Census of the mountain gorilla *Gorilla beringei beringei* population in Bwindi Impenetrable National Park, Uganda

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Abstract Mountain gorillas *Gorilla beringei beringei* are Critically Endangered, with just two small populations: in Bwindi Impenetrable National Park in south-western Uganda and the nearby Virunga Volcanoes on the borders with Rwanda and Uganda. A survey of the Bwindi population was carried out in 2002 and results were compared with the previous census in 1997. Our estimate of total population size increased over that period by *c.* 7% to 320 individuals and the structure and distribution of the population were largely unchanged. Signs of human disturbance were more common in 2002 than 1997, and gorillas tended to be found in areas of relative low disturbance. This suggested that disturbance could be a constraint on population growth and distribution but demographic stochasticity may also be responsible for the observed level of population change over a short time period. Other potential limiting factors, including habitat availability and disease, are discussed. While conservation activities in Bwindi have probably contributed to the stability of the population, strengthening of law enforcement and continued vigilance are needed to ensure the population's long-term growth and survival.

Keywords Bwindi Impenetrable National Park, *Gorilla beringei beringei*, human disturbance, mountain gorilla, population census, Uganda.

Introduction

Periodic censuses of threatened populations of high profile species help us to understand their population dynamics, assess the success of conservation programmes aimed at ensuring their survival, and ensure they receive continued attention from the global conservation community. Mountain gorillas *Gorilla beringei beringei* are a Critically Endangered (IUCN, 2006) subspecies of primate, living in only two populations: the Virunga Volcanoes, spanning the borders of Rwanda, Uganda and the Democratic Republic of Congo, and Uganda's Bwindi Impenetrable National Park (McNeilage *et al.*, 2001; Kalpers *et al.*, 2003). Both Bwindi and the Virungas are small islands of forest, surrounded by some of the highest rural human population densities in Africa. The forests have suffered considerable human disturbance in the past in the form of timber extraction, gold-mining, encroachment and poaching (Butynski, 1984). Much has been done in recent years to improve protection and management, with the creation of national parks and considerable support from international conservation organizations (Butynski & Kalina, 1993; Hamilton *et al.*, 2000; Lanjouw *et al.*, 2001). However, the small size of the remaining forests, coupled with the intense pressure from the surrounding human population, still presents considerable challenges to the park managers. Continuing immediate threats to the forests and their wildlife include illegal use of forest resources (poaching, pit-sawing and firewood collection), encroachment and demand for land, human-induced fires, invasive exotic species, and human-wildlife disease transmission (Babaasa *et al.*, 1999; Uganda Wildlife Authority, 2001; ARCOS, 2004; Olupot, 2004; A. Namara *et al.*, unpub. data; Sandbrook & Semple, 2006). In addition, past hunting and logging still have an impact on the forest, with greatly reduced canopy cover, altered vegetation composition and few large herbivores remaining. These current and historic threats raise questions about the ability of these islands of forests to survive and regenerate in the long-term, and emphasize the importance of

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close monitoring of the forests and the wildlife populations they support.

The Virunga gorilla population has been the subject of much research and several censuses over the last 30 years (Harcourt *et al.*, 1983; Weber & Vedder, 1983; Vedder, 1986; Sholley, 1991; Robbins *et al.*, 2001). The most recent censuses found that the population is increasing, despite over a decade of insecurity in the area (Kalpers *et al.*, 2003; Gray *et al.*, 2005). The Bwindi gorilla population, however, is less well studied. Intensive ecological and behavioural research has only been carried out within the last few years (Robbins & McNeilage, 2003; Stanford & Nkurunungi, 2003; Ganas *et al.*, 2004; Nkurunungi *et al.*, 2004; Robbins *et al.*, 2006). The earliest surveys estimated the gorilla population at <200 individuals (Schaller, 1963; Harcourt, 1981; Butynski, 1985) but these were not based on complete censuses of the entire forest and could have been underestimates. T. Butynski (pers. comm.) attempted to monitor all groups over a 7-year period up to mid-1993, during which time the population was estimated to be stable at *c*. 300 individuals (Butynski & Kalina, 1993). The only complete census of the entire protected area, using the complete sweep methods developed in the Virungas, was carried out in 1997. This method established a total population of 300 gorillas and tentatively concluded that the population size was stable relative to Butynski's earlier estimates (McNeilage *et al.*, 1998, 2001).

