ENVIRONMENTAL SCIENCE, ENGINEERING AND TECHNOLOGY

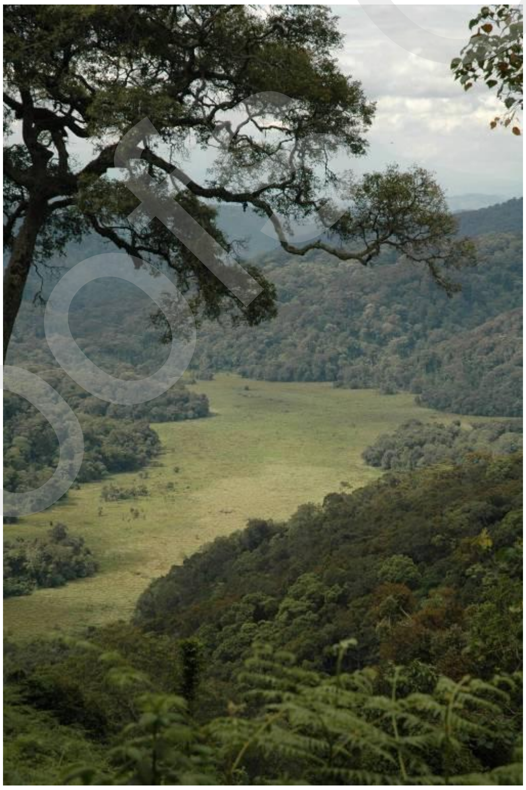
THE ECOLOGICAL IMPACT OF LONG-TERM CHANGES IN AFRICA'S RIFT VALLEY

In: The Ecological Impact of Long-Term Changes... ISBN: 978-1-61122-780-2
Editor: Andrew J. Plumptre, pp. 117-139

Chapter 7

LONG-TERM ECOLOGICAL AND SOCIO-ECONOMIC CHANGES IN AND AROUND BWINDI IMPENETRABLE NATIONAL PARK, SOUTH-WESTERN UGANDA

A. Kasangaki, R. Bitariho, P. Shaw, M. Robbins and A. McNeilage



Mubwindi Swamp in the centre of Bwindi Impenetrable National park– A.Plumptre/WCS.

INTRODUCTION

Bwindi Impenetrable National Park is a UNESCO World Heritage Site and is well known among conservationists because of its unique biodiversity that includes approximately half the world's population of mountain of gorillas. The extremely high human population density around the forest (200-300 people km^{-2}), coupled with a history of forest degradation through logging and other forms of human disturbance, has resulted in significant challenges to its conservation. When Bwindi was gazetted as a national park in 1991 there were extremely high levels of conflict between park staff and local communities, but over the intervening two decades there has been a very large investment in the conservation of this forest. In this chapter we review the available evidence of the long term changes in the forest habitats and wildlife over that period.

Bwindi Impenetrable National Park – History and Context

Bwindi Impenetrable National Park (BINP) is located in south-west Uganda (latitude 0°53′ S to 1° 08′ S; longitude 29° 35′ E to 29° 50′ E), and has an elevational range of 1,160-2,607 m above sea level, spanning an area of 331 km^2 (Figure 7.1). The National Park is located in the Districts of Kabale, Kanungu and Kisoro, and borders the Democratic Republic of Congo to the west. The forest was gazetted as the Impenetrable Central Forest Reserve in 1948 (Leggat & Osmaston, 1961). It was established both as a Forest Reserve and as an animal sanctuary, the latter to protect a population of the threatened mountain gorilla. Extractive use of the forest was allowed and, as a result, logging took place in most parts of the forest. The park is divided (by the Kitahurira-Kayonza road) into the North and South sectors, which differ considerably in terms of flora, fauna and elevation.

An account of the first systematic ecological and socio-economic research in Bwindi is given in Butynski (1984). It was this publication that highlighted the precarious condition of the forest and the urgent need for its conservation. The human population around Bwindi is one of the highest densities in the region. Its continued growth generates a high demand for forest resources as people have few alternatives in the surrounding area. As a result of recommendations made in Butynski (1984), Bwindi was gazetted as a National Park in 1991 by an act of Parliament.

The creation of the national park initially caused resentment among local communities, and conflict increased between the local people and park authorities. Cases of arson were reported, with many fires set in and around the park. Protected area managers and non - governmental organizations had to find ways of diffusing the conflict, and as a result several conservation and development projects were initiated around the park. Later in this chapter we will explore the effectiveness of these interventions.

The Institute of Tropical Forest Conservation (ITFC) was established in 1991, with the aim of documenting the biodiversity of the forest and to monitor ecological changes within and around the park. This research station has continued to carry out ecological and socio-economic research and monitoring in Bwindi and Mgahinga Gorilla parks. The research station carries out most of its research in close collaboration with protected area managers to enable them to make informed decisions about the management of the parks.

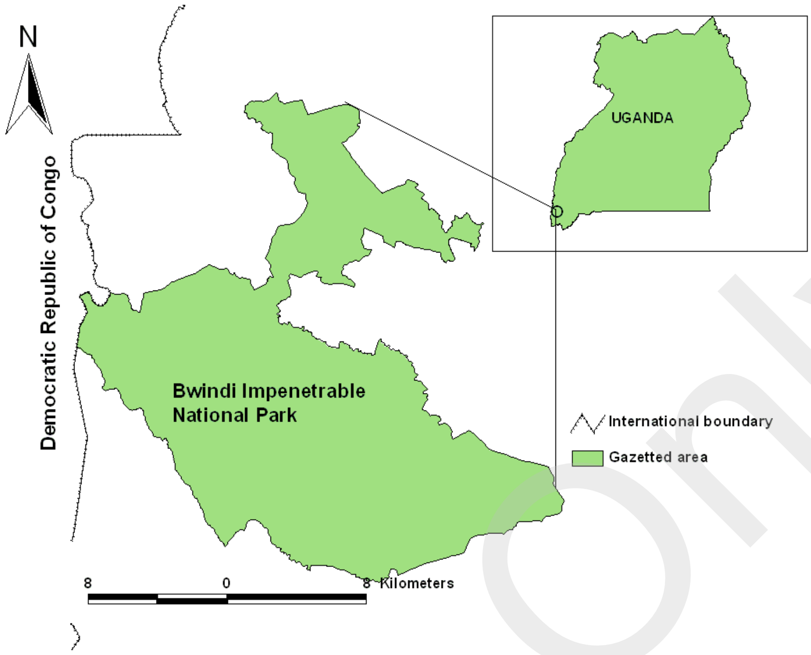


Figure 7.1. Map of Bwindi Impenetrable National Park, southwest Uganda.

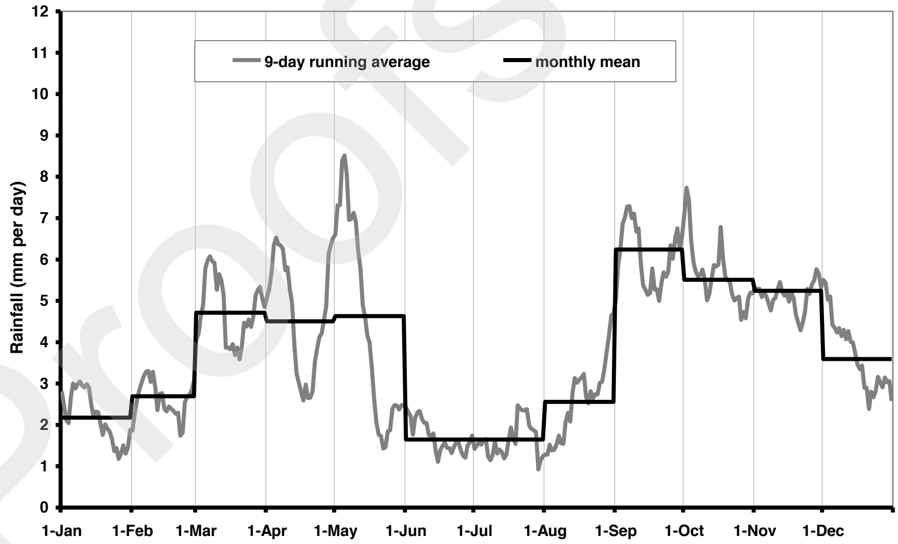


Figure 7.2. Precipitation rates at Ruhija during 1987-2006, represented as 9-day running means.

