Censusing the mountain gorillas in the Virunga Volcanoes: complete sweep method versus monitoring

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Abstract

The mountain gorillas (*Gorilla beringei beringei*) of the Virunga Volcanoes Range of Rwanda, Uganda, and the Democratic Republic of Congo are one of the most endangered ape populations in the world. Following a dramatic decline during the 1960s, and relative stability in the 1970s, the population steadily increased during the 1980s. Due to political instability and war, a complete census had not been conducted since 1989. Here we compare the results of a complete census using the 'sweep method' conducted in 2003 with those from a monitoring program, to estimate the size and distribution of the gorilla population. A total of 360 gorillas were counted from census measurements and known habituated groups. Based on quantitative assessments of the census accuracy, we calculated that an additional 20 gorillas were not counted, leading to an estimated population of 380 individuals, and a 1.15% annual growth rate since 1989. The Ranger Based Monitoring programme yielded similar results. The encouraging results must be viewed with caution, however, because the growth was concentrated almost entirely in one section of the Virungas. Additionally, the distribution of gorilla groups was negatively correlated with the frequency of human disturbances, which highlights the need to continue strengthening conservation efforts.

Key words: gorilla, growth rate, human disturbance, monitoring, population, social structure

Résumé

Les gorilles de montagne *Gorilla gorilla beringei* de l'aire de répartition des Volcans Virunga, au Rwanda, en Ouganda et en République Démocratique du Congo, sont une des populations de grands singes les plus menacées du monde. Après un déclin dramatique dans le courant des années 1960, et une stabilité relative dans les années 1970, la population s'est fermement reconstituée au cours des années 1980. Mais en raison de l'instabilité politique et de la guerre, il n'y avait plus eu de recensement total depuis 1989. Nous comparons ici les résultats d'un recensement complet effectué en 2003 par la méthode du balayage topologique (*sweep method*) avec ceux d'un programme de suivi, afin d'estimer la taille et la distribution de la population de gorilles. Nous avons dénombré un total de 360 gorilles en reprenant les chiffres du recensement et ceux des groupes habitués connus. En nous basant sur l'évaluation quantitative de la précision du recensement, nous avons calculé que 20 gorilles supplémentaires n'avaient pas été comptés, ce qui porte l'estimation à 380 individus et signifie un taux de croissance annuel de 1,15% depuis 1989. Le Programme de Suivi basé sur les gardes a obtenu des résultats comparables. Pourtant, ces résultats encourageants doivent être interprétés avec prudence étant donné que la croissance s'est presque entièrement concentrée sur une seule section des Virunga. De plus, la distribution des groupes de gorilles était négativement liée à la fréquence des perturbations humaines, ce qui souligne la nécessité de poursuivre le renforcement des mesures de conservation.

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Introduction

The mountain gorillas (*Gorilla beringei beringei)* of the Virunga Volcanoes Range (VVR) are one of the most endangered ape populations in the world (IUCN, 2000; Caldecott & Miles, 2005). It is essential to monitor this small, isolated population to detect changes that could influence its long-term survival. Without such monitoring, it is impossible to assess the effectiveness of current conservation strategies and to plan for future interventions. While it is difficult to precisely define what constitutes a viable population, both external environmental variables (threats) and population size and structure need to be taken into account when assessing the long-term viability of a population (Steklis & Gerald-Steklis, 2001).

The Virunga mountain gorilla population has been the subject of much research and several censuses since the late 1960s, but the region has also been affected by political instability and war since 1991. The full impact of the war, political instability and recent poaching events was unknown, as due to insecurity in this region, a complete census had not been conducted since 1989 (Sholley, 1991). Thus there was an urgent need to confirm the current status of the gorilla population by carrying out a systematic census of the VVR. The results of the 1989 census confirmed that following a dramatic decline during the 1960s, and a period of relative stability in the 1970s, the Virunga population had been steadily increasing in size during the 1980s. In 2000, the population size was estimated from data on habituated groups and those found during ranger patrols (Kalpers *et al.*, 2003). Results suggested that this growth had continued during the 1990s, although at a reduced rate. The major threats to this population include habitat loss, poaching, and the risk of disease transmission from humans to gorillas (Plumptre & Williamson, 2001). At least 5% of the population was known to have died from poaching during the 1990s and early 2000s (Kalpers *et al.*, 2003), stressing the need to have an accurate estimate of the entire population.

The aims of the census were to establish the impacts of conflict and conservation activities over a 14-year period, and to inform and direct future conservation strategies. Specifically, the objectives were to assess changes in the total population, as well as the population structure and growth rate, and to examine the distribution of the population in relation to its past distribution and patterns of human influence. A census such as this is an expensive and time-consuming exercise, and data on the population can also be obtained from monitoring of habituated groups and from Ranger Based Monitoring (RBM; Gray & Kalpers, 2005). A further objective of this study was to assess the ability of these data sources to provide reliable information on the population without having to carry out a complete census.