Given that gorillas have an approximately 4-year inter-birth interval (Watts, 1991) population growth will be inherently slow even at its maximum potential rate, and because each census requires a considerable investment of time and money, population censuses to monitor changes should normally be carried out approximately every 5 years. Habituated groups are monitored regularly to gather additional demographic information for assessing changes in population dynamics. The aim of the census carried out in 2002 was to assess changes in the population since 1997 and to increase our understanding of gorilla population dynamics in Bwindi, levels of human disturbance and their impacts on the gorillas, and the effectiveness of conservation efforts.

Methods

Gorilla census techniques

The procedure employed to census the gorilla population was based on that previously used in Bwindi and the Virungas, referred to as the complete sweep method (Sholley, 1991; McNeilage *et al.*, 1998, 2001). Six teams, consisting of trackers and team leaders, traversed the Park systematically from south-east to north-west, between January and March 2002. The Park was divided into small sectors (*c*. 5–10 km^2), centred around campsites and access points. One team was assigned to census each sector, proceeding in such a way that no more than 3 days were left between the completion of work in one sector and the beginning of work in the next contiguous sector to avoid the possibility of missing groups of gorillas as they range through their habitat. Where possible, teams in neighbouring sectors shared campsites, to allow better coordination of movements and comparisons of findings.

Each sector was searched by walking an irregular network of reconnaissance routes across the area. The actual route was determined largely by the terrain and the availability of existing trails, while ensuring that the routes were sufficiently dense so that no area was missed that could have been large enough for a gorilla group to spend more than 1 week in. To achieve this, trails were planned so that the distance between adjacent trails was never greater than 500–700 m. Gorillas construct a fresh nest each night in which to sleep, and when a recent gorilla trail (<5–7 days old) was found, it was followed until nest sites were located. Using topographic maps, along with locations determined with a global positioning system (GPS) every 250 m, compass and altimeter readings, each census team mapped as accurately as possible all paths taken and gorilla trails followed. By covering the area in this way, mapping and dating all gorilla trails and nest sites, and by marking nest sites once they had been counted, it was possible to ensure that all groups were found and that none was counted twice, and to distinguish similar sized but distinct gorilla groups found close to each other. Where signs of two groups of similar size were found in close proximity to each other, and the dates of the nest sites did not allow them to be confirmed as different groups, they were assumed to be from the same group. In this and previous censuses using similar techniques, the groups monitored regularly were found independently by this complete sweep method.

At each nest site, nests were counted and measurements of dung size were made and used, along with the presence/absence of silver hairs, to establish the age and sex composition of the group. Teams aimed to find at least three nest sites for each group to confirm group composition because individual nests or dung could be missed at one nest site. Dung size categories used were: adult male (SB), >7.2 cm (with silver hairs); adult female or blackback male (MED), 5.5–7.2 cm; juvenile/subadult (JUV), <5.5 cm (sleeping in own nest); infant (INF), generally <4 cm (sleeping in mother's nest).

Juvenile (3–6 years) and subadult (6–8 years) age categories were combined, because previous experience

indicated that dung sizes do not give sufficiently precise information to distinguish these two categories. Young individuals constructing their own nest were always considered here as the combined category juveniles/subadults, and not infants. In the absence of infant dung, adult female nests could not be distinguished from those of a comparable sized subadult (blackback) male, and were therefore classified as medium.

Dung of young infants (<1 year old) is rarely found in nests, and therefore the number of infants in the population is underestimated by these methods. However, a correction factor can be calculated for this, based on the fact that previous censuses of groups with known composition have shown that approximately one third of infants are missed in this way (Schaller, 1963). This correction factor was applied to the total number of infants in unhabituated groups.

Survey methods for human disturbance

The reconnaissance trails walked while looking for gorilla trails covered a large portion of the Park, and provided an opportunity to collect data on signs of human disturbance. Such signs were recorded, with the GPS location and estimated age of each. These included snares, pitfall traps, human tracks, poachers' camps, pit-sawing sites, building poles, firewood and bamboo cutting. Age was categorized as recent <3 months, old >3 months, and very old >10 years. The category very old was only used for pit-sawing sites, which are visible for many years and probably pre-dated the gazetting of the Park. These survey methods were the same as those used during the 1997 gorilla census, so that direct comparisons could be made in the frequency and distribution of signs of human disturbance over this period. Signs were analysed as encounter rates per km of reconnaissance trail walked. Total distance walked on each trail was measured using a combination of a hipchain (Topofil) with biodegradable thread, and GPS readings.