CHANGES IN RAINFALL AND TEMPERATURE OVER TIME

ITFC has monitored climate changes in and around Bwindi since 1987. Daily temperatures and rainfall levels have been collected over a 20-year period (1987-2006) at Ruhija station (2,350 m elevation). Maximum and minimum temperatures were recorded each day, and the mean maximum and mean minimum temperatures were calculated for each month. However, since these readings were occasionally missed, seasonal variation in precipitation was examined by calculating the mean daily precipitation for each month, and multiplying this figure by the number of days in the month. The same approach was used to estimate the total precipitation within a given season, e.g. the March-May wet season. In this analysis, months or seasons in which data were collected on at least 80% of days have been distinguished from those with fewer data.

Mean monthly figures for the 20-year period indicate an average annual precipitation of 1,378 mm at Ruhija. There are two rainfall peaks (March-May and September-November) and two dry season troughs (December-January and June-July). This annual bimodal pattern is common to most areas of the Albertine Rift, and suggests a relatively simple and well-defined hydrological system at Bwindi. In marked contrast, the sub-monthly pattern, here based on 7-day running means (Figure 7.2), reveals a remarkably robust intra-seasonal variability in precipitation, whereby the March-May wet season and, to a lesser degree, the September-November wet season, are interrupted by intense maxima flanked by temporary minima. The exact nature and significance of these patterns has yet to be determined, and is the focus of ongoing investigations (A. Seimon, pers comm.).

There has been no clear trend in annual precipitation at Ruhija over the 20-year period (Figure 7.3). Annual precipitation was relatively consistent between 1987 and 1996-97, with evidence of a slight rise from 1989 onwards. However, since 1998, annual precipitation has become more erratic, differing by as much as 870 mm between consecutive years (2003-04). To determine whether this pattern reflects a change in precipitation throughout the year, or in a particular season, precipitation trends were examined for each season separately. This showed that there has been little change in the volume of precipitation during the December-February dry season, but a slight decline in variability between years. Similarly, the June-August dry season has shown a decline in variability, but also a reduction in the volume of precipitation. In contrast, precipitation during the two wet seasons has become much more variable, particularly during the September-November wet season, which normally accounts for *c*. 37% of annual rainfall. Figure 7.4 shows that absolute differences in precipitation between consecutive years have not only become more marked, they have also become increasingly extreme throughout the 20-year span. Thus, very low rainfall during September-November in one year has increasingly been followed by very high rainfall during the same period in the following year, and *vice versa*.

The mean maximum and minimum temperatures recorded monthly at Ruhija showed little seasonal variation. The mean maximum temperature followed a bimodal pattern, broadly coinciding with that of precipitation, peaking in February-April and August-October. The degree of change was small however, mean maxima varying between 18.0 and 19.1ºC, while mean minima varied between 13.4 and 14.4ºC. During 1987-2004 there was no evidence of a consistent trend in the mean minimum and maximum temperatures. While temperatures dipped and then rose slightly during the late 1980s and early 1990s, they dropped again (by 1-2ºC) by the early 2000s.

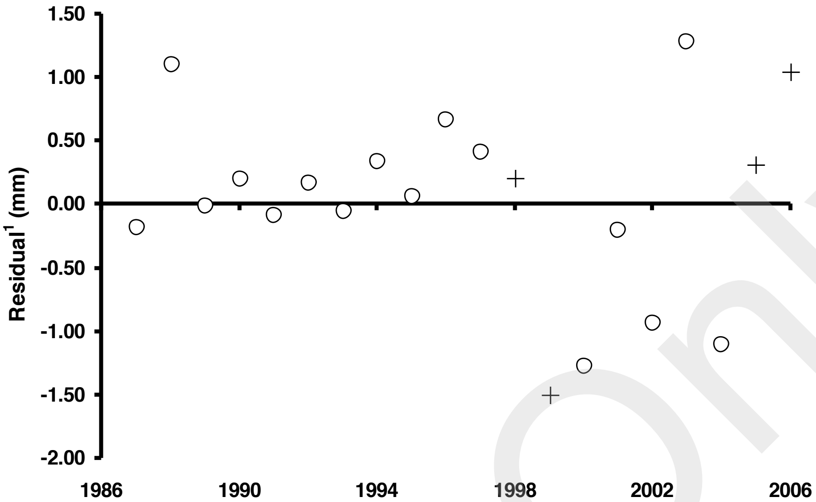


Figure 7.3. Trends in precipitation at Ruhija, 1987-2006. Each point shows the extent to which the daily precipitation recorded in a given year differed from the mean recorded throughout the 20-year period. A positive value thus indicates higher than average rainfall. O: data available for at least 80% of days in the year; +: data available for less than 80% of days. To examine yearly trends, the amount of precipitation recorded on a given day was compared with the mean value recorded on that date throughout the study period. The difference between these two values (the residual) was calculated for each date, and the mean residual calculated for the year in question. Hence a value of '+1.0' indicates that daily precipitation during that year exceeded the mean for 1987-2006 by an average of 1 mm.

In summary, there was no consistent trend in mean daily temperature or annual precipitation at Ruhija during 1987-2006. Precipitation became slightly less variable during at least one of the two dry seasons, however, and much more variable during the two wet seasons. In particular, precipitation during the September-November wet season not only became more erratic, but increasingly so over the 20-year span.

WATER QUALITY CHANGES IN BWINDI IMPENETRABLE NATIONAL PARK AND SURROUNDING AREAS

Water quality has been identified as a good indicator of forest health, since streams and rivers act as integrators of environmental conditions within watersheds (Allan 1995). Thus, by assessing water quality in rivers, it is possible to infer the condition of the catchments from which the river derives its water. ITFC has been implementing a water quality monitoring program since 1999. The parameters measured include water conductivity (µS/cm), water transparency (cm), dissolved oxygen (mg/l), pH, stream water temperature, stream depth and water discharge (m^3/s). In addition, aquatic insects are used as bioindicators of stream condition (see Kasangaki *et al*. 2006 for methods used). Water quality monitoring in Bwindi is based on variables that are easy to measure onsite using digital equipment and the methods are easy to replicate in other, similar stream types. Although the water quality monitoring program has been in existence since 1999, consistent and periodic sampling has been made quarterly over the last eight years since 2001.

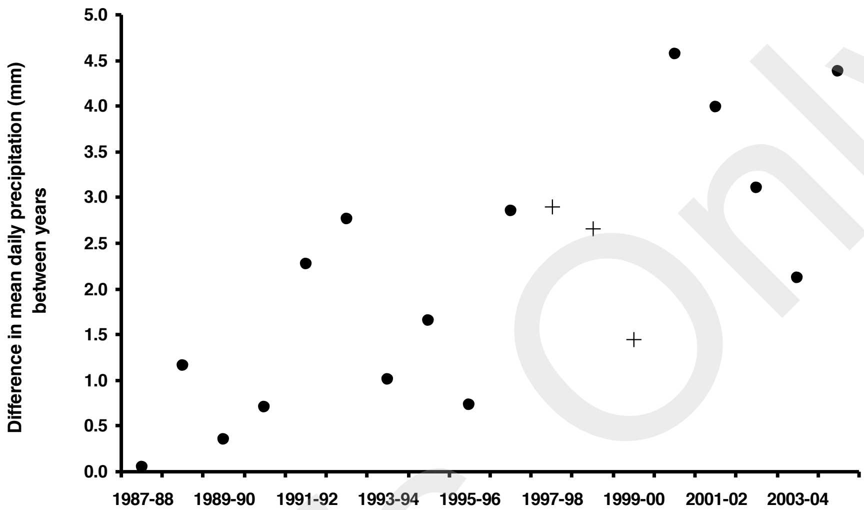


Figure 7.4. Variability in the amount of precipitation recorded during the September-November wet season in consecutive years. Each point represents the absolute difference in mean daily precipitation between consecutive years. A high value thus indicates extreme differences in rainfall between two consecutive years. '+': data available for less than 80% of days during the September-November wet season in one or both years. No data were available for this season in 2005 or 2006.

Analysis of stream water temperature across all sites has revealed a cyclic pattern with dips and rises over the eight year period. The lowest recorded mean stream temperature was 15.9 ºC in 2004 and the maximum was 16.4 ºC between 2006 and 2007. The amplitude of change in stream water temperature was much higher at sites outside of the forest, for example, at a point where the River Ishasha enters BINP forest, compared to the Munyaga site, at the falls inside the forest (Figure 7.5) signifying the importance of the forest in ameliorating water temperature. The cyclic nature of stream water temperature mirrored the variation in air temperature observed at Ruhija over a 20 year period as described in this section above. However, taking year 2001 mean water temperature as the base year and comparing it with 2008 mean water temperature; we found no significant changes in stream temperature. This finding seems to be in contradiction with studies in other sites (e.g. Kibale, Lwiro – chapters 5 and 2) where they have reported increases in air temperature over the years as an increase in air temperature would be expected to result in an increase in surface water temperature.