Materials and methods

Study area

The Virunga Volcanoes Range is an afro-montane forest of high biodiversity importance within the Albertine Rift that spans the borders of the eastern Democratic Republic of Congo (DRC), northwestern Rwanda and southwestern Uganda. The VVR covers an area of approximately 450 km^2 and ranges in altitude between 1850 and 4507 m above sea level. The area is comprised of three contiguous national parks; the Mikeno sector of Virunga National Park (DRC), Volcanoes National Park (Rwanda) and Mgahinga Gorilla National Park (Uganda) (Fig. 1).

Gorilla census methods

The sweep method employed to census the mountain gorilla population was based on that previously used in the VVR and Bwindi Impenetrable National Park, Uganda (Sholley, 1991; Mcneilage *et al.*, 2001). The VVR was divided into 22 sectors ranging in area from 10.45 to 34 km^2. The bare open and rocky areas on the summits of Mikeno and Karisimbi (above approximately 3600 m altitude), representing an area of 14.3 km^2, were not surveyed since gorillas are not known to use them. An area of approximately 5 km^2 near the Jomba outpost in DRC could not be surveyed because of insecurity at the time of the census, but information from park rangers was available on habituated groups in that area.

Six teams traversed the park systematically from west to east, proceeding such 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. Each sector was searched by walking an irregular network of reconnaissance routes, which were largely determined by the terrain and the availability of existing paths. Adjacent routes were never greater than 500–700 m apart, so the area in between was not large enough for a gorilla group to remain for more than one week. GPS readings were taken every 250 m along the routes.

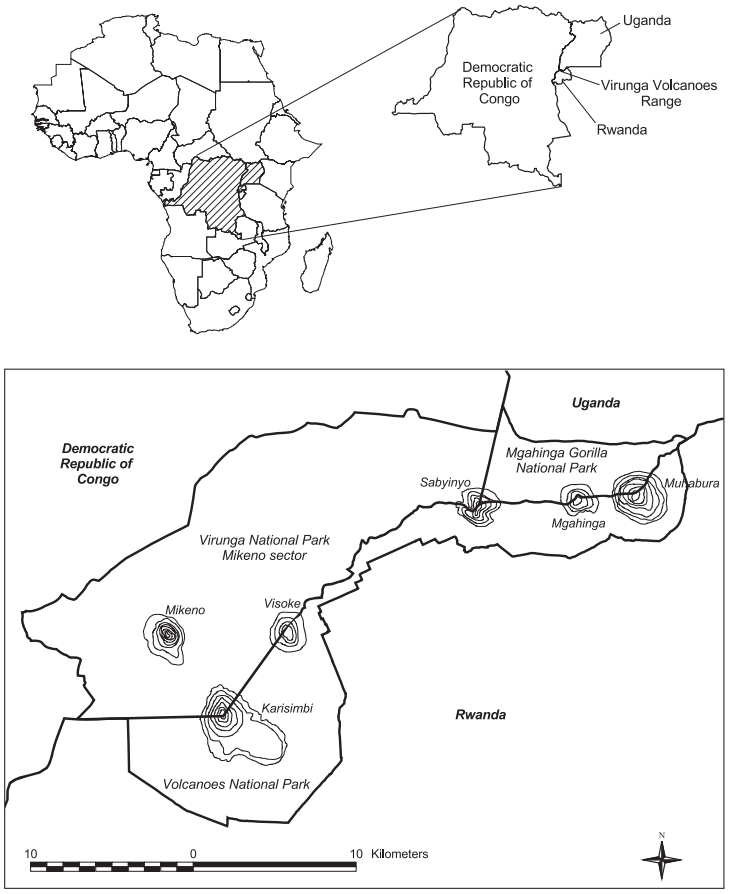

Fig 1 Location map of Virunga Volcanoes Range

Whenever recent gorilla trail (<5–7 days old) was found, it was followed until night nest sites were located. At each nest site, nests were counted and dung size measurements, along with the presence of silver hairs, were used to establish the age-sex composition of the group as: silverbacks, 'mediums', adult females, juveniles, and infants. Young individuals constructing their own nest were always considered as the combined category juveniles/subadults, and assigned to the dung size class 'juvenile'. Smaller dung found within the nest of an older individual was recorded as that of an infant. In the absence of infant dung, adult female nests could not be distinguished from those of a comparable sized (blackback) male, and were therefore classified as 'MEDIUM'.

Teams aimed to find at least three nest sites for each group to confirm its composition, because individual nests or dung could be missed at one nest site. By mapping and dating all gorilla trails and nest sites, it was possible to minimize the possibility that groups were missed, that none was counted twice, and to distinguish similar sized gorilla groups found close to each other.

Surveys of human disturbance

The reconnaissance routes walked while searching for fresh gorilla trail also provided an opportunity to collect data on signs of human disturbance. Such signs included antelope, buffalo and hyrax snares, pitfall traps, human paths and tracks, poachers' camps, dogs, actual sightings of poachers, cutting of building poles, firewood and bamboo, bee hives, signs of gathering wild honey, grazing, water collection and any other sign of people using the forest illegally. The location and age of the signs were also recorded ('recent' being less than 3 months, 'old' being greater than 3 months). The frequency of human disturbance was calculated as encounters per kilometre of reconnaissance trail walked (811 km in total).