Results

We estimated the total population size to be 320 gorillas based on the following calculations. The five habituated groups in Bwindi contained a total of 72 individuals at the time of the census. In addition to these, 22 unhabituated groups with 216 individuals and 10 lone silverback males were found, giving a total uncorrected population count of 298 individuals (Table 1). A total of 33 infants were counted in the unhabituated groups, so that we predict that another 17 would have been missed using our correction factor of one out of three infants missed because they were too young for their dung to be visible in the nests. This brings the corrected total to 315 individuals and, as with the previous census in Bwindi, we round this figure up to 320 as our best estimate of the population size, because experience shows that a small number of small groups or lone silverbacks can be missed with these methods. This method, as with previous censuses, does not give a confidence interval or error estimates around the population estimate but we retain this method of calculation for making direct comparisons with previous censuses.

The population estimate of 320 gorillas is a 6.7% increase in the estimated total population size over the 4.33 years since the previous census in September–October 1997, which is equivalent to a 1.0% annual growth rate. To control for any possible demographic stochasticity in birth rate and sampling error for missed infants and solitary males, we also compared the values of only nest builders within groups for which we have the most reliable direct counts. There was an increase from 224 to 241 individuals or a 7.6% increase, similar to the growth based on total population estimates.

While the total population size has increased slightly, the other population parameters, group size, percentage of immatures (infants, juveniles & subadults), and percentage of multimale groups are comparable with those found in 1997, which indicates a population with stable population growth (Table 2). Average group size was 11.3 individuals. Three groups (11%) could be considered very large, containing 20 or more gorillas. Twelve groups (44%) were multimale, with most of these groups containing 2 silverbacks and only 3 groups containing three silverbacks. The number of lone silverbacks found increased from 7 to 10, but these individuals are particularly difficult to find and to distinguish from each other using these census methods, so that this does not necessarily reflect an actual change in the population. A total of 72 out of 320 individuals (22.5%) or 5 out of 27 groups (18.5%) are habituated to human presence.

The location of groups found during the census is shown in Fig. 1. As with the 1997 census (Fig. 1) the gorillas were concentrated towards the interior and western areas of the southern sector of the Park. As with all previous surveys no gorillas were found in the northern sector. Signs of human disturbance were generally more frequent during this census than in 1997 (Fig. 2). The frequency of encounter of snares, beehives, tree cutting and honey gathering were all significantly higher in 2002. The overall distribution of human disturbance, however, was similar (Fig. 3). As with the 1997 census, gorillas were found in areas of relatively low human disturbance, and this pattern appears to be more clear in 2002. A significant negative correlation was found between signs of human

Table 1 Size and composition of gorilla groups found during the 2002 census. Medium age class refers to blackback males plus adult females without infants. These two categories cannot be distinguished from nest sites alone and are therefore combined for unhabituated groups (see text for details).

		No. of individuals of each type counted						
Group name	Type of group	Silverback	Medium	Blackback	Adult female	Juvenile	Infant	Total
Kyagurilo	Habituated	2			5	5	2	14
Mubare	Habituated	1			4	3	3	11
Habinyanja	Habituated	1		2	8	4	5	20
Rushegura	Habituated	1			5		2	8
Nkuringo	Habituated	2		3	7	5	2	19
G7	Unhabituated	1	3		1	1	1	7
I2	Unhabituated	1	3		2	2	2	10
K1	Unhabituated	2	11		3	4	3	23
L1	Unhabituated	2	12		3	5	3	25
M6	Unhabituated	2	5		1	3	1	12
M7	Unhabituated	2	8			4		14
M5	Unhabituated	2	2		1		1	6
Q4	Unhabituated		1		1		1	3
Q5	Unhabituated	1	4		1		1	7
CC8	Unhabituated	3	5			4		12
CC9	Unhabituated	2	2		1	1	1	7
DD1	Unhabituated	1	1		4		4	10
W1	Unhabituated	1	2		2	3	2	10
W2–4	Unhabituated	1	6		1	1	1	10
O2	Unhabituated	1	1		1	1	1	5
O4	Unhabituated	2	1		4	1	4	12
R2	Unhabituated	1	1		5	2	5	14
CC1	Unhabituated	1	3					4
DD2	Unhabituated	1	3			1		5
G1	Unhabituated	3	3		1	1	1	9
V4	Unhabituated	2	4					6
Y1	Unhabituated	1	2		1		1	5
D1	Lone male	1						1
O1	Lone male	1						1
M2	Lone male	1						1
W2–3A	Lone male	1						1
V2	Lone male	1						1
AA1	Lone male	1						1
CC7	Lone male	1						1
CC4	Lone male	1						1
GG1	Lone male	1						1
DD3	Lone male	1						1
Total		50	83	5	62	51	47	298