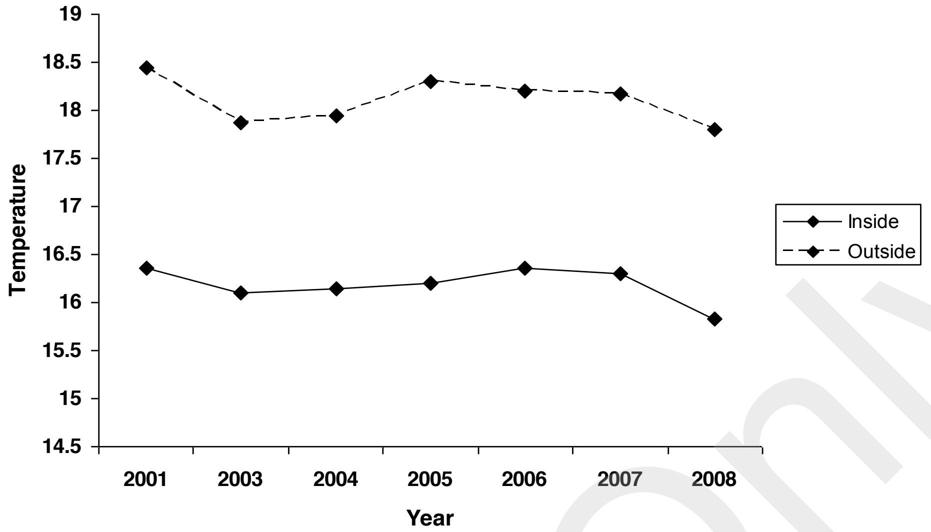


Figure 7.5. Variation in stream water temperature inside and outside Bwindi Impenetrable National Park over a seven year period.

Mean water conductivity increased over the eight year period from 56.1 in 2001 to 74.2 in 2008. Significant increases were noted particularly at sites outside of the forest (Figure 7.6). Other variables such as dissolved oxygen and pH have remained stable over the years. An increase in water conductivity is often an indicator of human induced changes within the landscape. Human impacts, such as poor farming practices on steep slopes and cultivation up to the banks of streams, result in runoff that increases stream water conductivity. At Buhoma, located in the western sector at about 1500 m asl, and the site for gorilla ecotourism, we observed a sudden rise in water conductivity that could be attributed to tourism-related activities, such as trampling on the numerous footpaths that traverse the area (Kasangaki *et al*. 2006). Stability in stream water temperature may mean that cold water species of aquatic insects such as the stoneflies (Plecoptera) and fish, the Albertine Rift endemic *Varicorhinus ruwenzorii* and the montane catfish *Amphilius uranoscopus* (Kasangaki, 2007) may not be in danger from the predicted increases in temperature due to climate change. Bwindi forest may be the only forest where a viable population of *V. ruwenzorii* still exists, since the Ruwenzori population has been negatively affected by the numerous dams built on the River Mubuku.

The Mbwa River Tract (MRT) is a 10 km^2 narrow strip of land along the north-eastern edge of the South sector of BINP. Some 1.17 km^2 of the tract was previously encroached on for agriculture, and in 1993 its residents were resettled through a compensatory scheme (Werikhe, 1994). A study carried out by Mwima & McNeilage (2003) has shown the extent to which this previously cultivated area has recovered ecologically, providing additional habitat for gorilla, bush pigs, duikers and baboons. Water quality in the nearby River Mbwa, a tributary of Ihihizo River has improved, which is likely to be as a result of forest regeneration. Water transparency in the stream is normally high (greater than 100 cm using a transparency tube) becoming turbid only after the rains, as a result of runoff from the road and surrounding agricultural areas (Kasangaki *et al*. 2006). Thus, restoration of the MRT has resulted in improved habitat quality and ecological functions of Bwindi forest.

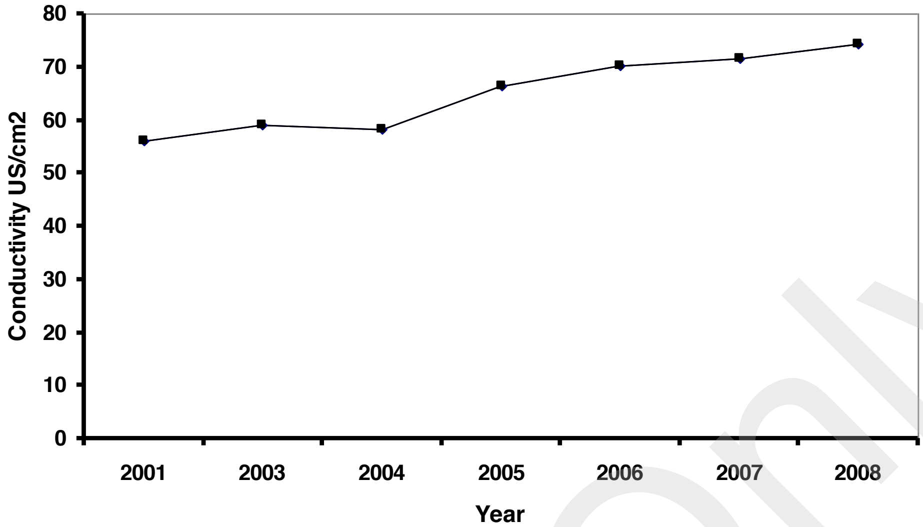


Figure 7.6. Variation in stream conductivity in Bwindi Impenetrable National Park and surrounding areas.

Changes in Forest Size and Extent

Forest loss between 1954 and 1990 was assessed by Scott (1992) from the Uganda Lands and Survey topographical maps derived from the 1954 aerial photographs and the 1990 aerial photographs. In 1954, the total forest area was approximately 442.7km^2. In 1990, the forest area was estimated to be 324.9km^2. This represents a reduction in forest area by 27% over a period of 36 years (Figure 7.7). Pockets of forest that remained by 1990 are too isolated from BINP itself to be considered part of the continuous forest vegetation. The north west and south west regions are where the greatest amount of deforestation has occurred. These were the only two areas where considerable forest remained in 1954. Population density is highest in areas to the south east and consequently these areas had lost the majority of their tree cover before the 1954 photographs were taken.

There remains today virtually no forest outside the national park boundary, with the exception of scattered remnants in the south west. In many areas the border to the National Park forms an extremely hard edge, with barely a tree remaining outside the boundary. However, despite the historical circumstances and the pressure of increasing population, the forest within the protected area boundary remains almost entirely un-encroached. Figure 7.8 shows a satellite image analysis of forest cover loss between 1987 and 2000 carried out by Laporte (2006), with very little forest loss other than small patches on community land away from the park.

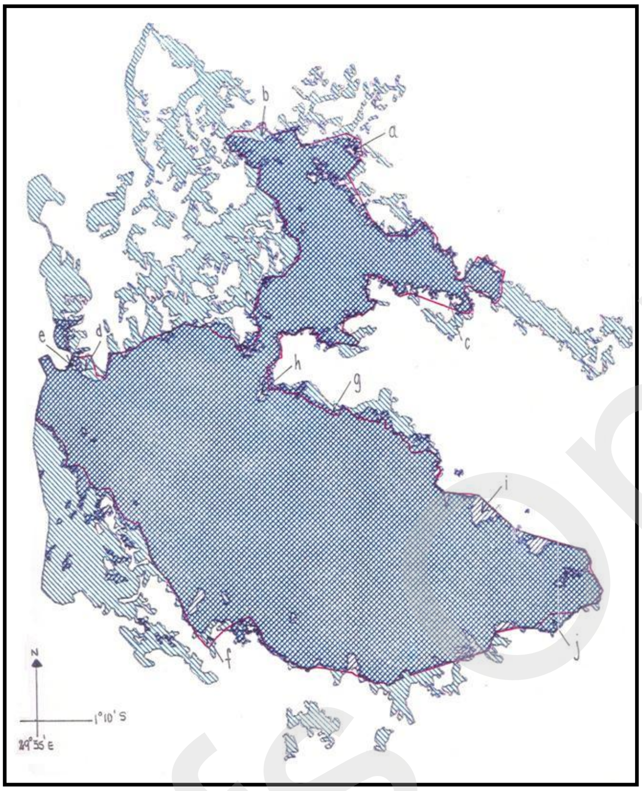
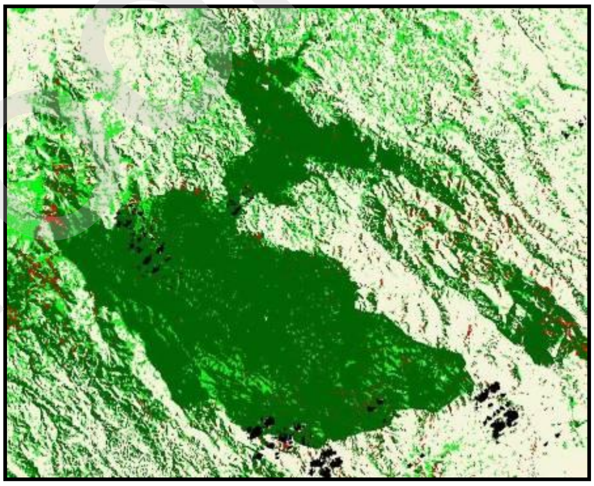


Figure 7.7. Map of BINP showing extent of the forest in 1954 (pale hatch) and 1990 (dark hatch). (*Source: Scott 1992*).



