Survey of *Raphia* swamp forest, Republic of Congo, indicates high densities of Critically Endangered western lowland gorillas *Gorilla gorilla gorilla*

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Abstract The Critically Endangered western lowland gorilla *Gorilla gorilla gorilla* is found at high density in the swamp forests of Lac Télé Community Reserve, northern Republic of Congo. Preliminary surveys for apes on the Reserve periphery in the 1990s indicated that this area may also contain high densities of apes and we wished to verify this. Using distance sampling methodology we surveyed 1,029 km^2 of the south-eastern Reserve periphery including *Raphia* swamp forests. We recorded 1,021 ape nests along 21 2-km transects. Results indicated that ape density estimated from nest group density, excluding old and very old *Raphia* nests (which may decay slowly), was very high: 6.81 weaned apes km^{-2} (95% confidence interval 3.93–11.84). Gorillas built most of the nests recorded: their density was estimated at 5.25 individuals km^{-2} (2.70–10.19). Most nests were constructed in *Raphia* swamp forest despite it covering only 25% of the study area. These are among the highest recorded densities of apes in Central Africa but, as nest decay rates in swamps are unstudied, we also estimated densities based on hypothetically slow nest decay rates and published data from other habitats. Gorilla densities may be linked to availability of monocotyledons as food and the natural protection from hunting offered by *Raphia* swamps. Gorilla density in swamp forest is spatially and temporally variable and surveys are required to estimate ape populations elsewhere in this habitat. Most *Raphia* swamps in Congo are unprotected, including the periphery of Lac Télé Community Reserve; protection and management are required to assure their continued availability for apes.

Introduction

Swamp forest in the Republic of Congo is known to contain high densities of Critically Endangered western lowland gorillas *Gorilla gorilla gorilla*. Surveys by Fay et al. (1989), Fay & Agnagna (1992) and Blake et al. (1995) found high densities of gorillas in the Likouala swamps of northeast Congo, in areas that are now on the south-eastern and eastern periphery of the Lac Télé Community Reserve, which was gazetted in 2001 (Fig. 1). Additionally, swamp forest in the Sangha region of northern Congo also contains high densities of gorillas (Poulsen & Clark, 2005; Malonga et al., 2007). Surveys and monitoring of large mammals in the Reserve and on its western periphery were carried out in 2002, 2004, 2005 and 2006. The surveys confirmed previous studies that the swamp forest contained high ape densities (Poulsen & Clark, 2004; Malanda et al., 2005; Stokes et al., 2008). The importance of monocotyledonous plants in the diets of western lowland gorillas is well-known (Sabatier-Pi, 1977; Calvert, 1985; Tutin & Fernandez, 1985; Carroll, 1988; Fay et al., 1989; Blake et al., 1995; Nishihara, 1995; Rogers et al., 2004). Much of the Likouala swamp forest has a sparse canopy with a dense understorey containing many monocotyledons such as *Raphia* spp., *Aframomum angustifolium* and *Pandanus candelabrum*. Fay et al. (1989), Fay & Agnagna (1992) and Blake et al. (1995) mentioned the frequent use of *Raphia* spp. as food by gorillas. Blake et al. (1995) noted the virtual absence of gorillas in zones without *Raphia*.

Threats to the wildlife and forests of northern Congo are increasing. The imminent threats in Lac Télé Community Reserve and surrounding forests are construction of new roads, hydrocarbon prospecting on the south-west periphery, allocation of logging concessions and an increasing human population. The swamp forests of the Likouala region may be directly affected by these threats and it is imperative that baseline data on the wildlife populations of these swamps are