disturbance and both the number of gorillas and the number of gorilla groups found in each sector (Spearman Rank Correlation $r_s = 0.315$, n = 39, P <0.05, and $r_s = 0.391$, P <0.01 respectively). However, the northern sector of Bwindi is only connected to the rest of the Park by a narrow neck of forest, and gorillas have not been found in this area within living memory. When this sector is excluded, the negative correlations between human disturbance and gorillas are no longer significant ($r_s = 0.174$, n = 34, P >0.05 for gorillas, and $r_s = 0.282$, P >0.05 for groups respectively).

As in 1997, gorillas were found more frequently in the interior of the Park than in exterior sectors. Significantly fewer individuals and groups were found in those sectors that bordered on the edge of the Park (Mann Whitney $U = 94$, P = 0.012, and $U = 105.5$, P = 0.029 respectively). However, when the northern sector was excluded from this analysis, only the comparison of the number of individual gorillas between interior and exterior sectors was significant ($U = 84$, P = 0.044), while there was no significant difference in the number of groups ($U = 95.5$, P = 0.10). Signs of human disturbance, on the other hand, are more frequent in the exterior sections ($U = 263.5$, P = 0.01 including the northern sector, and $U = 194.5$, P = 0.056 with the northern sector excluded), which also supports the

Table 2 Population parameter comparisons between 1997 and 2002 gorilla censuses.

Population parameter	1997	2002
No. of groups	28	27
No. of solitary males	7	10
No. of nest-builders in groups	224	241
No. of infants found in groups	49	47
Total population count (including missed infant correction)	292	315
Estimated population size	300	320
Mean group size	10.2	11.3
Range of group size	2–23	3–25
Median group size	10	10
Proportion of immature individuals in population	37%	36%
Proportion of multimale groups	46%	44%

conclusion that gorillas tend to be found in areas of lower human disturbance.

Discussion

This census estimated a total population size of 320 mountain gorillas in Bwindi Impenetrable National Park, which is a small increase (*c*. 7%) over the previous estimate in 1997. Although this is good news, the small size of the increase means that we would want to find further increases over time to confirm that there really is a consistent upward trend rather than simply a short-term fluctuation in the population. However, it is reassuring to know that there is no major decline. Based on demographic data from the Virungas, under optimal conditions, gorilla populations are capable of a 3–4% annual growth rate (Miller *et al.*, 1998; Steklis & Gerald-Steklis, 2001; Robbins & Robbins, 2004) but that seen in Bwindi appears to be lower, suggesting that certain factors are limiting the Bwindi population. Our estimate of the growth rate over these 5 years may also be affected by demographic stochasticity and/or errors in the census methods. For example, a baby boom in a species that has 4 year inter-birth intervals would result in high variability in birth rates, and hence growth rates, over a short time period such as the interval between the 1997 and 2002 censuses. In comparison, the Virunga population experienced maximum growth rates of *c*. 3% during the 1980s, but at other times growth rates have been close to that currently seen in Bwindi (Kalpers *et al.*, 2003), or in some cases even negative. We still do not have data on the inter-birth intervals, birth rates, nor mortality rates of Bwindi gorillas to predict what the growth rate of the population could be. Obtaining such information requires decades of monitoring known individuals (Miller *et al.*, 1998; Steklis & Gerald-Steklis, 2001; Robbins & Robbins, 2004).