Source: Laporte 2006.

Figure 7.8. Forest loss around Bwindi. Red areas indicate loss of forest cover between 1987 and 2000 derived from Landsat images.

CHANGES IN HABITATS IN BWINDI

Before Bwindi was gazetted as a National Park in 1991, widespread human activities, such as logging and encroachment for agriculture, resulted in habitat modification over a large scale. The Afromontane forest is quite different in structure from other forests, characterized by open canopy and very dense undergrowth in most parts. The range of habitats in Bwindi is unique due to its altitudinal range and in many ways is more similar to what is found in Nyungwe Forest in Rwanda than the nearby Virunga Volcanoes. The vegetation types and habitats in Bwindi forest vary with altitude and past disturbance regimes. Nkurunungi *et al*. (2004) described the major vegetation types and habitats at two sites of different elevation: Buhoma (lower altitude) and Ruhija (high altitude). The major vegetation types are open forest, mixed forest, mature forest, swamp forest, riverine forest, and regenerating forest. They reported a greater diversity of plant species and greater tree- and shrub densities at lower elevations, compared to the high altitude site, whereas there was a higher density of understory herbs at the high altitude location. Plant community composition is related to altitude (Ganas *et al*., 2008) and there are significant differences in plants available for large mammals such as mountain gorillas depending on location, but little temporal variation (Ganas *et al*., 2008, 2009). It is unknown what impacts past disturbances such as logging and/or the extirpation of buffalo have had on the habitat, particularly the dense understorey.

Olupot *et al*. (2009) assessed the major anthropogenic threats to the park-people interface around Bwindi, and reported that wood and pole harvesting was the major threat to the integrity of the edge. They found other threats to include the occurrence of exotic species, degradation of adjacent habitat fragments and the high impact of problem animals on some of the neighbouring communities. They concluded that since the threats were mostly associated with the edges of the Park, when previously they were widespread throughout the Park, that illegal resource harvesting had been reduced since the forest was upgraded to a national park. Park legislation, enforcement and related conservation efforts have been effective, but there should be increased effort to manage the people-park interface (Olupot *et al*. 2009).

However, although disturbance to the forest caused by illegal resource harvesting may have greatly declined in recent years, the previous history of logging may still be having an impact on the structure and regeneration of the forest. Many forest gaps were created and natural ones enlarged through logging (Babaasa *et al*. 2004). A subsequent lack of tree regeneration within the gaps has been attributed by Babaasa *et al*. (2004) to the smothering of tree seedlings and saplings by dense tangles of herbs, shrubs and semi-woody climbers such as *Sericostachys scandens* (Babaasa *et al*. 2004). Gap size in Bwindi is considerably larger than, for example, in Kibale National Park, perhaps due to regular tree falls on the steep-sided slopes (Babaasa *et al*. 2004). Although gaps reduce canopy forest cover, they may be favoured by herbivorous fauna, such as gorillas, duikers, bushbucks and elephants that frequent them for food. It has been argued that gaps should be maintained or even artificially created, with the aim of increasing the gorilla population, which use them as feeding areas. However, the fact that Bwindi has lost so much canopy cover in the past, coupled with evidence that tree regeneration in gaps is limited, suggests that increasing gaps would cause Bwindi to deviate further from a natural forest state and would not therefore be recommended for the conservation of overall biodiversity. Furthermore, gorillas feed on fruit and other plants found in mature forest habitat, so modifying this habitat type would alter the gorillas' diet.

CHANGES IN ANIMAL POPULATIONS

Large Mammals

With few exceptions, only circumstantial or anecdotal evidence is available for animal population trends in Bwindi. Overall, there is a widespread belief that populations of large mammals, such as duikers, are increasing, as a result of increased protection and a reduction in poaching. The frequency of sightings of species such as duikers appears high compared to ten years ago, especially on the road between Ruhija and Kabale and trails around the Ruhija area. Carnivores such as genets, civets, jackals and golden cats have been sighted in the past decade although infrequently (M. Robbins, pers. comm.). More evidence of large mammal increases can be derived from an increase in incidences of crop depredation reported by the local communities and in park records. However, a few quantitative studies have been carried out to estimate the populations of large mammals, and these currently provide a baseline against which population future changes may be assessed. For example Babaasa (1994) estimated the population of elephants in Bwindi to be 27, and currently estimates the population to be less than 40 (D. Babaasa pers. comm.). The giant forest hog is thought likely to be extinct, due to poaching activities. Buffalo and leopards were also thought to occur in Bwindi in the past, but are no longer present. The absence of buffalo may have important implications for the dynamics of the forest understorey.

Bwindi contains about 44% of the remaining endangered mountain gorillas in the world. Given their critically endangered status, they have been the best studied of the large mammals in the park. The diet of Bwindi mountain gorillas differs substantially from their counterparts in the Virunga Volcanoes and their di*et al*so varies within Bwindi, largely due to differences in food availability (Ganas *et al*., 2004). In addition to variation in the species of herbaceous vegetation consumed, Bwindi gorillas consume fruit, which is rarely available in the Virungas (Ganas *et al*., 2004). The Bwindi mountain gorillas also have larger annual home ranges and longer daily travel distances than Virunga mountain gorillas (Robbins and McNeilage, 2003; Ganas and Robbins, 2005). Such ecological differences may translate into variation in behavior and population dynamics (Robbins, 2008; Robbins *et al*., 2009).

The mountain gorillas are also the one species for which repeated census have been carried out. The population was estimated at 300 gorillas within sections of the park surveyed during 1987-1993 (Butynski & Kalina 1993). In 1997, the entire park was surveyed over a two month period using the same systematic 'sweep census' as has been applied in the Virunga Volcanoes (McNeilage *et al*., 2001; Gray *et al*., 2009). It was estimated that the entire park contained 300 gorillas, suggesting that either the earlier surveys overestimated the population size, or that it had remained stable during the decade. Another 'sweep census' was conducted in 2002, with the population increasing to 320 gorillas, which represents a 1% annual growth rate (McNeilage *et al*., 2006). However, these results were called into question following another sweep census in 2006 that also incorporated genetic analysis as a method to identify most individuals of the population. Genotypes of the gorillas, obtained from faeces left in the night nests, lead to the finding that some gorillas make more than one nest each night and that some groups were counted twice, because it was not possible to discriminate among them using the data obtained from the nest sites alone. While the nest count results suggested that the population had increased to 340, in combination with the more precise and accurate genetic analysis, the population was estimated to comprise only 300 gorillas (Guschanski *et al*. 2009). Because of the possibility of both over- and under-counting of gorillas, due to a variety of factors, it is not possible to establish the accuracy of earlier censuses, making it difficult to determine with certainty if the population has been increasing or declining over the past two decades. However, in all likelihood, the population has been relatively stable in size for at least the past two decades.

Several patterns have, nonetheless, emerged concerning the distribution of gorillas in the park. The gorillas were found to be concentrated more in the center of the southern sector of the park, although groups were located along the edge in many locations (Figure 7.9). The eastern region was devoid of gorillas in the 1997, 2002, and 2006 censuses, despite it containing suitable vegetation. Anecdotal evidence from the local people indicates that gorillas were poached out of this area in the 1970s and 1980s. The northern sector of Bwindi, long considered unsuitable habitat for the gorillas because of the lower altitude, was not known to contain any gorillas until one of the groups habituated for tourism began to use the southern portion of it in 2006. It is not known how many gorillas the northern sector could support.