Other data for population estimates

Results from the census were compared with two other sources of information: habituated groups and/or a ranger based monitoring (RBM) programme. On a daily basis, rangers track and monitor thirteen gorilla groups habituated for tourism and in PNV Karisoke Research Centre staff track and monitor an additional three groups habituated for research. Each animal is individually identified in the habituated groups so that precise compositions are known. Their actual compositions were used in calculating the total population estimate, and for assessing the accuracy of the census methods.

The RBM programme also provides two methods for counting unhabituated gorillas: (i) regular observations of groups and lone silverbacks that have adjacent or overlapping home ranges with the habituated groups are made during daily gorilla monitoring. Rangers have made repeated nest counts and therefore have a good knowledge of the location, and size of these groups; and (ii) in areas without habituated gorilla groups, ranger patrols regularly find signs of unhabituated gorilla groups, and they record the location and estimate the size of the group using nest counts. The main limitation to these two methods is that rangers do not take dung measurements nor note the presence of silver hair in nests, so an estimate of the number of infants and the age/sex composition of the groups is not made. To limit the possibility of double counting any unhabituated group, we only considered the groups that had repeated observations, or that were recorded at least 5 km apart from each other during the same patrol.

Calculation of population size

To estimate the total population size, previous censuses have applied a correction factor of 5% to the number of gorillas estimated from nest counts and known groups, to allow for the fact that the dung of small infants (less than approximately 1 year old) is not usually found in nest counts, and for the possibility that some groups might be missed during the census (Sholley, 1991; Mcneilage *et al.*, 2001). In this census, we were able to calculate more precise correction factors for these two sources of error, because a large portion of the population is in habituated groups, for which the group composition is known exactly. These groups were also counted and their composition estimated, using the same sweep census techniques as for unhabituated groups. To calculate these correction factors, we used the proportion of infants in known groups that were not recorded during the nest counts of the same groups in the census, along with the proportion of known groups that were not found at all, to calculate these correction factors. We also compared the unhabituated groups found by the census with those known through the RBM.

Spearman's correlations were used to investigate the relationship between the distribution of gorillas and sign of human activities by sector. Densities of both groups and individuals were used in the analysis, as human disturbance might have an impact on both the number of groups and the group sizes in a particular area. The home range of some gorilla groups may overlap with more than one census sector, however similar correlations were obtained when values for each sector were replaced by the average of that sector plus all directly adjoining sectors (not shown).

Results

Population estimate from census data

At the time of the census, research and tourist programmes were monitoring sixteen habituated groups containing 269 individuals, plus four habituated lone silverbacks (Table 1). Additionally, the census found twelve unhabituated groups containing 80 individuals, and seven unhabituated lone silverbacks. Thus, a total of 360 gorillas were counted from census measurements and/or known habituated groups.

Two of the sixteen habituated groups were not found during the census. Since the census methods missed 12.5% of habituated groups, we assumed that it also missed the same proportion of unhabituated groups (1.7 groups). We estimated that those missed unhabituated groups would have contained fifteen gorillas in total, because the median group size was nine gorillas. We used the median group size rather than mean, because the distribution of group size is skewed by a small number of very large groups (Table 1). This estimate of missed gorillas also matches those in groups found by the RBM but not in the census (see below).

The census counted 172 nest-builders in the habituated groups that it found, which equals 95% of the actual count (181) in those groups (Table 2). However, as expected, accuracy was much lower for infants, because dung is

Table 1 Population of the Virunga mountain gorillas in 2003. Data were taken from habituated groups (HAB) when available, from the census (CEN), and/or from the Ranger Based Monitoring programme (RBM)

Name	HAB	CEN	RBM	SB	MED	BB	ADF	JUV	INF	UNK	Total
Amahoro-A	Y	Y	Y	1		1	5	4	2		13
Amahoro-B	Y	Y	Y	1			2	1	1		5
Beetsme	Y	Y	Y	5		3	8	5	4		25
Groupe 13	Y	Y	Y	1			5	2	1		9
Humba	Y	Y	Y	1			4	4	3		12
Kabirizi	Y	Y	Y	1			14	5	14		34
Kwitonda	Y	Y	Y	1			4	6	3		14
Lulengo	Y	Y	Y	2		1					3
Mapuwa	Y	Y	Y	1			6		3		10
Munyaga	Y	Y	Y	1		4		1			6
Nyakagezi	Y	Y	Y	2			3	5	1		11
Pablo	Y	Y	Y	4		5	17	14	12		52
Rugendo	Y	N	Y	1			2	3			6
Sabyinyo	Y	Y	Y	2			3	3	1		9
Shinda	Y	N	Y	8		2	7	4	4		25
Susa	Y	Y	Y	3		4	10	9	9		35
A3	N	Y	Y	1	6			2		2	11
A4	N	Y	N	1	4			2	1	1	9
A6	N	Y	N	1	4			1	3		9
KCB1	N	Y	Y	2	2			3			7
KCB2	N	Y	Y	2	3			1	1		7
KCB3	N	Y	Y	1	5			2			8
KCB4	N	Y	Y	1	2			2	1		6
KCV1	N	Y	N	1	3			2	1		7
NCU2	N	Y	Y	1	2						3
RRB1	N	Y	Y		3			2	1		6
TCJ2	N	Y	Y	1	2						3
U1CZ	N	Y	Y	2	2						4
Mik01	N	N	Y								3
PNV04	N	N	Y								5
PNV07	N	N	Y								5
PNV09	N	N	Y								2
Buhanga	Y	Y	Y	1							1
Karateka	Y	Y	Y	1							1
Pili Pili	Y	Y	Y	1							1
Ruzirabwoba	Y	Y	Y	1							1
A1	N	Y	N	1							1
A5	N	Y	Y	1							1
H1	N	Y	Y	1							1
NCU3	N	Y	Y	1							1
TCJ1	N	Y	Y	1							1
VCB1	N	Y	Y	1							1
OCJ	N	Y	Y		1						1
PNV10	N	N	Y	1							1