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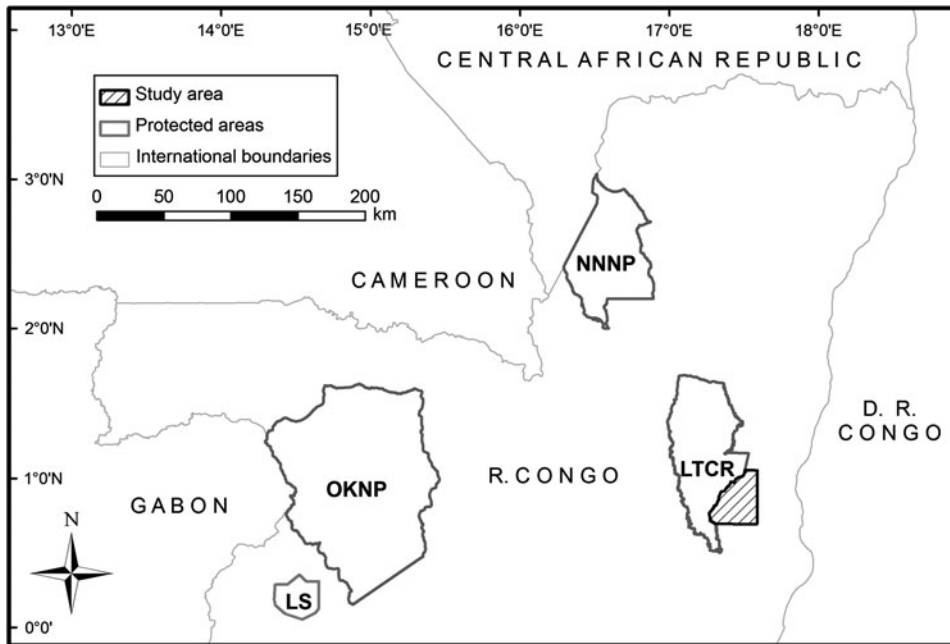
FIG. 1 Lac Télé Community Reserve (LTCR), the study area along the Batanga River, and other protected areas in northern Congo. NNNP, Nouabalé-Ndoki National Park; OKNP, Odzala-Kokoua National Park; LS, Lossi Sanctuary.

available. Given the suspected abundance of gorillas in *Raphia* swamps (Fay et al., 1989; Fay & Agnagna, 1992; Blake et al., 1995), the recent upgrading of the threat status of the western lowland gorilla to Critically Endangered (IUCN, 2008), and that previous surveys of gorillas in the *Raphia* swamps of Congo were carried out before distance sampling methodology (Buckland et al., 2001) had become widely used for large mammal surveys in this region, we focused our survey efforts on the *Raphia* swamp forest south-east of Lac Télé Community Reserve (Fig. 1) to assess its importance for conservation of apes. This site is relatively accessible and is part of a larger potential *Raphia* zone (Appendix).

Study area

The Likouala swamps of northern Congo are part of the largest wetland in Africa, covering 62,500 km² and straddling the Oubangui and Congo rivers, the border between the Republic of Congo and the Democratic Republic of Congo (DRC). Lac Télé Community Reserve is the sole protected area in swamp forest in the Republic of Congo. Conservation activities in the Reserve are managed in partnership between the Ministère de l'Economie Forestière and the Wildlife Conservation Society. Management planning focuses on the development of participative community management within traditional territories and the control of illegal hunting of protected species, including gorillas. Ninety percent of the Reserve comprises swamp forest (and a small area of savannah) that is flooded seasonally or permanently (see Poulsen & Clark, 2004, for a more complete description of the Reserve). Swamp and seasonally flooded forest are dominated by dicotyledonous

tree species, whereas the *Raphia* swamp forest of this study is almost entirely composed of *Raphia* spp. and some other herbaceous monocotyledons. The periphery of the Reserve is composed of similar habitat to that within its limits except for the terra firma mixed forest in managed logging concessions to the north-west and three zones of *Raphia* swamp to the north-east, east and south-east (Appendix), the latter of which is the focus of this article.

There are access constraints to the Likouala swamps: all travel is by boat and there is only one road connecting the swamps to other parts of the Likouala region. We therefore selected a relatively small area of 1,029 km² named after the Batanga River (the south-eastern border of the Reserve), which had been partially surveyed by Fay & Agnagna (1992) in 1989 and 1990. Satellite imagery indicates that the *Raphia* swamp extends far beyond our study area (Appendix).