There is also evidence that human disturbance is having an impact on the gorilla population. When the distribution of gorillas (Figure 7.9) is compared with disturbance patterns (Figure 7.10) for each of the censuses, it can be seen that gorillas tend to be found in areas of low disturbance. A negative correlation is found in each case between the number of gorillas and gorilla groups found in each sector with the encounter rate of signs of human disturbance (Table 7.1).

Analysis of the life history data from known individuals in the gorilla groups habituated for research or tourism from 1993 to –2007, and comparisons with the mountain gorillas of the Virunga Volcanoes, adds some insight into the population dynamics of the Bwindi mountain gorillas (Robbins *et al*., 2009). The Bwindi gorillas have a significantly lower birth rate and longer inter-birth intervals than their Virunga counterparts. Unfortunately, not enough data exist to calculate mortality rates per age class, except for infants (< 3 years old). Infant mortality in Bwindi was not significantly different from that of the Virunga mountain gorillas. Using the birth rate from Bwindi and the mortality rates from the Virungas, Leslie matrix models predict that the population should be growing at an annual rate of 2.5-4.4% (depending on whether unexplained 'disappearances' from the habituated groups were of gorillas that either dispersed or died). However, even with the inaccuracies inherent in the sweep census method, it is unlikely that the entire population could be growing at this rate. For example, had there been 300 gorillas in 1986, with an annual population growth rate of 3%, there would have been 540 gorillas in the park in 2006. These results suggest that the habituated groups may be faring better than the unhabituated groups, perhaps due to better monitoring and protection. It is possible that the population is at or near to carrying capacity, although there are areas of the park currently under-utilized by the gorillas (eg. the eastern region). Further analysis is necessary to understand the complex interactions among human disturbance, ecology, and the gorillas' population dynamics.

Table 7.1. Spearman rank correlations of human disturbance encounter rates and the number of gorillas and gorilla groups found during each of the censuses by sector

Year	Gorillas	Groups
1997	r_s = -0.279, p<0.05	r_s = -0.298, p<0.05
2002	r_s = -0.315, p<0.05	r_s = -0.391, p<0.01
2006	r_s = -0.317, p<0.05	r_s = -0.380, p<0.01

n = 39 in each case

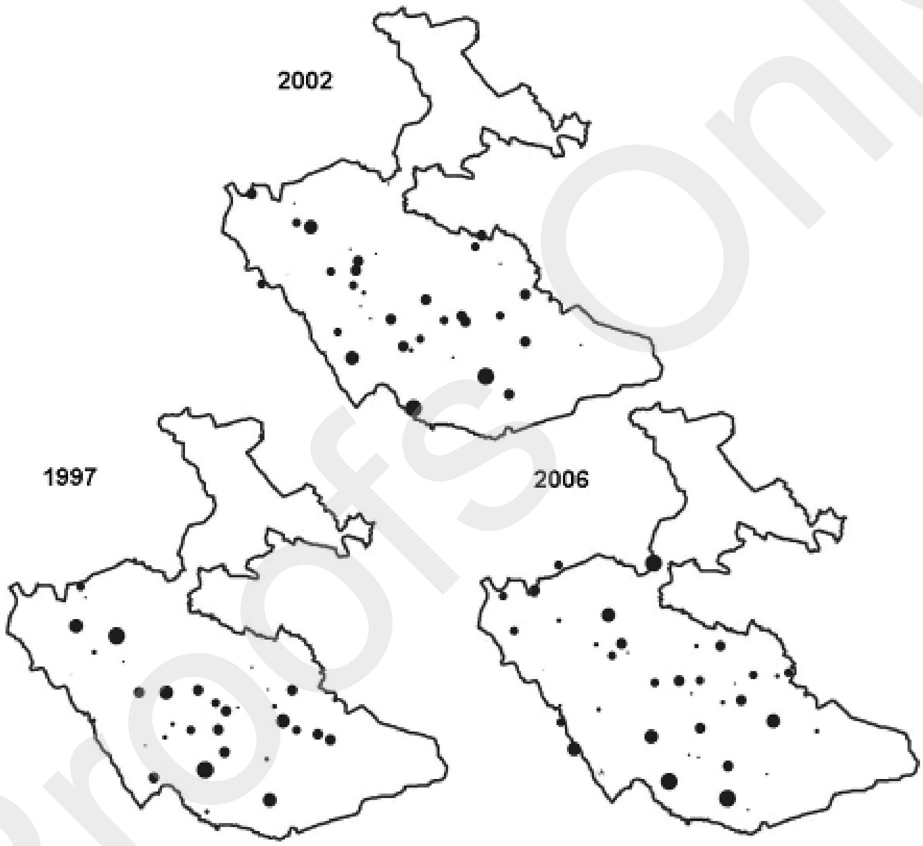


Figure 7.9. The distribution of gorilla groups found during three censuses in Bwindi. Each circle represents one group, with the size of the circle proportional to the size of the group.

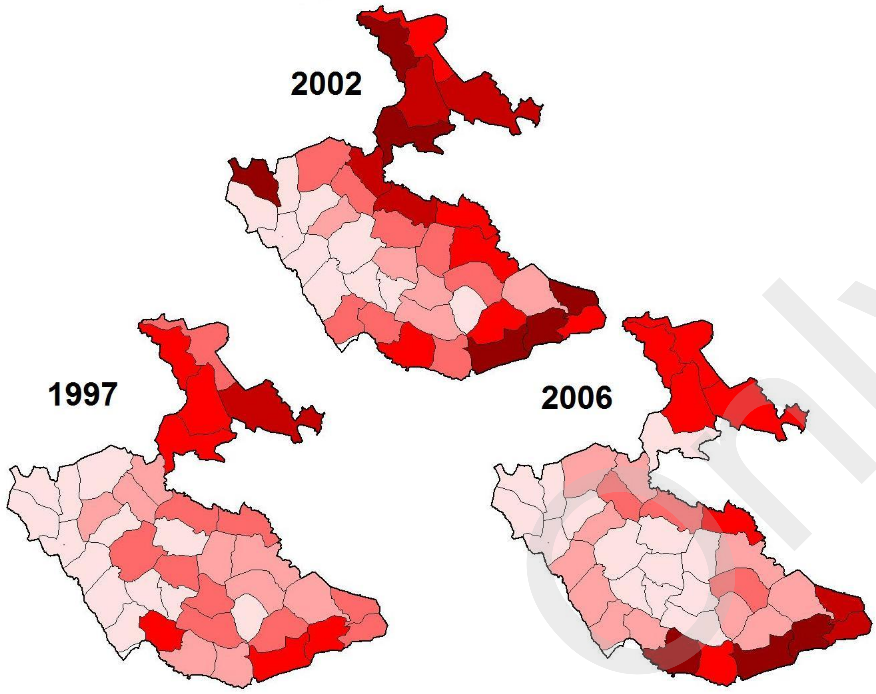


Figure 7.10. Distribution of human disturbance in Bwindi during the three gorilla censuses. The darker the shading for each sector the higher the encounter rates of signs of human disturbance. The same shading scale is used for all years.

Birds

Bwindi's diverse bird fauna includes 25 species classed as 'restricted-range' (occupying a global range of 50,000 km^2 or less), of which 23 are endemic to the Albertine Rift and four are listed as globally threatened (Stattersfield *et al*. 1998; BirdLife International 2009). Despite this, and the forest's relative accessibility within the Rift, there are as yet no reliable trend data for Bwindi's bird populations.