SB = silverback, dung >7.2 cm diameter and silver hairs present, MED = adult female (AF) or blackback (BB), dung 5.5–7.2 cm diameter, JUV = juveniles, dung >5.5 cm diameter, INF = infant, UNK = unknown due to crushed faeces in nest.

typically not detected for infants less than 1 year of age in their mother's nest. Only 36 of 57 infants were found in the nest counts of habituated groups. Since the census methods missed 37% of infants in habituated groups, we

Table 2 Comparison of census measurements with known compositions of habituated groups. Nests of Shinda's group and Rugendo's group were not counted during the census, and are therefore not included here

	Group size		Nest builders		Silverbacks		Mediums		Juveniles		Infants	
Group	Census	Known	Census	Known	Census	Known	Census	Known	Census	Known	Census	Known
AmahoroA	10	13	9	11	1	1	4	7	4	3	1	2
AmahoroB	4	5	4	4	1	1	2	2	1	1	0	1
Beetsme	24	25	20	21	2	5	13	11	5	5	4	4
Groupe13	8	9	7	7	1	1	3	4	3	2	1	2
Humba	12	12	9	9	1	1	7	6	1	2	3	3
Kabirizi	30	34	24	20	1	1	13	14	10	5	6	14
Kwitonda	15	14	14	11	1	1	5	6	8	4	1	3
Lulengo	2	3	2	3	0	2	2	1	0	0	0	0
Mapuwa	7	10	6	7	1	1	5	6	0	0	1	3
Munyaga	6	6	6	6	3	1	3	4	0	1	0	0
Nyakagezi	9	11	8	10	1	2	4	5	3	3	1	1
Pablo	45	52	32	38	3	4	22	22	7	12	13	14
Sabyinyo	8	9	7	8	2	2	5	4	0	2	1	1
Susa	28	35	24	26	4	3	12	19	8	4	4	9
Total	208	238	172	181	22	26	100	111	50	44	36	57

assumed that it also missed the same proportion of infants in unhabituated groups. Eight infants were found in the nest counts of unhabituated groups, so we estimated that five additional infants were missed in those groups. We made no attempt to correct for missed lone silverbacks, as the number of these that are monitored each day is too small to allow the probability of missing a lone silverback to be estimated.

After accounting for 20 unhabituated gorillas that may have been missed (five missed infants, plus fifteen gorillas in missed groups), we estimated a total population size of 380 gorillas. Our estimate is 5.6% greater than the actual count of 360, so our overall correction factor is very similar to the 5% value used in previous censuses.

Population estimate from ranger based monitoring programme

The RBM programme recorded thirteen unhabituated groups containing 73 gorillas, plus seven lone silverbacks (Table 1). Thus the RBM programme reported a total of 80 unhabituated gorillas, which is comparable to the 87 individuals recorded by the census, and gives a total of 353 gorillas. The number of observations per group ranged from two to nine, and their sizes ranged from two to fifteen nesting individuals. Although nine of the unhabituated groups found by RBM could be identified among those found during the census, RBM recorded four small groups (a total of fifteen individuals) that were not found by the census. One of these was high on the slopes of Mount Mikeno (three nests, group Mik01), two others on the southern side of Mount Karisimbi (two nests, group PNV09; and five nests, group PNV07); and one group on the slopes of Mount Sabyinyo (five nests, group PNV04). Conversely, the census teams located three unhabituated groups that not recorded by RBM. Two of these groups were located in areas where there were few patrols during 2003 (groups A4 and A6). A third group was identified by census team members in an area of high gorilla group density (group KCV1). Since both methods missed some groups, it remains possible that other groups were missed by both methods, and our total population estimate of 380 individuals could still be regarded as conservative.

Growth rate

The estimated population size of 380 gorillas represents a 17% increase in the population size from 1989 to 2003, or a 1.15% annual growth rate. This growth rate is lower than the 3.1% annual growth rate observed during the 1980s and the 3.8% projected annual growth rate forecasted by a population viability analysis (Miller *et al.*, 1998). Between 24 and 29 gorilla deaths caused by insecurity and/or poaching are known to have occurred between 1989 and 2003 (Fig. 2). We can predict that if

these unnatural deaths had not occurred there would be a total of 33 additional gorillas (based on 3.8% growth rate) in the population in 2003 for a total population size of 413. However, a population of 413 in 2003 would have resulted in only a 1.75% annual growth rate since 1989, and these unnatural deaths explain only a small proportion of the discrepancy between the projected and actual population size from 1989 to 2003 (380 versus 546 gorillas), suggesting that additional factors led to the reduced population growth rate.

