii* SPRAGUE	1910-2220	-	-	-	-	-	-	-	-	-	-	-	-	x
95	Myrtaceae	*Syzygium* sp.	1835-1835	-	-	x	-	-	-	-	-	-	-	-	-	-
96	Ochnaceae	*Campylospermum vogelii* (HOOK . f.) FARRON	1900-1900	-	-	x	-	-	-	-	-	-	-	-	-	-
97	Ochnaceae	*Ochna afzelii* R. BR. ex OLIV.	1910-2435	x	x	x	-	x	-	-	*	-	-	-	x	x
98	Ochnaceae	*Ochna holstii* ENGL.	1880-2010	-	-	x	-	-	-	-	-	-	-	-	-	-
99	Olacaceae	*Strombosia scheffleri* ENGL.	1590-2390	x	x	x	-	-	-	-	-	x	-	-	-	x
100	Olacaceae	*Strombosia* sp.	1860-1860	-	-	-	-	-	-	-	-	x	-	-	-	-
101	Oleaceae	*Chionanthus africanus*	1600-2020	-	x	x	-	-	*	-	-	-	-	-	-	-
102	Oleaceae	*Olea capensis*	1810-2675	x	x	x	x	x	x	-	x	x	x	*	x	x
103	Oliniaceae	*Olinia rachetiana* A. JUSS.	2200-2650	x	-	-	x	x	x	x	x	-	x	x	x	x
104	Pitosporaceae	*Pittosporum mildbraedii* ENGL.	2420-2460	-	-	-	-	-	-	x	-	-	-	-	-	-
105	Podocarpaceae	*Podocarpus falcatus* (THUNB.) R. BR ex MIRB	2100-2330	x	x	-	-	-	-	-	-	-	-	-	+	x
106	Podocarpaceae	*Podocarpus latifolius* (THUNB.) R. BR ex MIRB	1700-2665	x	x	x	x	x	x	x	x	-	x	x	x	x
107	Proteaceae	*Faurea saligna* HARVEY	1780-2560	x	x	-	*	x	x	x	-	x	+	-	-	x
108	Rhizophoraceae	*Cassipourea louisii* LIBEN	1610-2400	x	x	-	x	x	x	x	-	-	-	-	*	-
109	Rhizophoraceae	*Cassipourea gummiflua* TUL.	1650-2260	x	x	x	-	-	x	-	-	x	-	-	-	-
110	Rhizophoraceae	*Cassipourea ndando* J. LEONARD ex FLORET	1760-2230	-	-	x	-	-	-	-	-	x	-	-	-	x
111	Rhizophoraceae	*Cassipourea ruwensorensis* (ENGL.) ALSTON	1590-2475	x	x	x	x	x	x	x	*	x	x	x	x	x
112	Rhizophoraceae	*Cassipourea* sp	1960-2250	x	-	x	-	-	-	-	-	-	-	-	-	x
113	Rosaceae	*Hagenia abyssinica* (BRUCE) J. F. GMELIN	1590-2675	x	x	x	*	x	x	x	x	x	x	x	x	x
114	Rosaceae	*Prunus africana* (Hook. F.) KALKMAN	1720-2520	x	x	-	-	-	x	x	-	-	x	x	x	x
115	Rubiaceae	*Aulacocalyx diervilloides* (SCHUMANN) E. PETIT	2210-2300	-	-	-	-	-	-	-	-	-	-	-	-	x
116	Rubiaceae	*Bertiera racemosa* (G. DON) SCHUMANN	1660-1660	-	x	-	-	-	-	-	-	-	-	-	-	-
117	Rubiaceae	*Calycosiphonia spathicalyx* (K. SCHUMM.) ROBBRECHT	1910-1950	x	x	-	-	-	-	-	-	-	-	-	-	-
118	Rubiaceae	*Canthium oligocarpum* HIERN.	1830-2020	-	-	-	-	-	-	-	-	x	-	-	-	-
119	Rubiaceae	*Canthium* sp	1890-1890	-	-	-	-	-	-	-	-	x	-	-	-	-
120	Rubiaceae	*Chassalia subochreata* (DE WILD.) ROBYNS	1770-1950	-	x	-	-	-	-	-	-	-	+	-	-	-