A number of studies have been conducted with the aim of compiling a comprehensive species inventory (Butynski & Kalina 1989, 1993; Kalina & Butynski 1996;) and establishing the altitudinal ranges, habitat requirements or population densities of Bwindi's forest birds (e.g. Keith 1980; Bennun 1986; Shaw & Shewry 2001; Gottschalk & Ampeire 2008; Shaw 2010). Together, these provide a baseline against which changes in their distributions or densities might one day be assessed. Recent studies, based at Ruhija, have focussed on bird densities and altitudinal zonation in and adjacent to the forest (G.M. Malinga, L. Twanza, pers. comm.), and on the ecology of crimsonwing species (S. Espley pers. comm.). There is also an ongoing study of the breeding biology and annual survival of the Stripe-breasted Tit, an Albertine Rift endemic (Shaw 2003; Yatuha & Dranzoa 2010). Established in 1995, some 30 nestboxes were erected initially in the vicinity of the ITFC Research Station, rising to 50+

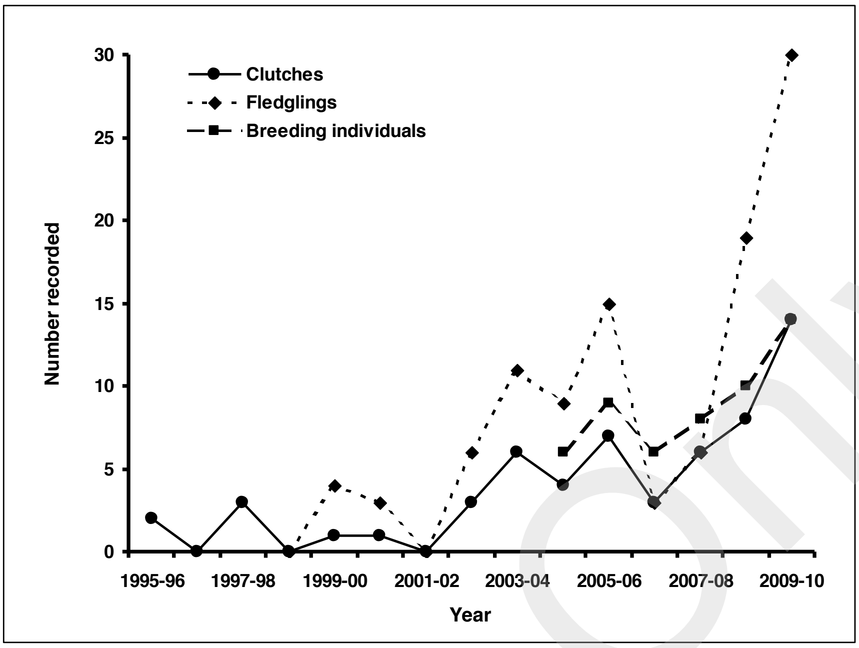


Figure 7.11. The number of Stripe-breasted Tit clutches, fledglings and breeding individuals recorded in the vicinity of Ruhija during 1995-2010. Since most clutches are laid in December-February, each breeding year has been taken to span 1 December – 30 November. 'Breeding individuals' here excludes non-breeding helpers.

in 2003. During the late 1990s and early 2000s, 0-3 clutches were recorded annually, reflecting the species' low population density (Figure 7.11). This figure increased to 3-8 during 2005-09, and then to 14 in 2009-10. Prior to 2008 the general rise in pairs and productivity is likely to have reflected an increased tendency to use nestboxes, rather than a genuine population change. However the increases seen in 2008-10, during which the number of nestboxes available remained broadly static, suggests that there may have been a genuine rise in the local population. These observations are based on very small samples, however, and further monitoring is required to reliably determine population trends.

CHANGES IN COMMUNITY ATTITUDES AND BEHAVIOR IN RESPONSE TO CONSERVATION STRATEGIES

Following the gazettement of Bwindi Impenetrable Forest as a National Park in 1991, hostility between the local communities and wildlife authority staff increased. Fires, set by arsonists, resulted in loss of forest (Kasangaki *et al*. 2001, Babaasa *et al*. 1999). In order to diffuse the tension that existed between local communities and protected area managers, several integrated conservation and development programs were initiated around the park. They included resource harvest programs in multiple use zones (see below); a revenue sharing scheme, in which 20% of the park entry fees from visitors (but not the gorilla visit permits) are given to the local communities to invest in developmental activities, such as health centers, schools and road construction; an ICD project was established by CARE and a Trust fund was created that funded community projects.

There is evidence that these interventions have been effective at improving relations between the local population and park authorities, as the local communities now see the park as their own, as evidenced from the economic benefits they gain mainly from tourism-related activities. For example, surveys showed improved community attitudes towards participation in putting out fires started accidentally within the forest (Kasangaki *et al*. 2001, Babaasa *et al*. 1999).

In 2006 a study was carried out around Bwindi Impenetrable and Mgahinga National Parks, aimed at testing the effectiveness of integrated conservation and development (ICD) strategies in reconciling the interests of biodiversity conservation and socio-economic development interests. The study focussed particularly on interventions which aimed both to improve livelihoods and to increase support for conservation, in terms of the attitudes and behaviour of local communities (Blomley *et al*. 2010). Six ICD strategies were selected: sustainable agriculture programmes and on-farm substitution, both of which aimed to reduce the demand for park resources; multiple use of forest resources; tourism; revenue-sharing; and a local conservation trust fund which aimed to provide communities with sustainable benefits derived from the parks. The study assessed the impact of each strategy in improving community attitudes to conservation and cooperation with park authorities, and reducing illegal resource exploitation (both in terms of a behavioural change resulting from improved attitudes and a direct reduction in the use of forest resources). Data were collected from a range of sources, including previous socio-economic and ecological research, questionnaire interviews of almost 600 households, focal group discussions targeted at key groups of people from local communities and from organisations implementing ICD, and surveys of human impact in the parks.

Results from the study showed that community attitudes to the parks have improved greatly since gazettement, and that ICD strategies have played an important role in this (Blomley *et al*. 2010). The poorest people generally had less positive attitudes at the outset, but on receiving park-related benefits, showed a more pronounced, positive change in attitude than those on higher incomes. Community cooperation with Park authorities has also improved, particularly the willingness to assist in fighting fires and, to a lesser extent, reporting of illegal activities. Here again, ICD strategies have played an important role in this improvement.

While both community members and park staff stated that illegal resource extraction had decreased, there was little evidence to support this from data on illegal activities within the parks in recent years (Blomley *et al*. 2010). Law enforcement was by far the most frequently cited reason as to why illegal activities would be reduced, although ICD strategies were sometimes also cited.

Blomley *et al*. (2010) conclude that ICD strategies have, through their impact on community support for conservation, reduced some of the threats to biodiversity in Mgahinga and Bwindi, in particular fires and politically driven threats (e.g. degazettement, roads). There is also evidence that ICD strategies have made the protected area authority's work easier, through improved community cooperation, and have at least the potential to reduce the cost of law enforcement. ICD strategies, however, do not seem to have had a major impact in reducing illegal forest resource exploitation, and effective law enforcement is needed to back up ICD strategies. This could be due to a number of factors. First, illegal activities are mainly thought to be conducted by poorer people, but many of the strategies have not reached the lowest wealth categories very effectively. Second, ICD has not been effective in establishing explicit links between rights/benefits and responsibilities at the community level, particularly with regards to preventing illegal activities. Third, crop damage by problem animals remains a serious challenge, and has a strong negative impact on attitudes, which may have diluted the potential impact of ICD. Lastly, ICD strategies were originally intended to improve livelihoods so that local people no longer needed to access forest resources. Considerable time and resources have been invested in ICD in SW Uganda and this has resulted in a significant change in attitudes. However it is perhaps not realistic to expect this investment to have resulted in such significant changes in people's livelihoods that they simply no longer have any need or interest in accessing forest resources.

IMPACTS OF LOCAL COMMUNITY USE OF PLANT RESOURCES

For centuries Bwindi forest has provided a source of livelihood for local people. The forest has been used for the extraction of plant resources for food, weaving and medicinal purposes and house construction. The forest was also a major source of protein for the local people, in the form of bush meat and fish (Bitariho & Barigyira in press). However, all of these activities were stopped in 1991 when Bwindi was gazetted as a national park, resulting in conflicts between park managers and the local people.

After the 1992 Rio de Janeiro conference (the 'Earth Summit'), events led to a shift in management policies, resulting in a greater emphasis on involving local communities in park management. Collaborative forest management began in Bwindi in 1994 with local people being allowed to harvest plant resources important for medicinal and weaving purposes, from areas at the park periphery called 'multiple use zones'. Plant harvesting in these multiple use zones has been on-going since 1994.

In 2001 the Institute of Tropical Forest Conservation established Permanent Sample Plots (PSPs) in the multiple use zones and non-multiple use zones of Bwindi Impenetrable National Park to monitor plant harvest impacts. We established 10 PSPs in a harvest zone and another 10 PSPs in a non-plant harvest site, to monitor changes in the density, regeneration and yields of harvested plants. We also examined forest societies' records to determine harvested plant off-takes from the forest since 1994. We have been monitoring changes of the three most-utilised plants: *Rytigynia kigeziensis* (Rubiaceae), *Ocotea usambarensis* (Lauraceae) and *Loeseneriella apocynoides* (Celastraceae), as indicators of plant harvest impacts in Bwindi Impenetrable National Park.