Methods

Survey design

We used line transect distance sampling, analysed with *Distance v. 5.0* (Thomas et al., 2006), to estimate densities of gorillas and chimpanzees *Pan troglodytes*. In line transect distance sampling observers traverse lines of aggregate length L and the number n of objects of interest is counted and the perpendicular distance to each is recorded. For indirect signs, such as great ape sleeping nests, production and decay rates are estimated and used to convert sign density into animal or animal group density (Buckland et al., 2001).

Distance v. 5.0 (Thomas et al., 2006) was used to place line transects systematically, with a random start within the

survey area. Sampling effort represented a balance between obtaining sufficient survey precision and the financial and logistical constraints of conducting surveys across such a remote, inaccessible area. The sampling plan assumed a target coefficient of variation (CV) of 25% for density estimations of great ape nest groups. In calculating the total sampling effort required to attain density estimates with 25% precision we took encounter rates n_o/L_o of great apes from baseline surveys conducted by Fay et al. (1989), Fay & Agnagna (1992) and Poulsen & Clark (2004). Total line transect length L is calculated as follows (Buckland et al., 2001), where $CV_t(\hat{D})$ denotes the target CV of 25% for the density estimate and dispersion parameter $b = 3$, as recommended by Buckland et al. (2001):

$$L = \left(\frac{b}{[CV_t(\hat{D})]^2} \right) \times \left(\frac{L_0}{n_0} \right).$$

All 21 transects (Appendix) were 2 km in length. Transects were placed perpendicular to the Batanga River to improve precision in abundance estimations as a result of vegetation gradients and any associated gradients in ape density.

During the survey the end of one transect and the beginning of the next were connected by guided recces that followed the path of least resistance through the forest rather than following a straight-line bearing (Hall et al., 1998; Walsh & White, 1999). Guided recces do not deviate more than 40° from the compass bearing, and may be used to assess the intensity and type of hunting if human paths are followed. Recces used in combination with line transects therefore provide an effective technique for establishing a baseline of wildlife and human activity at this site (Blake et al., 2007).

Data collection

The distance sampling line transect survey was conducted between March and May 2007 during the dry (low water) season. Methods broadly followed those suggested by White & Edwards (2000). Three teams worked simultaneously across the survey zone and were composed of a principal observer responsible for nest sightings and a second observer who observed signs on the ground, including human sign. To minimize impact on the forest, permanent transects were not cut. A straight-line bearing through the forest was followed using machetes to open each transect just sufficient to enable the team to pass. A location, recorded with a global positioning system, was recorded at the beginning, midpoint and end of each transect. We noted all changes in forest type along the transect and position along the transect using a hip chain. We recorded all observations of great ape nests and dung, all other large mammal signs and all signs of human activity together with associated forest type, age of sign, vegetation type and hip chain distance. For all great ape

nests we recorded the perpendicular distance between the transect and the centre of the nest. Here, we report only the results of the data collected on great apes.

Forest types

The four major forest types encountered were: (1) swamp forest, permanently flooded and dominated by the tree species *Hallea stipulosa*, *Alstonia boonei*, *Sarcocephalus pobeguinii*, *Uapaca guineensis*, *Uapaca heudelotii*, *Uapaca paludosa*, *Macaranga schweinfurthii*, *Xylopia rubescens* and *Coelocaryon botryoides*; (2) swamp forest with lianas; (3) forest flooded for only a few months of the year and dominated by *Lophira alata*, *Chrysophyllum perpulchrum*, *U. heudelotii* and *Sterculia bequaertii* and (4) *Raphia* swamp, primarily composed of *Raphia* spp. palms with dense undergrowth including some *Pandanus* spp. and *A. angustifolium* and a few trees. *Raphia* spp. palms were almost exclusively found in *Raphia* swamp, with few occurring in other forest types.

Great apes

We recorded construction type for all great ape nests (sensu Tutin et al., 1995) and, for those in trees, we recorded the height and species of tree in which the nest was built. We defined nest groups as all nests created by the same ape species and of the same age class created $\leq$ 50 m from each other. We classified each nest as definitely chimpanzee or gorilla if verifying signs (faeces, odour or hair) were present. Chimpanzees have not been recorded building ground nests in this region and therefore we attributed the nests on the ground to gorillas and any associated arboreal nests of the same age class as nests on the ground also to gorillas (Tutin & Fernandez, 1984). For the remaining nests in trees we followed Tutin et al. (1995): for those tree nests for which the nest-building ape species could not be verified by associated signs we recorded the species as ape. Nest age and construction definitions were based on Tutin & Fernandez (1984).