Possible factors that could constrain population growth include the availability of good gorilla habitat, disease and human disturbance. Little is known as yet about the quality of the vegetation in Bwindi for gorilla foraging, although on-going research is mapping the vegetation and investigating the gorillas' ecology and habitat requirements, and will provide us with a better understanding of the number of gorillas Bwindi could support. The densities of gorillas in suitable habitat in Bwindi and the Virungas are similar at present (Robbins *et al.*, 2006), but there are considerable differences in the species' ecology between the two sites. The diet of Bwindi mountain gorillas is remarkably different from that in the Virungas and the diet of gorillas ranging at different altitudes within both Bwindi and the Virungas is noticeably different (McNeilage, 2001; Ganas *et al.*, 2004; Nkurunungi, 2004). This is primarily because of differences in habitat types within and between the two forests (McNeilage, 2001; Ganas *et al.*, 2004; Nkurunungi *et al.*, 2004). The ranging patterns of Bwindi gorillas are also different from those in the Virunga Volcanoes, with the daily travel distance and annual home range size being greater in Bwindi (Robbins & McNeilage, 2003; Ganas & Robbins, 2005; Robbins *et al.*, 2006). These studies of the diet and ranging of Bwindi gorillas suggest that their habitat requirements cannot be extrapolated from what has been observed in the Virunga Volcanoes.

Little is also known about the potential impact of diseases on the population. Disease transmission resulting from close contact between people and habituated gorilla groups, as well as gorillas coming into contact with human settlements around the Park, is considered a potentially serious threat to the population (Wallis & Lee, 1999; Woodford *et al.*, 2002; Sandbrook & Semple, 2006). An outbreak of scabies did occur since the last census in 1997 in the Nkuringo sector of the population, where gorillas regularly range around the edge of the Park and come into contact with the surrounding human population. However, there is no evidence that this caused widespread mortality in the gorilla population. In Bwindi the proportion of the population that is habituated to the presence of people is considerably lower than that in the Virungas. In the Virungas 50% of groups and 70% of individuals in groups are monitored each day (Gray *et al.*, 2005), whereas the figures for Bwindi are 15% of groups and 23% of individuals. While habituated groups appear to reproduce normally, the risk of disease transmission remains, and there is evidence of the effects of tourist presence on gorilla behaviour (Muyambi & McNeilage, unpubl. data).