Results show no significant difference in the biomass production of two medicinal plants (*R. kigeziensis* and *O. usambarensis*) when harvested and non-harvested plant populations are compared (t-test = 0.798; P = 0.43; One-way ANOVA = 2.06; P = 0.11) (Bitariho *et al*. 2006). However the commercially utilised weaving plant *L. apocynoides*, appears to have suffered a negative impact from harvesting. The diameter class distribution of the harvested *L. apocynoides* population differed significantly from that of the non-harvested population (Yates corrected X^2 (df-t) = 10.21, P<0.001) (Ndangalasi *et al*. 2007). As a result the harvest of *L. apocynoides* from Bwindi has been banned by park authorities. Results further show a decline in the amount of medicinal bark harvested (of *R. kigeziensis and O. usambarensis*) and the number of bark harvesters since the multiple use programme started in 1994 (Figure 7.12).

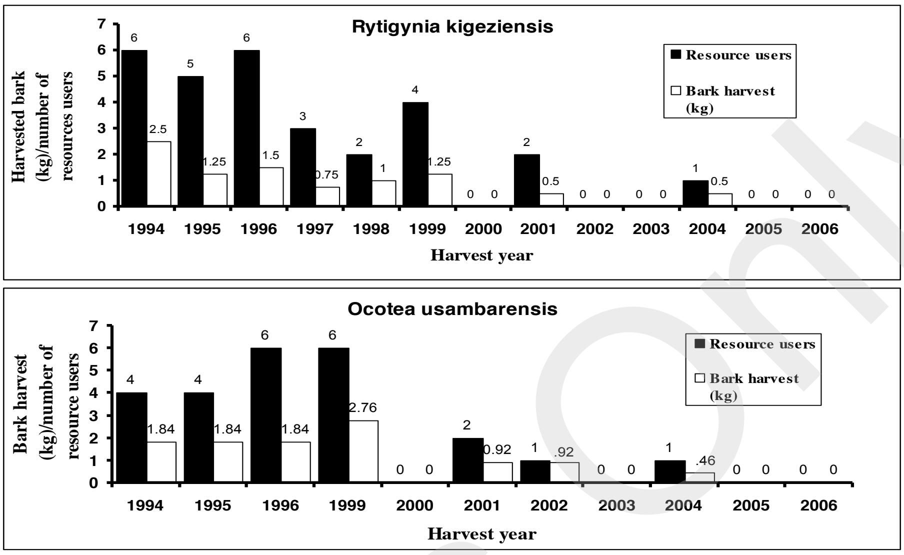


Figure 7.12. Annual bark harvest of *Rytigynia kigeziensis* and *Ocotea usambarensis* in Bwindi Multiple Use Zones.

The monitoring results suggest that bark harvesting for medicinal use in Bwindi Impenetrable National Park is sustainable, as it has been shown to cause minimal impacts on the harvested plants. Most of the medicinal plant utilization is at a subsistence level to treat body ailments and diseases locally. Bark from the two monitored plants is used in the treatment of intestinal worms (parasites) and coughs. Government programs providing health facilities in villages and increases in rural household incomes seem to have reduced the demand for bark as medicines. Bark harvesting for medicinal use thus appears sustainable only if it continued at the present local subsistence level. However, there is a danger of the harvest being increased, following the recent introductions of herbal clinics in the nearby towns of Butogota, Kanungu and Kabale.

Ironically, other government programs for improving rural incomes through cash crop growing, especially tea, may have increased the demand for weaving materials, which are used in making tea harvest baskets. *L. apocynoides* is in high demand for making tea harvest baskets, stretchers and storage granaries, and products made from it tend to last long. Kayonza Tea Factory, in the vicinity of Bwindi Impenetrable National Park, was started in 1966 and, by 1995, processed 4 million kilograms of green tea leaf annually. Following refurbishment in 1995, the factory started harvesting 12 million kilograms of green tea leaf annually (C Tumwesimire, Chairman of Kayonza Tea Factory pers. comm.). This has increased the demand for tea harvest baskets, and although other plants such as *Phoenix* *reclinata* have been used as alternatives (due to the scarcity of *L. apocynoides*), *L. apocynoides* is the most preferred. With such high demand for *L. apocynoides*, the ban on its harvesting from Bwindi Impenetrable National Park should be continued, to allow its recovery.

FUTURE PROSPECTS FOR BWINDI

In many ways Bwindi can be considered a great conservation success. Twenty years ago high levels of disturbance and conflict severely threatened the forest. Since then, however, there has been virtually no further loss of forest cover, and conflicts have been greatly reduced. The mountain gorilla population appears to be stable, and although no systematic data exist on other species, subjective impressions are that there has been a recovery of other species as well. However, continuing immediate threats to the forest and its wildlife include illegal use of forest resources (poaching, pit-sawing, firewood collection), human induced fires, and human-wildlife disease transmission (Babaasa *et al*. 1999; McNeilage *et al*. 2006, Olupot *et al*. 2009; Rwego *et al*., 2008; Cranfield, 2008). McNeilage *et al*. (2006) reported an increase in signs of human disturbance when they compared the gorilla census results of 1997 and 2002. The frequency with which snares, beehives, tree cutting and honey gathering were encountered was significantly higher in 2002, but was less elevated in 2006. This increase in illegal activities is taking place despite heightened patrols by the park rangers. There is thus a need to assess the effectiveness of the patrol teams in curbing illegal activities. Other priority research topics include investigating the effects of poaching on the populations of hunted mammal species, such as duikers, bushbucks and bushpigs.

Although Bwindi is currently protected as a National Park, several challenges still threaten its existence in perpetuity. These include invasive species of plants, such as *Lantana camara*, which is spreading particularly in the north-eastern part of the park. Safari & Byarugaba (2008) recommended physical removal (uprooting and burning) of lantana thickets to encourage regeneration of the natural forest. They attribute its rapid spread to past forest disturbance, such as logging and encroachment for agriculture when the forest was being managed as a forest reserve. *Lantana camara* removal from the forest should be given high priority by Park authorities, as it is spreading rapidly and could compromise the ecological integrity of the park.

Climate change impacts are yet to be elucidated for the Bwindi forest ecosystem. However, some changes have been noted, such as an increase in water conductivity between 1999 and 2008 that could be related to climate change. We need to assess how climate change will affect the biodiversity of the forest, through the contraction or expansion of species' ranges. There is also a need to assess the potential effects of climate change on ecosystem services that the forest provides, such as stream hydrology and rainfall patterns in the area.

While tourism (gorilla viewing) is considered to be a strategic conservation approach for the gorillas, the park and the local communities, there are obvious risks associated with it. These include disease transmission to the gorillas and behavioral changes through disturbance. Given that the mountain gorilla is a flagship species for Bwindi and they are very few in number, efforts should be made to manage gorilla tourism with the gorillas' well-being first in mind, so as to not diminish their numbers or the ecosystem of Bwindi.

Given Bwindi's very high biodiversity value, reflected in its status as a World Heritage Site, it is critical that conservation efforts continue to address these ongoing challenges. Continued long term monitoring focusing on issues of management importance will be important in measuring the success and ensuring the effectiveness of these efforts.

ACKNOWLEDGMENTS

Long-term research at ITFC has been funded by a number of donors, including the Dutch Government, USAID, the John D and Catherine T MacArthur Foundation, WWF, WCS, Bwindi Mgahinga Conservation Trust, CARE, IGCP and Max-Plank Institute for Evolutionary Anthropology. The hard work of a large number of people working at ITFC has made this long term research possible, and in particular the ITFC field assistants are acknowledged for their dedicated work in field activities. We would like to thank Anton Seimon for the help with data analysis of the climate data from Ruhija. Douglas Sheil reviewed an earlier version of the chapter.

REFERENCES

Allan, J.D. (1995). *Stream Ecology: Structure and Function of Running Waters*. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Babaasa, D. (1994) *Status, Distribution and Feeding Ecology of Elephants in Bwindi Impenetrable National Park, South Western Uganda*. MSc thesis, Makerere University.

Babaasa, D., Eilu, G., Kasangaki, A., Bitariho, R. & McNeilage, A. (2004). Gap characteristics and regeneration in Bwindi Impenetrable National Park, Uganda. *African Journal of Ecology,* 42, 217-224.

Babaasa, D., Kasangaki, A. & Bitariho, R. (1999). *Fire Control and Prevention in Bwindi Impenetrable and Mgahinga Gorilla National Parks*. Unpublished Report, Institute of Tropical Forest Conservation, Kabale, Uganda.

Bennun, L.A. (1986). Montane birds of the Bwindi (Impenetrable) Forest. *Scopus, 10*, 87–91.

BirdLife International (2009). Important Bird Area factsheet: Bwindi Impenetrable National Park, Uganda. Downloaded from the Data Zone at http://www.birdlife.org on 30/6/2010.