	Family	Species	Altitude (Min-Max)	BUSORO	BWEYEYE	GISAKURA	KAGANO	KIVU	MUZIMU	NSHILI	NYABIHU	NYABITIMBO	RUBYIRO	RUZIZI	UWASENKOKO	UWINKA
121	Rubiaceae	*Galiniera coffeoides* DELILE	1640-2660	x	x	x	x	x	x	x	x	-	x	x	x	x
122	Rubiaceae	*Hallea rubrostipulata*	1590-1830	-	x	-	-	-	-	-	-	-	-	-	-	-
123	Rubiaceae	*Hymenodictyon floribundum* (HOCHST. Et STEUDEL) B.L. ROBINSON	1590-1640	-	x	-	-	-	-	-	-	-	-	-	-	-
124	Rubiaceae	*Ixora burundensis* BRIDSON	1590-2260	x	x	x	-	-	-	-	-	x	-	-	-	x
125	Rubiaceae	*Oxyanthus speciosus* DC.	1740-2330	x	x	x	-	-	-	-	-	x	-	-	-	x
126	Rubiaceae	*Pausinystalia ituriense* DE WILD.	1630-2400	-	x	x	-	-	-	-	-	x	-	-	-	x
127	Rubiaceae	*Pavetta* aff. *manyanguensis* Bridson	1770-2020	x	x	-	-	-	-	-	-	-	-	-	-	-
128	Rubiaceae	*Pavetta pierlotii* BRIDSON	2350-2350	-	-	-	-	x	-	-	-	-	-	-	-	-
129	Rubiaceae	*Psychotria mahonii* C.H. WRIGHT	1750-2660	x	-	x	x	x	x	x	x	x	x	x	x	x
130	Rubiaceae	*Psychotria palustris* E. PETIT	1610-2495	x	x	-	-	x	x	x	-	-	-	x	-	x
131	Rubiaceae	*Psydrax subcordata* (DC) Bridson var. *subcordata*	1620-2575	x	x	x	x	x	x	x	x	-	x	x	x	x
132	Rubiaceae	*Rytigynia* sp	1940-2500	x	-	x	-	-	-	*	-	x	-	-	-	x
133	Rubiaceae	*Rytigynia bangshawei* (S. MOORE) ROBYNS var. *lebrunii* (ROBYNS) VERDC	1940-2020	x	-	-	-	-	-	-	-	-	-	-	-	-
134	Rubiaceae	*Rytigynia bridsonii*	2285-2370	-	-	-	x	x	-	-	-	-	-	-	-	-
135	Rubiaceae	*Rytigynia bugoyensis* (K. KRAUSE) VERDC.	2250-2340	-	-	-	-	-	-	x	x	-	-	-	-	-
136	Rubiaceae	*Rytigynia kigeziensis*	1810-2665	x	x	-	x	x	x	x	x	-	x	x	x	x
137	Rubiaceae	*Rytigynia kiwuensis* (K. KRAUSE) ROBYNS	2310-2480	-	-	-	-	-	-	-	x	-	-	-	-	-
138	Rubiaceae	*Rytigynia* sp2	2400-2400	-	-	-	-	-	-	-	-	-	-	-	-	x
139	Rubiaceae	*Sericanthe leonardii* (HALLE) ROBBRECHT	1600-2430	x	x	x	-	-	-	-	-	-	x	-	-	x
140	Rubiaceae	*Tarenna pavettoides* (HARVEY) SIM	2220-2465	-	-	-	x	-	-	-	-	-	x	-	x	x
141	Rubiaceae	*Tarenna rwandensis* BRIDSON	1660-2080	x	x	x	-	-	-	-	-	x	-	-	-	-
142	Rubiaceae	*Tricalysia kivuensis*	1910-1910	-	-	-	-	-	-	-	-	x	-	-	-	-
143	Rutaceae	*Oricia renieri* G. GILBERT	1600-2310	x	x	x	-	-	-	-	-	x	-	-	-	x
144	Rutaceae	*Vepris stolzii* VERDOORN	1600-2265	x	x	-	-	-	x	-	-	x	-	-	-	x