Density estimates

Distance v. 5.0 (Thomas et al., 2006), incorporating group size data, was used to estimate encounter rate, detectability, density and abundance of gorillas and chimpanzees. If all nests located on the line were detected with certainty, then the density of great ape nest groups in the study area surveyed, D_s, is estimated as (Buckland et al., 2001):

$$\hat{D}_s = \frac{n\hat{f}(0)}{2L},$$

where $\hat{f}(0)$ is the probability density function of the perpendicular distances evaluated at zero distance and

n/L is the encounter rate. $\hat{f}(0)$ can be interpreted as $1/\hat{\mu}$, where $\hat{\mu}$ is referred to as the effective strip half-width and corresponds to the perpendicular distance from the transect line within which the number of undetected groups (distance to nest group is from the centre of the group) is equal to the number of groups detected beyond it. Two times the effective strip half-width multiplied by L gives the effective area surveyed. The density of great apes $\hat{D}$ is obtained by dividing the estimated nest group density $\hat{D}_s$ by the estimated production rate $\hat{p}$ and mean time to decay $\hat{c}$ and multiplying by the mean nest group size $\bar{s}$ (calculated from fresh or recent nests only). The density of nest groups and great apes is multiplied by the surface area A of the study area to obtain the corresponding abundance estimate $\hat{N}_s$ or $\hat{N}$, respectively. To improve model fit, data were grouped into distance intervals for analysis. Model selection was based on Akaike's information criterion (Burnham & Anderson, 2002) and the results of the χ^2 goodness-of-fit test were also considered.

Production and decay rates for ape nests

For our principal analysis we used a nest decay time of $91.5 \pm$ SE 1.67 days for both gorillas and chimpanzees and a nest production rate of $1.09 \pm$ SE 0.05 per day obtained from extensive line transect surveys conducted in Nouabalé-Ndoki National Park c. 175 km to the north-west (Morgan et al., 2006). This sampling error was incorporated into the calculation of confidence intervals. We know little about the decay rate of ape nests made from *Raphia* and it is possible that *Raphia* nests decay far more slowly than nests made from other vegetation (Blake et al., 1995; F. C. Iyenguet, pers. obs.; R. Kormos, unpubl. data). To obtain a conservative estimate we therefore included only fresh and recent *Raphia* nests for all the analyses (and all nests made with other plant species). Additionally, we explored the influence of nest decay rate on our estimations by applying a range of published decay rates (19.2–170 days) for ape nests from other sites and studies in Africa (Tutin & Fernandez, 1984; Tutin et al., 1995; Brugière & Sakom, 2001; Matthews & Matthews, 2004) and a systematic series of hypothetical slow (200–600 days) decay rates, comparing these to our initial estimate.

Results

A total of 1,021 ape nests in 195 groups were recorded along the 42 km of 21 transects. The following analysis is based on 680 fresh and recent *Raphia* nests and all nests of other plant species occurring in 141 groups. Of these nests we positively identified 494 gorilla nests in 83 groups. Based on these data our principal analysis estimated great ape density as 6.81 weaned individuals km^{-2} (95% confidence intervals, CI, 3.93–11.84) and gorilla density as 5.25 weaned individuals km^{-2} (95% CI 2.70–10.19 Table 1, Fig 2). Gorilla density estimates for our results, based on published or hypothetical nest decay rates, range from a minimum of 0.80 individuals km^{-2} (95% CI 0.41–1.54; hypothetical decay rate of 600 days) to 25.00 individuals km^{-2} (95% CI 12.95–48.24; published decay rate of 19.2 days; Tables 2 & 3). Numbers of chimpanzee and unidentified ape nests were too low to permit density estimation for either allocation scenario; distance sampling requires at least 60–80 objects per stratum (objects in this case are ape nest groups) to fit a detection function reliably and to obtain a reliable estimate of density (Buckland et al., 2001).