Bitariho, R. & Barigyira, R. (in press). Rapid assessment of plant resources for local community use in Bwindi Impenetrable National Park, S.W. Uganda. *Biotropica*

Blomley, T., Namara, A., McNeilage, A., Franks, P., Rainer, H., Donaldson, A., Malpas, R., Olupot, W., Baker, J., Bitariho, R. & Infield, M. (2010). *Development and gorillas: Assessing the impact of fifteen years of integrated conservation and development in South Western Uganda*. Natural Resource Issues, *23*. IIED, London.

Butynski, T.M. & Kalina, J. (1989). Additions to the known avifauna of the Impenetrable (Bwindi) Forest, south western Uganda. *Scopus, 12*, 79–82.

Butynski, T.M. & Kalina, J. (1993). Further additions to the known avifauna of the Impenetrable (Bwindi) Forest, southwestern Uganda. *Scopus, 17*, 1–7.

Butynski, T.M. (1984) *Ecological Survey of the Impenetrable (Bwindi) Forest, Uganda, and Recommendations for its Conservation and Management*. Unpublished Report, New York Zoological Society, New York, USA.

Butynski, T.M., & Kalina, J. (1993). Three new mountain national parks for Uganda. *Oryx, 27,* 214–224.

Cranfield, M. (2008). Mountain Gorilla Research: The Risk of Disease Transmission Relative to the Benefit from the Perspective of Ecosystem Health. *American Journal of Primatology, 70,* 751–754.

Ganas, J., & Robbins, M.M. (2005). Ranging behavior of the mountain gorillas (*Gorilla beringei beringei*) in Bwindi Impenetrable National Park, Uganda: a test of the ecological constraints model. *Behavioural Ecology & Sociobiology, 58,* 277-288.

Ganas, J., Nkurunungi, J.B., & Robbins, M.M. (2008). Temporal and spatial variability of herbaceous vegetation consumed by mountain gorillas in an Afromontane rainforest. *Biotropica, 41,* 37-46.

Ganas, J., Ortmann, S., & Robbins, M.M. (2009). Food choices of the mountain gorilla in Bwindi Impenetrable National Park, Uganda: the influence of nutrients, phenolics, and availability. *Journal of Tropical Ecology*, *25,* 123-134.

Ganas, J., Robbins, M.M., Nkurunungi, J.B., Kaplin, B.A., & McNeilage, A. (2004). Dietary variability of mountain gorillas in Bwindi Impenetrable National Park, Uganda. *International Journal of Primatology, 25,* 1043-1072.

Gottschalk, T.K. & Ampeire, S. (2008). A nest record of Oberländer's Ground Thrush *Zoothera oberlaenderi*. *Bulletin of the African Bird Club, 15,* 250-252.

Gray, M., McNeilage, A., Fawcett, K., Robbins, M.M., Ssebide, B., Mbula, D., & Uwingeli, P. (2009). Censusing the mountain gorillas in the Virunga Volcanoes: complete sweep method vs. monitoring. *African Journal of Ecology*.

Guschanski, K., Caillaud, D., Robbins, M.M., & Vigilant, L. (2008). Females shape the genetic structure of a gorilla population. *Current Biology*, *18,* 1809-1814.

Guschanski, K., Vigilant, L., McNeilage, A., Gray, M., Kagoda, E. & Robbins, M.M. (2009). Counting elusive animals: comparing field and genetic census of the entire mountain gorilla population of Bwindi Impenetrable National Park, Uganda. *Biological Conservation, 142*, 290-300.

Kalina, J. & Butynski, T.M. (1996). *Check-list of the birds of the Bwindi Impenetrable Forest, Uganda*. Nairobi: East Africa Natural History Society.

Kasangaki, A. (2007). *Effects of anthropogenic disturbance on stream fish assemblages of Bwindi Impenetrable National Park, southwestern Uganda*. Unpublished PhD Thesis, 182 pp. Mbarara University of Science & Technology, Mbarara.

Kasangaki, A. Babaasa, D. McNeilage, A. Efitre, J. & Bitariho, R. (2006). Links between anthropogenic perturbations and benthic macroinvertebrate assemblages in Afromontane Forest Streams in UgandaHydrobiologia, 563, 231-245.

Kasangki, A. Babassa, Bitariho, R, and Mugiri, G. (2001). A Survey of burnt areas in Bwindi Impenetrable and Mgahinga Gorilla National Parks, south west Uganda. Unpublished report, Institute of Tropical Forest Conservation.

Keith, S. (1980). The avifauna of the Impenetrable Forest, Kigezi, Uganda with special reference to altitudinal distribution. *Proc. Fourth Pan-Afr. Orn. Congr*., pp. 159–167.

Laporte, N. (2006). *The Albertine Rift Protected Area Watch (PAWAR)*. The Woods Hole Research Center, MA, USA.

Leggat, G.J. & Osmaston, H.A. (1961) *Working Plan for the Impenetrable Forest Reserve, Kigezi District*. *Period 1961–1971*. Unpublished report to the Uganda Government, Uganda Forest Department, Entebbe.

McNeilage, A., Plumptre, A.J., Brock-Doyle, A. & Vedder, A. (2001). Bwindi Impenetrable National Park, Uganda: gorilla census, 1997. *Oryx, 35,* 39-47.

McNeilage, A., Robbins, M.M., Gray, M., Olupot, W., Babaasa, D., Bitariho, R., Kasangaki, A., Rainer, H., Asuma, S., Mugiri, G. & Baker, J. (2006). Census of the mountain gorilla population in Bwindi Impenetrable National Park, Uganda. *Oryx, 40*, 419-427.

Mwima, P.M. & McNeilage, A. (2003). Natural regeneration and ecological recovery in Bwindi Impenetrable National Park, Uganda. *African Journal of Ecology, 41*, 93-98.

Nkurungi, J.B., Ganas, J., Robbins, M. M. and Stanford, C.B. (2004). Acomparison of two mountain gorilla habitats in Bwindi Impenetrable National Park, Uganda. *African Journal of Ecology*, 42, pp. 289-297.

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

Robbins, M.M. (2008). Feeding Competition and Female Social Relationships in Mountain Gorillas of Bwindi Impenetrable National Park, Uganda. *International Journal of Primatology*, *29,* 999-1018.

Robbins, M.M. & McNeilage, A. (2003). Home range and frugivory patterns of mountain gorillas in Bwindi Impenetrable National Park, Uganda. *International Journal of Primatology*, *24,* 467 – 491.

Robbins, M.M., Gray, M., Kagoda, E., & Robbins, A.M. (2009). Population dynamics of the Bwindi mountain gorillas. *Biological Conservation, 142,* 2886-2895.

Rwego, I.B., Isabirye-Basuta, G., Gillespie, T.R., Goldberg, T.L. (2008). Gastrointestinal Bacterial Transmission among humans, Mountain Gorillas, and Livestock in Bwindi Impenetrable National Park, Uganda. *Conservation Biology, 22,* 1600-1607.

Safari, C. & Byarugaba, D. (2008). Control of *Lantana camara* L. in Bwindi Impenetrable National, south-western Uganda. *African Journal of Ecology, 46,* 456-458.

Scott, P. (1992). Fringe Benefits: *Minor forest product collection within buffer zones as a potential tool for conflict resolution for Bwindi Impenetrable National Park*. Unpublished MSc thesis, Agricultural University of Norway.

Shaw, P. & Shewry, M. (2001). Population density and habitat associations of restricted-range bird species at Ruhija, Bwindi Impenetrable Forest, Uganda. *Bird Conservation International, 11,* 161–174.

Shaw, P. (2003). Breeding activity and provisioning rates of Stripe-breasted Tits *Parus fasciiventer* at Bwindi Impenetrable Forest, Uganda. *Ostrich, 74,* 129-132.

Shaw, P. (2010). Niche partitioning and densities of Albertine Rift endemics and their congeners in Bwindi Impenetrable Forest, Uganda. *Ostrich, 81,* 7-17.

Stattersfield, A.J., Crosby, M.J., Long, A.J. & Wege, D.C. (1998). *Endemic Bird Areas of the world: priorities for biodiversity conservation*. BirdLife Conservation Series No. 7. Cambridge: BirdLife International.

Werikhe, E.W.S. (1994). *Socio-demographic survey of the Mbwa River tract in Bwindi Impenetrable National Park, southwest Uganda*. Unpublished report.

Yatuha, J. & Dranzoa, C. (2010). Observations on the breeding behaviour of the Stripe-breasted tit (*Parus fasciiventer*) in Bwindi Impenetrable National Park, Uganda. *African Journal of Ecology* 48(2): 511-516.