The percentage of the population that was immature is 41%, which is at roughly the 40% threshold that has traditionally been considered 'healthy' for population growth (Table 3). For habituated groups, 123 of 269 gorillas (45.7%) were immature. For unhabituated groups, 25 of 80 gorillas (31.1%) were immature, or with adding the correction factor of five missed infants, 30 of 85 (35.3%) were immature. The values for unhabituated groups did not differ significantly from habituated groups (e.g. with added infants: chi-square = 2.864, df = 1, $P = 0.091$).

Social structure

The gorillas were found in 32 social groups in 2003 (Tables 1 and 3). Between 28 and 32 social groups have been found over the past three decades, while the overall population size has increased. In 2003, the median and mean group sizes were 7.5 and 11.4 individuals, respectively. The median group size has remained roughly the same over the past three decades, while the mean and standard deviation have increased steadily, which reflects the greater proportion of the social groups that contain over 20 individuals. Habituated groups are significantly larger than unhabituated groups (16.8 versus 5.9 mean group size, Mann–Whitney *U*-test, $U = 211.0$, $P = 0.002$; 11.5 versus 6.0 median group size). The proportion of multimale groups (36%) remained within the range that has been observed in the past censuses. The number of lone silverbacks has varied greatly between censuses, but because of the difficulty of locating those males, it is not possible to determine if those variations are due to sampling effort or a true reflection of change in the population.

Gorilla distribution across the Virunga Volcanoes Range

As in previous censuses, the majority of groups were found in the central part of the VVR, around Mount Visoke and in the saddle area between Visoke and Sabyinyo, with fewer groups in the southern and eastern parts (Fig. 3). In contrast to previous censuses, however, no groups were found on Mount Mikeno. The most dramatic population growth has occurred among the three research groups and one tourist group (Susa) in the southeastern corner of the Virungas. These four groups contained 80 gorillas in 1989 and 137 in 2003, which represents a 3.9% annual growth rate. No gorillas have immigrated into this subpopulation since 1989, and only thirteen individuals have emigrated.

In contrast, essentially no growth has occurred in the eastern sector, which extends from the saddle area to the west of Mt. Sabyinyo to the eastern border of the VVR. It is an area of concern because of its small size, long and narrow shape, large amount of park boundary, and isolation from the main body of the VVR. However, it is somewhat problematic to monitor its population changes because several groups move in and out. In 2003, a total of 58 gorillas including eight social units and three solitary males were found in this region, which is essentially the same as the 57 gorillas in 2000, 57 in 1989, and 60 gorillas in the 1978–1979 census (Weber & Vedder, 1983; Sholley, 1991).

A fluctuating population has been observed among the seven groups habituated for tourism in the Democratic Republic of Congo. The population declined from 92 gorillas in 1996 (Sikubwabo Kiyengo & Mushenzi Lusenge, 1997) to only 75 gorillas in 2000, before rebounding to 85 gorillas in the 2003. Much of the decline was caused by the killing of silverbacks by armed militia and the emigration of individuals out of these groups, whereas the more recent rebound can be attributed to births and not immigrations.

Patterns of human disturbance and gorilla distribution

Antelope snares, paths and tracks of people, and bamboo and wood cutting were the most commonly encountered signs of human disturbance found (Table 4). Signs of human disturbance were found throughout the VVR but were most concentrated in the sectors to the south of Karisimbi and Mikeno, and in the eastern part of the VVR around Mount Muhavura (Fig. 4). Bamboo cutting, honey gathering and wood cutting were more restricted to specific sectors, although again mostly towards the extreme ends of the massif. The total signs of human disturbances were negatively correlated with density of