Seven habitat types were recorded during the survey (Fig. 3). Nests were constructed in all except grass savannah along rivers but most nests (64.0%) were constructed in *Raphia* swamp where nest frequency was disproportionately higher than the abundance of this habitat ($\chi^2 = 849.451$, df = 3, P < 0.0001; Fig. 3).

Human activity indices calculated from recce surveys were low (encounter rate 0.19 sign km^{-1} of transect) and the interpolated map of human activity shows it to be peripheral to the main area of high ape density and closest to navigable rivers (Fig. 4).

Discussion

Our results indicate that very high densities of great apes (5.25 gorillas km^{-2} and 6.81 great apes km^{-2}, based on

TABLE 1 Ape densities and abundance estimates in the study area along the Batanga River (Fig. 1) using decay rates from Morgan et al. (2006), with total survey effort in km (L), number of observations (n) of nest groups and nests, encounter rate km^{-1} (n/L) of nest groups and nests, nest group density km^{-2} ($\hat{D}_s$), individual density km^{-2} ($\hat{D}$, with 95% confidence interval), and abundance ($\hat{N}$, with 95% confidence interval), and coefficient of variation (%CV) for density. Density and abundance estimates for chimpanzees and unidentified apes were not calculated as numbers of confirmed nests observed were so low. Old and very old *Raphia* nests were excluded from the calculations (see text for further details).

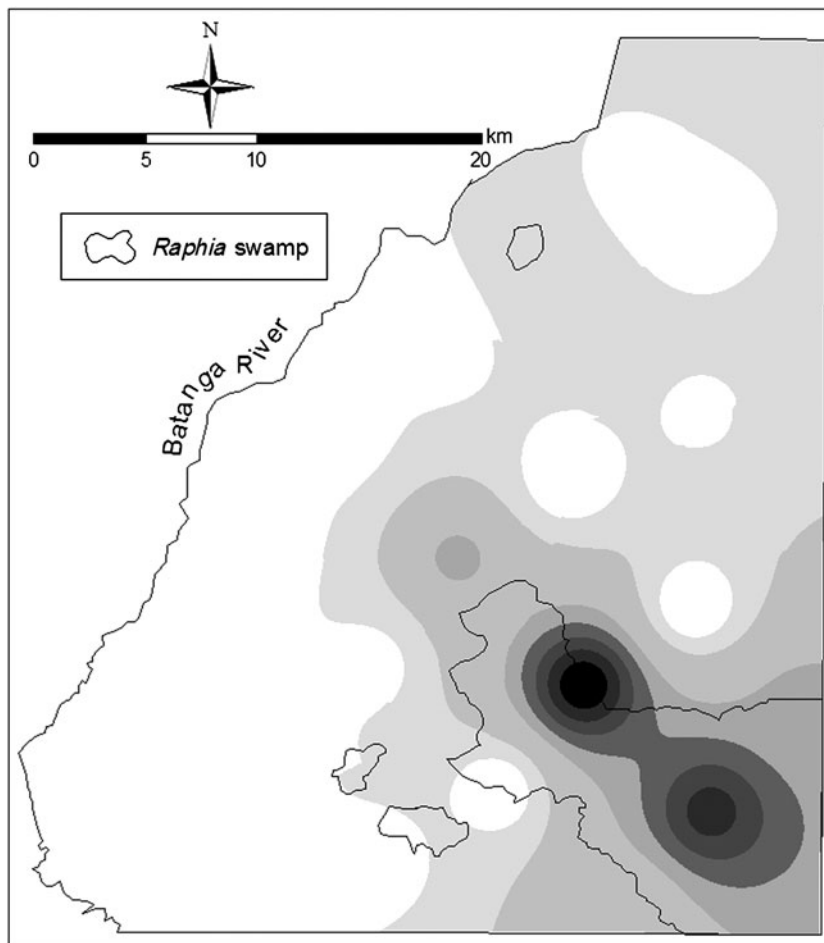| Species	L (km)	n (nests)	n/L (nests)	$\hat{D}_s$	$\hat{D}$ (95% CI)	$\hat{N}$ (95% CI)	%CV
Ape	42	140 (732)	3.33 (17.43)	126.61	6.81 (3.93–11.84)	7,647 (4,044–12,183)	26
Gorilla *Gorilla gorilla gorilla* (confirmed nests)	42	83	1.97	91.41	5.25 (2.70–10.19)	5,402 (2,778–10,486)	33
Chimpanzee *Pan troglodytes*	42	9	0.21				
Unidentified ape	42	5	0.12				