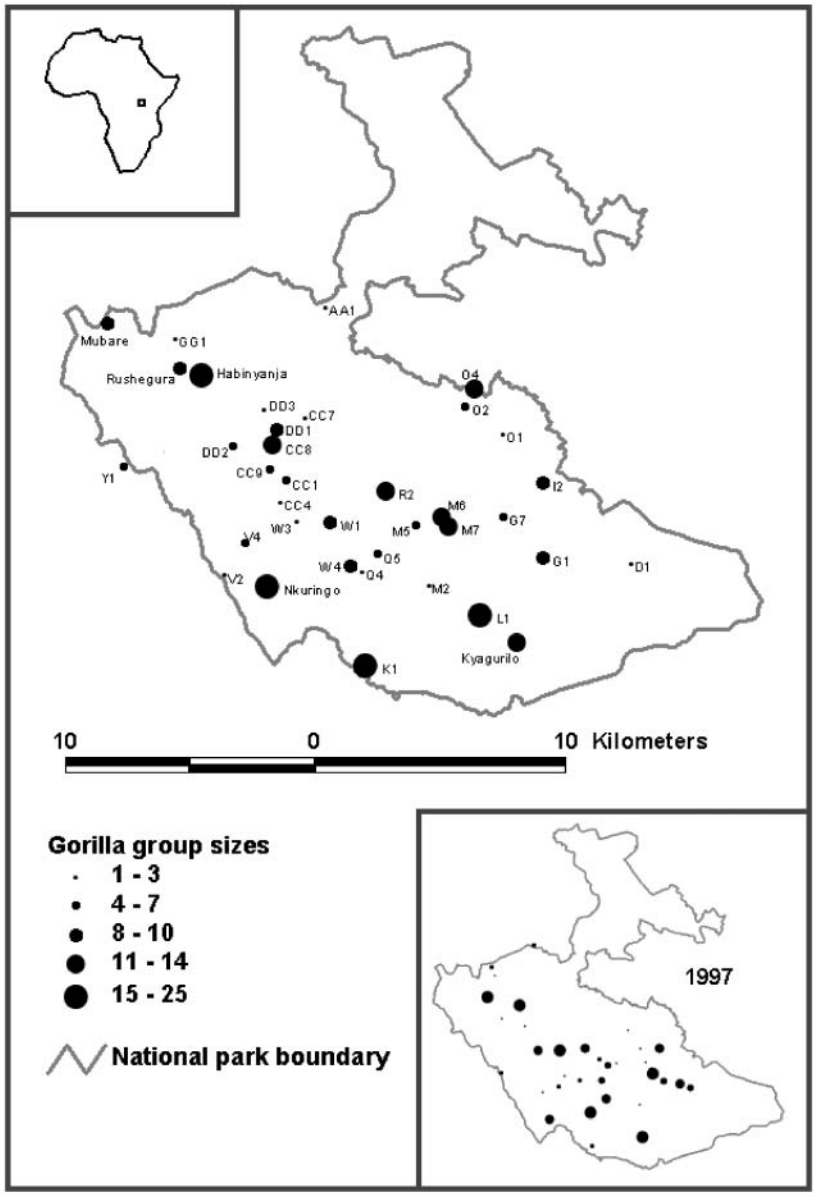

Fig. 1 Bwindi Impenetrable National Park (see inset of Africa for location) with the location and relative size of gorilla groups (see Table 1) found during the 2002 census. The location and size of groups from the 1997 census is shown in the inset for comparison.

Different forms of human disturbance still occur in Bwindi and levels in 2002 were considerably higher than in 1997. Both censuses also found some evidence that gorillas are more likely to be found in areas of relatively low disturbance, suggesting that such disturbance could be having a negative impact on the population. However, human disturbance is currently low in Bwindi, and lower than levels before the forest was gazetted as a National Park (Baker, 2004) and than many other forests in the area (Plumptre, 2002; Gray *et al.*, 2005). Although it is clear that mountain gorillas can survive, and even increase in numbers, in areas of high human disturbance (Kalpers *et al.*, 2003), the impact of such disturbance on both birth and mortality rates is not well understood. As in previous years few gorilla groups were found in the eastern part of the southern sector. This area is traversed by a road, and is subject to some of the highest levels of human disturbance in the Park (Olupot, 2004). Consideration should be given to relocating this road around the outside of the Park and to strengthening law enforcement in this area.

In conclusion, the indication that there has been a small increase in the Bwindi gorilla population since 1997 is undoubtedly positive news. Reviews of the effectiveness of conservation in this area have shown that intensive community conservation and integrated conservation and development initiatives around Bwindi over the last 15 years have had a significant impact on local community attitudes and support for

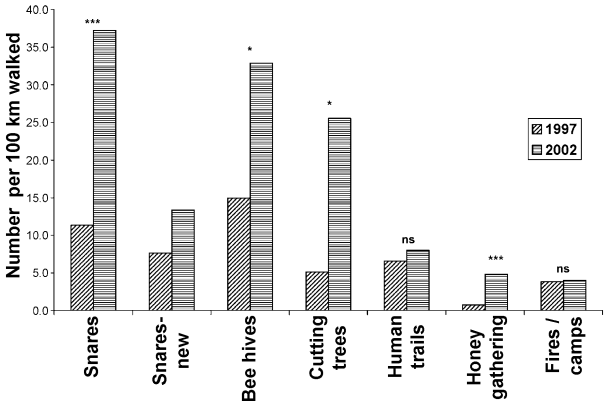

Fig. 2 A comparison of encounter rates of different types of human disturbance during the censuses of 1997 and 2002. Statistical comparisons are based on Wilcoxon matched pairs tests by sector (n = 39; *** $P < 0.001$, * $P < 0.05$).

conservation (Baker, 2004; A. Namara *et al.*, unpubl. data). However, these reviews found little evidence of the effectiveness of such programmes at directly reducing human disturbance within the Park. The increased levels of human disturbance found during this census are clearly a cause for concern. While more detailed analysis of the impact of human disturbance on gorillas, as well as the capacity of the available habitat within Bwindi to support increased numbers of gorillas, is needed before we can firmly conclude that disturbance is a serious constraint on population growth, these findings highlight the need for increased law enforcement effort as well as further developing ways of working with local communities to discourage illegal use of forest resources.