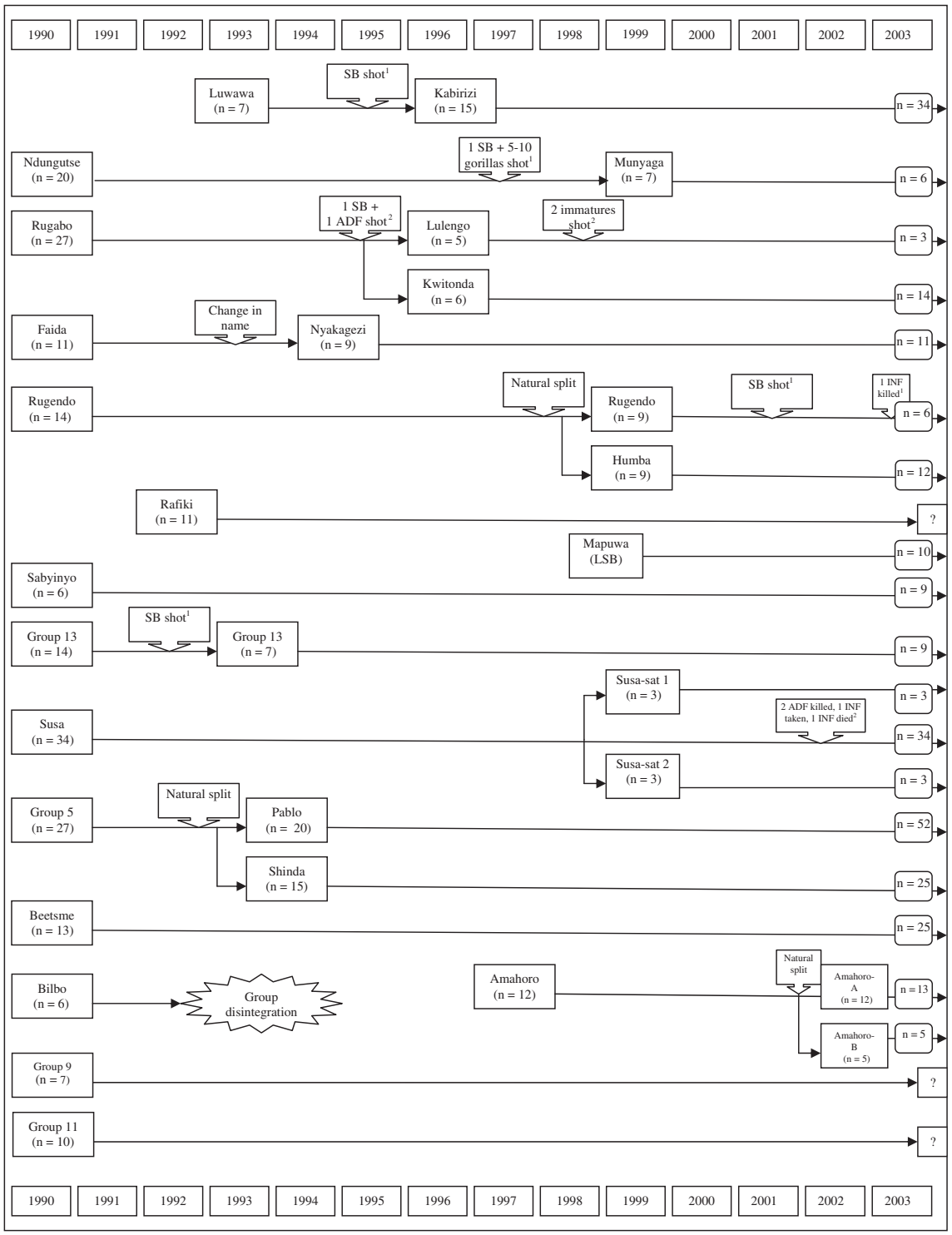

Fig 2 Time line of changes among the habituated gorilla groups in the Virunga Volcanoes Range, 1990–2003. Names are group names, usually named after the dominant silverback. Names of some groups were changed because of a change in the dominant silverback. SB, silverback; ADF, adult female; n, group size; ? fate of group unknown (lack of access due to insecurity); 1, accidental; 2, deliberate

Table 3 Population parameters for Virunga Mountain Gorilla Population from 1971–2000. See text for explanation of estimated population size

Census year	Total gorillas counted	Estimated population size	No. of social groups	Mean group size	Median group size	No. of solitary males	% Multimale groups	% Immature	% of social groups with >20 individuals
1971–73[1]	261	274	31	7.9 (na)	Na	15	42	39.8	na
1976–78[2]	252	268	28	8.8 (4.4)	7	6	39	35.8	3.5
1981[3]	242	254	28	8.5 (na)	na	5	40	39.7	na
1986[4]	279	293	29	9.2 (5.5)	8	11	14	48.1	7
1989[5]	309	324	32	9.2 (7.1)	7	6	28	45.5	9
2000[6]	359	359–395	32	10.9 (9.7)	8	10	53[a]	44.7[a]	15.6
2003[7]	360	380	32	11.4 (11.2)	7.5	11	36[b]	41.0[b]	15.6

Numbers in parentheses for mean group size is the standard deviation.
na = data not available for calculating this variable.
[a]For 2000, % multimale groups and % immature are calculated from the seventeen habituated groups only.
[b]These numbers do not include the four groups found only by RBM, for which only the number of nests was observed. (1) Harcourt & Groom (1972); Groom (1973), (2) Weber & Vedder (1983), (3) Aveling & Harcourt (1984), (4) Vedder & Aveling (1986), (5) Sholley (1991), (6) Kalpers *et al.* (2003) and (7) This study – includes both census and RBM results unless otherwise indicated.