145	Rutaceae	*Zanthoxylum gilletii* (DE WILD.) WATERMAN	1610-2320	x	x	-	-	-	-	-	-	x	-	-	-	x
146	Rutaceae	*Zanthoxylum mildbraedii* (ENGL.) WATERMAN	1650-1980	-	x	-	-	-	-	-	-	x	-	-	-	-
147	Sapindaceae	*Pancovia golungensis* WELW.	1780-2100	-	-	-	-	-	-	-	-	x	-	-	-	x
148	Sapindaceae	*Zanha golungensis* HIERN.	1840-1840	-	-	-	-	-	-	-	-	-	-	-	-	x
149	Sapotaceae	*Pouteria altissima* (A. CHEV.) AUBREV. et PELLEGR.	1870-1870	-	-	-	-	-	-	-	-	x	-	-	-	-
150	Sapotaceae	*Chrysophyllum gorungosanum* ENGL.	1590-2390	x	x	x	-	-	x	-	-	x	-	-	-	x
151	Sapotaceae	*Chrysophyllum pruniforme* PIERRE ex ENGL.	1860-1860	-	-	-	-	-	-	-	-	x	-	-	-	-
152	Sapotaceae	*Zeyherella rwandensis* (TROUPIN) LIBEN	1610-2410	x	x	x	-	-	-	-	-	x	-	-	-	x
153	Sterculiaceae	*Cola pierlotii* R. GERMAIN	1720-1930	-	x	x	-	-	-	-	-	x	-	-	-	-
154	Sterculiaceae	*Dombeya goetzenii* SCHUMANN	1690-2460	x	x	-	-	*	x	x	-	-	-	-	-	x
155	Sterculiaceae	*Leptonychia melanocarpa* R. GERMAIN	1930-1940	-	-	-	-	-	-	-	-	x	-	-	-	-
156	Theaceae	*Balthasarea schliebenii* (MELCHIOR) VERDC.	1820-2500	-	x	x	+	x	x	x	x	x	x	x	x	x
157	Theaceae	*Ficalhoa laurifolia* HIERN.	1650-2500	x	x	x	x	-	x	-	x	x	x	x	*	x
158	Thymelaeaceae	*Peddiea africana*	2290-2290	-	-	-	-	-	-	-	x	-	-	-	-	-
159	Thymelaeaceae	*Peddiea rapaneoides* GILG	2240-2450	-	-	-	x	x	-	-	x	-	x	x	-	-
160	Tiliaceae	*Grewia mildbraedii* BURRET	1590-2220	x	x	x	-	-	-	-	-	x	-	-	-	x
161	Ulmaceae	*Celtis gomphophylla*	1880-1880	-	-	-	-	-	-	-	-	x	-	-	-	-
162	Ulmaceae	*Trema orientalis* (L.) BLUME	1650-2090	-	x	-	-	-	-	-	-	x	-	-	-	-
163	Violaceae	*Rinorea angustifolia* (THOUARS) BAILLON *engleriana* (DE WILD. et Th. DUR.)	1600-2220	-	x	x	-	-	-	-	-	x	-	-	-	x

Appendix 4.2. Number of plots in which each species was the dominant species, and the relative dominance of each species, in the herbaceous layer.
n = number of plots in which a species was dominant; Rel. Dom. = percentage of the total number of plots in which a species was dominant
B = Bamboo, HC = Human Clearing, F = Fern, CL = Clearing, CF = Closed Forest, OF = Open Forest, M = Marsh, S = Savanna, BZ = Burned Zone

	HABITAT	B		HC		F		CL		CF		OF		M		S		BZ	
Overall rank	Species	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.