Fig. 2 Interpolated map of gorilla nest group density in the study area along the Batanga River (Fig. 1). Interpolated values of nest group density were made across a surface from a series of points (the centroid of each transect) by using the Inverse Distance Weighted technique in the *Spatial Analyst* extension of the geographical information system *ArcView v. 3.2* (ESRI, Redlands, USA).

a published nest decay rate of 91.5 days; Morgan et al., 2006) occur in the survey area giving an estimated potential population of 5,402 gorillas and 7,008 great apes (Table 1) in a relatively small area of 1,029 km². This density is much higher than the previous figure estimated from a small part of this study site (Fay & Agnagna, 1992) and is one of the

highest density estimates ever calculated for great apes and for gorillas (Table 1). See Poulsen & Clark (2004, 2005), Maisels et al. (2006), Morgan et al. (2006), Malonga et al. (2007) and Stokes et al. (2008) for comparison of density estimates from other sites in Central Africa. Human activity was low throughout the whole survey area (Fig. 4).

TABLE 2 Gorilla density and abundance estimates (with 95% confidence intervals) calculated using nest density from this study and nest decay rates (in decreasing order of magnitude) from published studies. Our principal analysis (from Table 1) is in bold.

Site	Mean decay time (days)	Density (95% CI)	Population (95% CI)	Habitat (reference)
Ngotto, SW Central African Republic	170	2.82 (1.46–5.45)	2,905 (1,505–5,608)	Semi-deciduous forest (Brugière & Sakom, 2001)
Campo Ma'an, SW Cameroon	133	3.61 (1.87–6.96)	3,714 (1,924–7,168)	Semi-deciduous forest (Matthews & Matthews, 2004)
Ndoki, N Congo	91.5	**5.25 (2.70–10.19)**	**5,402 (2,778–10,486)**	Semi-deciduous forest (Morgan et al., 2006)
Lopé, Gabon	78	6.15 (3.19–11.88)	6,332 (3,281–12,222)	Semi-evergreen forest (Tutin et al., 1995)
Belinga, NE Gabon	61.7	7.78 (4.03–15.01)	8,005 (4,147–15,451)	Semi-evergreen forest (Tutin & Fernandez, 1984)
Campo Ma'an, SW Cameroon	57	8.42 (4.36–16.25)	8,665 (4,489–16,725)	Semi-deciduous forest (Matthews & Matthews, 2004)
Belinga, NE Gabon	52.7	9.11 (4.72–17.58)	9,372 (4,856–18,090)	Semi-evergreen forest (Tutin & Fernandez, 1984)
Belinga, NE Gabon	50.9	9.43 (4.88–18.20)	9,704 (5,027–18,729)	Semi-evergreen forest (Tutin & Fernandez, 1984)
Belinga, NE Gabon	19.2	25.00 (12.95–48.24)	25,725 (13,328–59,652)	Semi-evergreen forest (Tutin & Fernandez, 1984)

TABLE 3 Extrapolated gorilla density and population estimates (with 95% confidence intervals) using nest density from this study and hypothetically slow nest decay rates, incorporating only fresh and recent nests in the model.

Mean decay time (days)	Density (95% CI)	Population (95% CI)
600	0.80 (0.41–1.54)	823 (426–1,589)
550	0.87 (0.45–1.68)	898 (465–1,733)
500	0.96 (0.50–1.85)	988 (512–1,907)
450	1.07 (0.55–2.06)	1,098 (569–2,118)
400	1.20 (0.62–2.32)	1,235 (640–2,383)
350	1.37 (0.71–2.65)	1,411 (731–2,724)
300	1.60 (0.83–3.09)	1,646 (853–3,178)
250	1.92 (0.99–3.71)	1,976 (1,024–3,813)
200	2.40 (1.24–4.63)	2,470 (1,279–4,767)