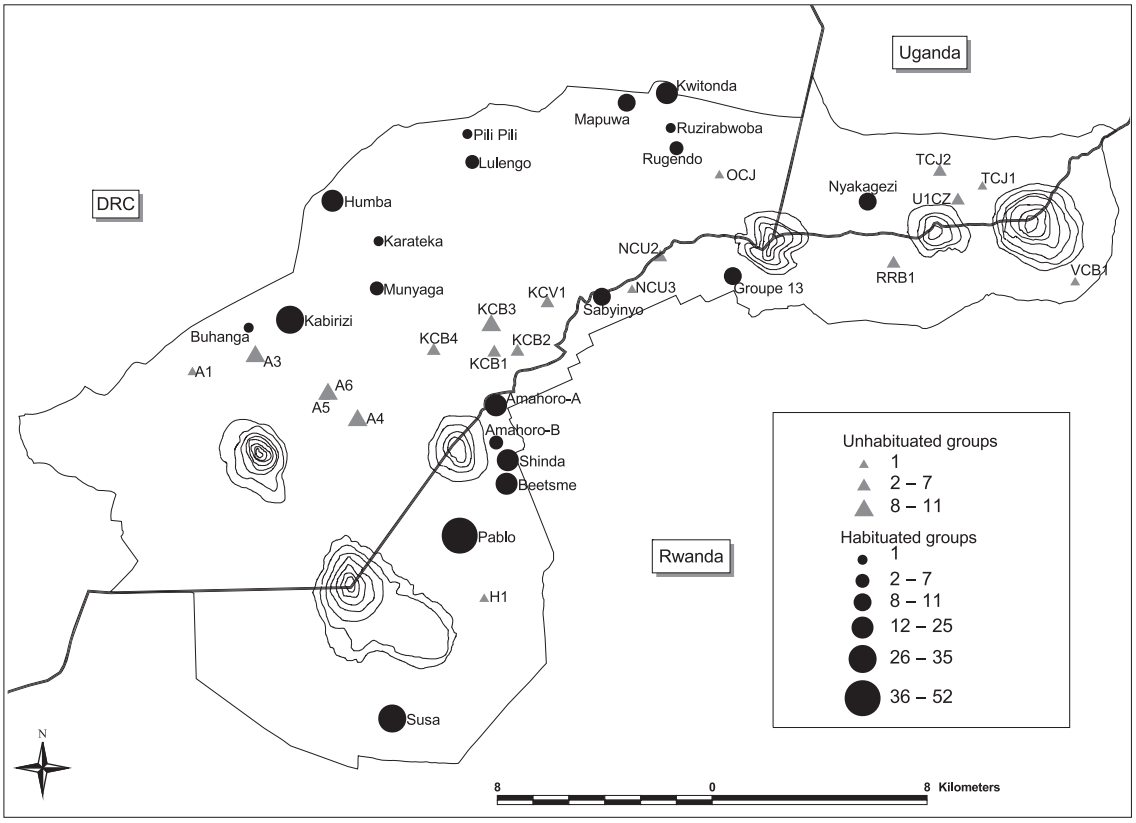

Fig 3 Distribution of gorilla groups during the 2003 census

Table 4 The total number of times different forms of human disturbance were found on reconnaissance trails during the census. For certain signs that occur in discrete units more than one individual or item may be found at a single encounter

Human sign	Total number of encounters	Encounter rate per km walked	Total number of individuals /items
Antelope snares	149	0.184	241
Human paths/tracks	118	0.145	–
Bamboo cutting	79	0.097	–
Wood cutting	39	0.048	–
Camps	20	0.025	–
Bee hives	17	0.020	35
Hyrax snares	15	0.018	24
Honey gathering	14	0.017	17
Grazing	9	0.011	–
Poachers	4	0.005	10
Water collecting	4	0.005	–
Dogs	4	0.005	5
Buffalo snares	3	0.004	7

gorillas ($r = -0.58$, n = 22, $P < 0.01$) and gorilla groups ($r = -0.51$, n = 22, $P < 0.05$).

Discussion

This first population estimate for the entire Virunga Volcanoes Range since 1989 has revealed a 17% increase to 380 mountain gorillas, despite the conflict and insecurity in the area over the past 14 years. This growth represents a remarkable conservation achievement, and is an extraordinary tribute to the perseverance and dedication of the national park authorities and their partners, and to the collaboration between the three countries in protecting and managing this transboundary ecosystem. In contrast, other populations of eastern gorillas, *Gorilla beringei graueri,* have been seriously impacted by armed conflicts throughout their habitat in eastern DRC (WCS, 2000; Yamagiwa, 2000).

Although the current results are encouraging, particular aspects show cause for concern about the conservation status of the population. First, the population has increased at only a 1.15% annual growth rate, compared with the 3–4% growth that has been predicted from computer simulations (Miller *et al.*, 1998; Steklis & Gerald-Steklis, 2001; Robbins & Robbins, 2004), and was actually observed in the 1980s. The computer simulations suggested that the higher predicted growth rate arises from low estimates of mortality rates, rather than high estimates of birth rates (Robbins & Robbins, 2004). Approximately 24–29 gorilla deaths are known to have been caused by insecurity and/or poaching in the past 14 years, but these unnatural deaths do not entirely account for the reduced growth rate since the 1980s.