1	*Pteridium aquilinum*	1	3.03	9	19.57	18	45.00	11	11.96	8	3.72	33	5.98	14	13.08	18	26.47	108	43.03
2	*Senecio mannii*			2	4.35			1	1.09			7	1.27	2	1.87	3	4.41	20	7.97
3	*Arundinaria alpina*	26	78.79	1	2.17			1	1.09			13	2.36	1	0.93			19	7.57
4	*Hypericum revolutum*	2	6.06	1	2.17							8	1.45	34	31.78	6	8.82	13	4.78
5	*Lobelia giberroa*			1	2.17							3	0.54	2	1.87			10	3.98
6	*Mikania cordata*			1	2.17	1	2.50	4	4.35			5	0.91	1	0.93			6	2.39
7	*Kotschya africana*						0.00	1	1.09							3	4.41	4	1.59
8	*Anisorus* sp					1	2.50	1	1.09	10	4.65	6	1.09			1	1.47	4	1.59
9	*Senecio maranguensis*			6	13.04			1	1.09			2	0.36	1	0.93			4	1.59
10	*Pycnostachys meyeri*			1	2.17	1	2.50	1	1.09	2	0.93	3	0.54					5	1.99
11	*Polygala ruwenzoriensis*					1	2.50	1	1.09			1	0.18			3	4.41	3	1.20
12	*Chassalia subochreata*							2	2.17	34	15.81	46	8.33	3	2.80	2	2.94	3	1.20
13	*Mimulopsis excellens*			5	10.87	2	5.00	8	8.70	52	24.19	75	13.59	2	1.87	1	1.47	3	1.20
14	*Sericostachys scandens*			5	10.87			17	18.48	23	10.70	63	11.41	3	2.80			3	1.20
15	*Triumphetta cordifolia*			2	4.35	2	5.00	9	9.78	2	0.93	14	2.54	1	0.93			3	1.20
16	*Mimulopsis solmsii*	2	6.06	1	2.17			5	5.43	5	2.33	38	6.88					3	1.20
17	*Vernonia lasiopus*			1	2.17							3	0.54					3	1.20
18	*Anthospermum usambarensis*													1	0.93	7	10.29	2	0.80
19	*Rytigynia bridsonii*									14	6.51	10	1.81			1	1.47	2	0.80
20	*Lobelia mildbraedii*									1	0.47	2	0.36	8	7.48			2	0.80
21	*Allophylus chaunostachys*			2	4.35			3	3.26	25	11.63	70	12.68	3	2.80			2	0.80
22	*Macaranga kilimandscharica*			6	13.04			3	3.26	2	0.93	9	1.63					2	0.80
23	*Begonia meyeri-johanis*							2	2.17	5	2.33	3	0.54					2	0.80
24	*Gynura scandens*					3	7.50	1	1.09			2	0.36					2	0.80
25	*Vernonia* sp											1	0.18					2	0.80
26	*Blechnum tabulare*							1	1.09									2	0.80
27	*Erica kingaensis*							1	1.09			2	0.36	4	3.74	5	7.35	1	0.40
28	*Clutia paxii*															3	4.41	1	0.40
29	*Philippia benguelensis*	2	6.06			2	5.00	2	2.17	1	0.47			2	1.87	2	2.94	1	0.40
30	*Xymalos monospora*					1	2.50			1	0.47	2	0.36			2	2.94	1	0.40
31	*Schefflera goetzenii*							2	2.17	5	2.33	16	2.90	2	1.87			1	0.40
32	*Galiniera coffeoides*					3	7.50	1	1.09	2	0.93	16	2.90	2	1.87			1	0.40
33	*Psychotria mahonii*									1	0.47	7	1.27	1	0.93			1	0.40
34	*Neoboutonia macrocalyx*					1	2.50	1	1.09	1	0.47	5	0.91	1	0.93			1	0.40
35	*Alchornea hirtella*							1	1.09	7	3.26	20	3.62					1	0.40
36	*Rytigynia kigeziensis*							1	1.09	1	0.47	10	1.81					1	0.40
37	*Stapifiella ulugurica*											6	1.09					1	0.40
38	*Solenostemon sylvaticum*											1	0.18					1	0.40
39	*Vernonia* sp			1	2.17													1	0.40
40	*Piper capense*																	1	0.40
41	*Plectranthus edulis*																	1	0.40
42	*Pycnostachys goetzenii*																	1	0.40

	HABITAT	B		HC		F		CL		CF		OF		M		S		BZ	
Overall rank	Species	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.	n	Rel. Dom.