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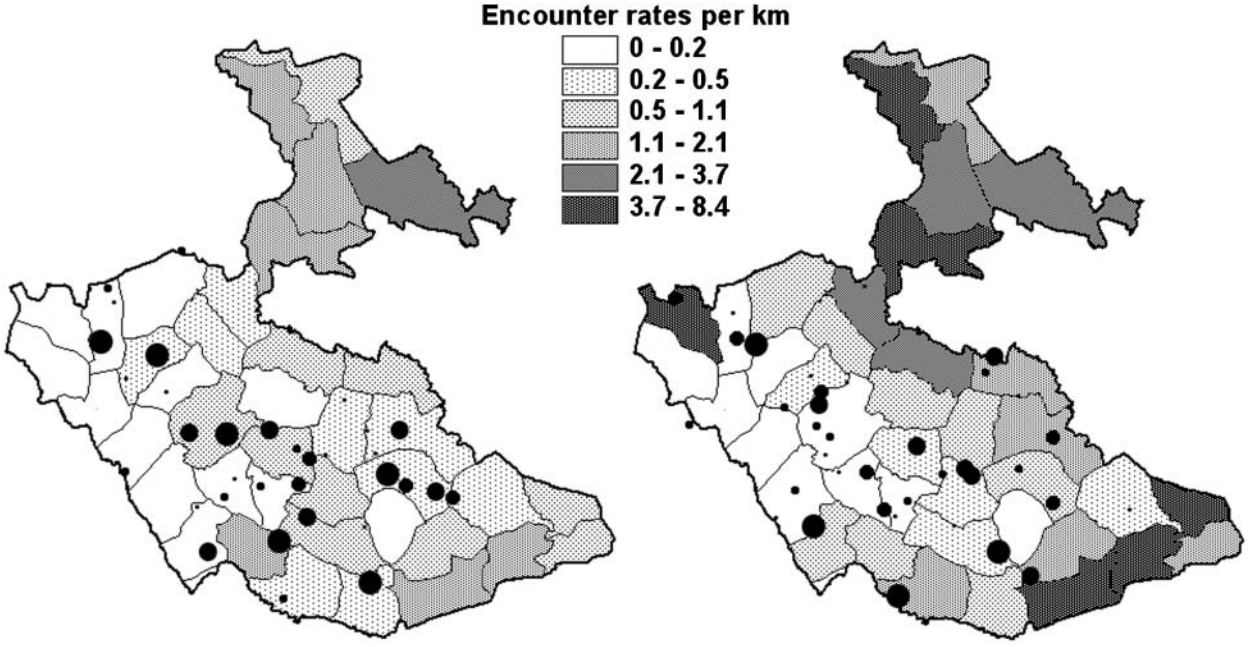

Fig. 3 The distribution of signs of human disturbance across Bwindi in 1997 and 2002 (see Fig. 1 for location). The shading by sector represents the relative encounter rates in each sector during each census. The location and relative size of gorilla groups found during each census is also shown for comparative purposes (see Fig. 1).

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Biographical sketches

The authors have all worked in Bwindi for several years with different organizations collaborating in gorilla conservation, and coordinated and lead census teams during this study. Alastair McNeilage studied gorilla ecology in the Virungas and the Central Africa Republic, and is now the director of the Institute of Tropical Forest Conservation (ITFC) developing applied research and conservation programmes in Uganda. Martha Robbins has been studying the behavioural ecology, reproductive strategies, population biology and social systems of mountain gorillas for the past 16 years, in both the Virungas and Bwindi. Maryke Gray, Helga Rainer and Steven Asuma work with the International Gorilla Conservation Programme, supporting Park management, ranger based monitoring, tourism development and local community enterprises around Bwindi. William Olupot, Dennis Babaasa, Robert Bitariho and Aventino Kasangaki work with ITFC, studying different aspects of forest ecology. Ghad Mugiri was the Monitoring and Research Warden for Bwindi with the Uganda Wildlife Authority, and has since taken over as Warden-in-charge. Julia Baker is carrying out research on illegal activities within Bwindi under different management regimes.