Indeed, a second cause for concern is that nearly all of the growth can be attributed to the Karisoke plus Susa (K&S) subpopulation, while other subpopulations have stagnated or even decreased, and some areas contain few

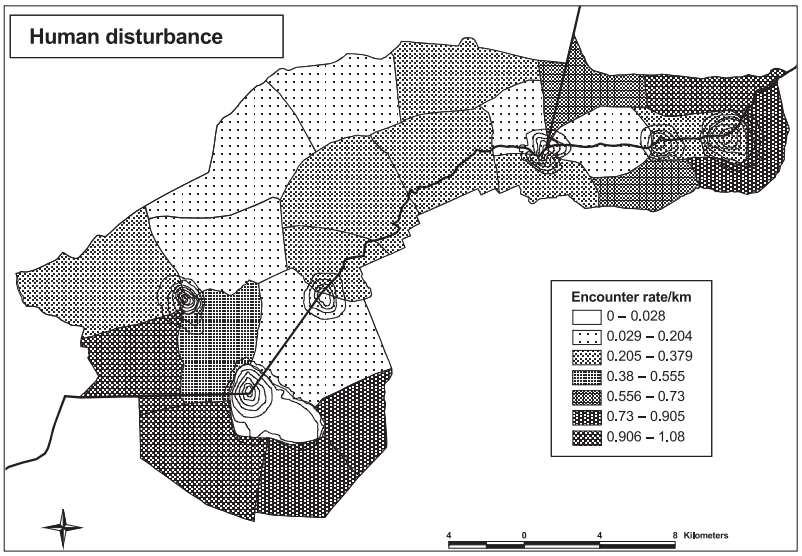

Fig 4 Distribution of human disturbances in the Virunga Volcanoes Range

or no gorillas at all. The higher growth rate in the K&S subpopulation may be attributed to better ecological conditions than other areas of the park (Mcneilage, 2001) and/or to better protection. Lower habitat quality has been cited as a reason for the fact that previous censuses have generally found few gorillas in the eastern section of the park (Weber & Vedder, 1983). However, much of the area with few or no gorilla groups, such as Mikeno and the southern side of Karisimbi, does contain good gorilla habitat (Mcneilage, 1995), and Mikeno has supported significant numbers of gorillas in the past.

During this census, gorillas were generally found in areas with lower human disturbance, as indicated by a negative correlation between gorilla density and signs of human disturbance. Such human disturbance is almost certainly having a negative impact on the population, and could be reducing the effective area of gorilla habitat available for population growth. The year 2002 also marked a resurgence of direct poaching and presumed trade of infant mountain gorillas, with three separate poaching events leading to the deaths of at least nine gorillas. The south sides of both Mount Karisimbi and Mount Mikeno have suffered from high levels of human disturbance in the past, and previous studies have attributed the low gorilla numbers in this area to human impacts (Weber & Vedder, 1983; Mcneilage, 1995). Mount Mikeno has been badly affected by insecurity and has been inaccessible to patrols for much of the last decade. Recent patrols have recorded signs of intensive human impacts, including habitat degradation from cattle grazing. Future management strategies should include research to better understand the variability of ecological conditions in other regions of the VVR (e.g. Mcneilage, 2001) as well as improved protection and monitoring for the gorillas located in these other regions.

A third potential cause for concern is the concentration of gorillas in relatively large habituated groups. The majority of the population (50% of groups; 70% of gorillas) is now habituated to human presence, and habituated groups are significantly larger than unhabituated groups. While habituated groups are able to receive nearly daily monitoring and veterinary interventions when necessary, habituation may discourage interactions with unhabituated groups, and therefore reduce the likelihood of unhabituated female immigrating into the habituated groups. At this stage we cannot say whether the large group sizes of habituated groups are a positive or negative sign for the population.

This study gave us the opportunity to compare the results using the sweep method with data from habituated groups and data being collected by the RBM programme. Both methods yielded similar estimates of the total population size. Data from habituated groups showed that at the nest sites, the census teams were recording an accurate number of nest-building gorillas, but young infants were missed as expected. The RBM did not record some groups that were located by the census, but they did record small groups (high on the volcanoes and in the ravines) that were missed by the census teams. Previous census reports have suggested that small groups are less likely to be located with the census techniques used because their trails may be difficult to locate and/or they may range in only a very small area over a few days period (Sholley, 1991). Despite some limitations of the RBM data collection, this study shows that it can routinely provide a great deal of useful information on the unhabituated groups and that it is a key tool for monitoring the gorilla population. Because such a large proportion of the groups and population are habituated and the RBM programme provides accurate information on the unhabituated groups, the question can be raised whether it is necessary to do a full census of this population once every 5 years or not. Alternatively, full censuses could be conducted only when events trigger concern that there may be a decline in the population. These two databases (monitoring of habituated groups and RBM) could be augmented with targeted 'mini-censuses' in specific sectors of the VVR that receive less patrol coverage or are less well monitored.

In summary, the census shows that it is possible for conservation efforts to succeed even under difficult conditions, while at the same time emphasizing the continued threats and challenges that this critically endangered population faces. These findings further highlight the need to strengthen conservation efforts as we look towards the future of improved protected area management, transboundary collaboration and peace building in the region, and international support to provide increased protection for this unique, highly endangered mountain gorilla population.

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