43	*Acyranthes* sp																	1	0.40
44	*Crotalaria* sp																	1	0.40
45	*Pycnostachys* sp																	1	0.40
46	*Athyrium tanganyikense*																	1	0.40
47	*Myrica mildbraedii*													4	3.74	4	5.88		
48	*Cliffortia linearifolia*															4	5.88		
49	*Hedythyrsus thamnoides*															1	1.47		
50	*Myrica humilis*															1	1.47		
51	*Virectaria major*															1	1.47		
52	*Mimulopsis arborescens*					1	2.50					6	1.09	4	3.74				
53	*Rubus runssorensis*					1	2.50			3	1.40	1	0.18	2	1.87				
54	*Brillantasia cicatricosa*							3	3.26	1	0.47	7	1.27	1	0.93				
55	*Philippia johnstonii*											2	0.36	1	0.93				
56	*Vernonia kirungae*							1	1.09			1	0.18	1	0.93				
57	*Clutia abyssinica*											1	0.18	1	0.93				
58	*Dracaena afromontana*							1	1.09					1	0.93				
59	*Cyperus latifolius*													1	0.93				
60	*Hagenia abyssinica*													1	0.93				
61	*Peddiea rapaneoides*													1	0.93				
62	*Phytolacca dodecandra*													1	0.93				
63	*Rutidea fuscescens*											4	0.72						
64	*Mikaniopsis teddlei*									3	1.40	3	0.54						
65	*Rubus kivuensis*									1	0.47	3	0.54						
66	*Syzygium guineense*											3	0.54						
67	*Cassipourea ruwensorensis*											2	0.36						
68	*Leonotis mollissima*											2	0.36						
69	*Rubus pinnatus*											2	0.36						
70	*Monanthotaxis orophila*									2	0.93	1	0.18						
71	*Pavetta pierlotii*									1	0.47	1	0.18						
72	*Rapanea melanophloeos*									1	0.47	1	0.18						
73	*Solanum mauritianum*							2	2.17			1	0.18						
74	*Impatiens sthulmanii*							1	1.09			1	0.18						
75	*Urera hypselodendron*					1	2.50					1	0.18						
76	*Clerodendrum johnstonii*			1	2.17							1	0.18						
77	*Allophylus macrobotrys*											1	0.18						
78	*Impatiens niamniamensis*											1	0.18						
80	*Plectranthus laxiflorus*											1	0.18						
81	*Psychotria palustris*											1	0.18						
82	*Cyperus* sp											1	0.18						
83	*Vernonia* sp											1	0.18						
84	*Maytenus acuminata*									1	0.47								
85	*Begonia mannii*							1	1.09										
86	*Tacazzea apiculata*							1	1.09										
87	*Microglossa pyrifolia*					1	2.50												
	Total	33	100.00	46	100.00	40	100.00	92	100.00	215	100.00	552	100.00	107	100.00	68	100.00	251	100.00

Appendix 6.1. Ranking of sites for the conservation of mammals, birds and plants as derived by complementarity analysis.

Site	Mammal SR	Bird SR	Plant SR	Total SR scores	ARE Mammals	ARE Birds	ARE Plants	Total ARE scores
Busoro	0	9	0	9	0	11	0	11
Bweyeye	0	13	13	26	0	0	13	13
Gisakura	11	8	12	31	11	0	11	22
Kagano	0	4	9	13	0	0	0	0
Kivu	0	5	11	16	0	0	12	12
Muzimu	0	2	5	7	0	0	0	0
Nshiri	0	12	6	18	0	0	10	10
Nyabihu	0	0	7	7	0	0	0	0
Nyabitimbo	0	11	10	21	0	0	0	0
Rubyiro	0	10	0	10	0	12	0	12
Ruzizi	0	7	0	7	0	0	0	0
Uwasenkoko	12	3	0	15	0	0	0	12
Uwinka	13	6	8	27	13	13	0	26

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The establishment of priority regions for the conservation of biodiversity has become a major focus of biologists in recent years. Most of this effort has been devoted to identifying priorities at a global level, but there is a need for priority-setting exercises at more local levels as well. This working paper, Biodiversity surveys of the Nyungwe Forest Reserve in S.W. Rwanda, introduces a set of techniques that can be used to identify priority areas for conservation within nature reserves. These techniques are applied to biological survey data recently collected in the Nyungwe Forest, Rwanda. Nyungwe is Rwanda's largest remaining forest and is one of the most biologically important lower montane rainforests in Africa. It is home to 13 species of primates, 260 species of birds, and more than 260 species of trees and shrubs. Many species found at Nyungwe occur only in the Albertine Rift region of central Africa, making the forest of considerable conservation importance. Using the priority setting techniques described here to analyze data from the most extensive surveys yet conducted in Nyungwe, we have identified the most important regions of the forest for the conservation of mammal, bird, and tree species richness and endemism. The methods used here to determine priority areas for conservation in the Nyungwe Forest will be valuable to project managers and conservation biologists engaged in priority setting exercises for the conservation of biodiversity at nature reserves around the world.

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