Ape nest production and decay rate

We recognize that where nest decay rates are used to estimate density they should optimally be carried out concurrently with a study of nest decay rates and that *Raphia* nest decay rates are poorly known. Nest decay rates in other published studies of African apes vary widely (Table 2) and in Kalimantan, Indonesia, orangutan nests have been found to persist for up to 600 days (Mathewson et al., 2008). However, this latter study included recording nests after leaves have fallen off, a total of 38% of decay time (S. Wich, pers. comm.). Nests of this condition were not recorded by White & Edwards (2000), the method used in this study. The use of palms by chimpanzees has been reviewed, but production and decay rates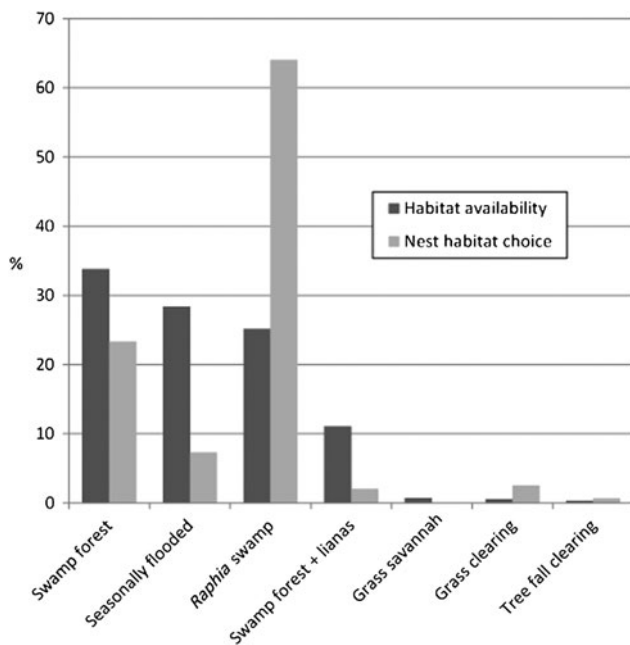 of palm-constructed nests have not been studied (Humle & Matsuzawa, 2004). *Raphia* is a typical construction material for chairs and roofing in the region and is known to be relatively resilient to rotting. Our approach of excluding old and very old *Raphia* nests for the analysis is conservative. This eliminated older *Raphia* nests that could have inflated our density estimates, and only 14.5% of the nests that were included in the analysis were made from *Raphia*. Thus, a large proportion of the nests were made of materials with a decay rate that is likely to be close to that published in previous studies (Morgan et al., 2006). Fresh nests are categorized by the presence of odour and dung and recent nests by green vegetation, no odour and possibly dung (Tutin & Fernandez, 1984). It is thus highly unlikely that nests that are many months old would have been recorded in these categories. The inclusion of the standard error of nest decay rate from Morgan et al. (2006), which tends to increase the range of the confidence intervals (Plumptre, 2000), had limited influence.

We calculated densities using decay rates from other published studies (Table 2) but even when calculated using the slowest published decay rates, the lowest density estimate for the Batanga swamps of 2.82 individuals km^{-2} (95% CI 1.46–5.45) is still high. Using hypothetically slow decay rates of up to 600 days (Table 3) the estimated gorilla density of 0.80 individuals km^{-2} is still moderately high. However, we did not carry out a simultaneous study of nest decay rates and nest production rates (see Bradley et al., 2008, for a recent study of nest production rates) and there may be some bias contributed to the density estimate from both these factors. We recommend incorporating a *Raphia*-specific nest decay study in subsequent ape surveys in this area to reduce bias from this source.

Gorilla habitat preference and density variation

The apes in Batanga were concentrated in an area of *Raphia* swamp in the south-east of the survey zone (Fig. 2) covering 25% of the surface area. On three transects we recorded no nests and, on four transects, >100 nests. However, the confidence intervals of the density estimate in our study are comparable to those found elsewhere (Table 1; Poulsen & Clark, 2004). Williamson & Usongo (1996) also found that *Raphia* swamp harboured high densities of gorillas and Maisels & Cruickshank (1996) noted high densities of both ape species in marsh forest.

The high densities we found may be related to the amount of food available for gorillas in *Raphia* swamp, a preference already noted by Fay et al. (1989), Fay & Agnagna (1992), Blake et al. (1995) and Bermejo (1999), who observed that gorillas eat almost all terrestrial monocotyledon species whatever the morphology. Monocotyledons are known to be only lightly chemically defended, if at all (Rhoades & Cates, 1976; Waterman, 1984), and are favoured

FIG. 3 Percentage of habitat types in the study area along the Batanga River (Fig. 1) compared with habitat nesting preference of great apes.
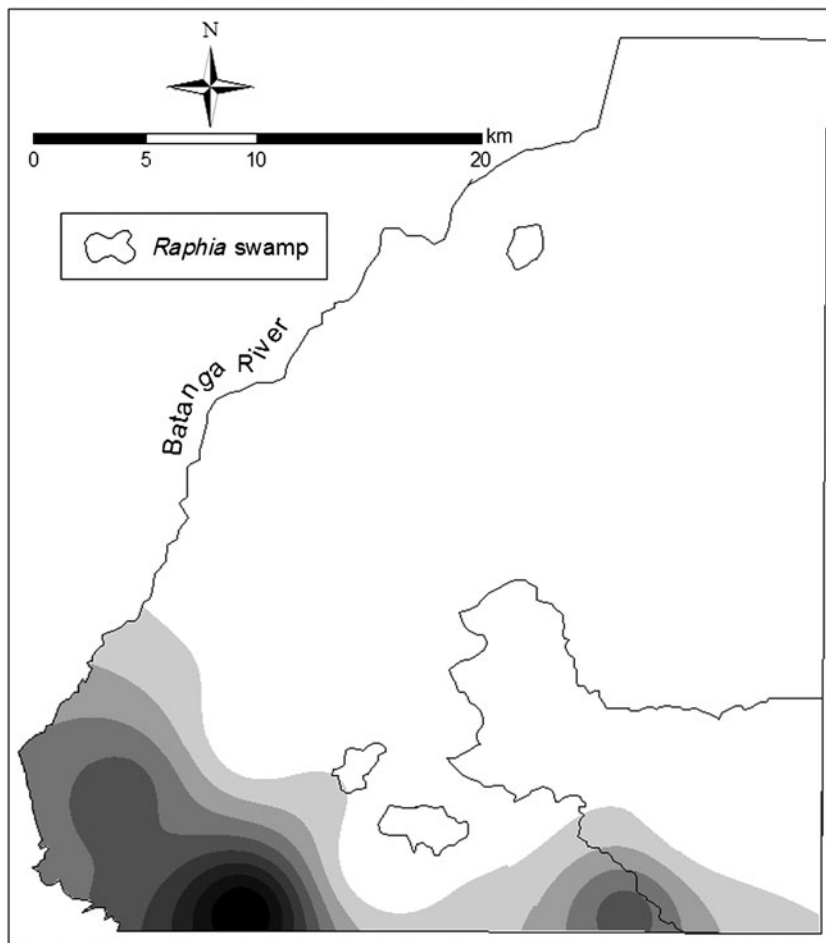
FIG. 4 Interpolated map of encounter rate of human activity signs (paths and machete cuts) from guided reconnaissance surveys in the study area along the Batanga River (Fig. 1). Interpolation was as described in the caption to Fig. 2, using human activity signs as the points.

by many generalist herbivores, not only gorillas. The year-round availability of monocotyledons in *Raphia* swamps may be attractive to gorillas and they may be sedentary in this habitat. This is in contrast to the gorillas in the swamp and terra firma forest of Lac Télé Community Reserve that apparently move between habitats, possibly because of fluctuating fruit availability (Poulsen & Clark, 2004; Malanda et al., 2005). Gorilla densities in swamp forest vary both spatially and temporally (Fay et al., 1989; Fay & Agnagna, 1992; Blake et al., 1995; Williamson & Usongo, 1996; Poulsen & Clark, 2004; Malanda et al., 2005). Thus, surveys should be stratified by habitat where possible and conservation land-use planning should take into account year-round habitat requirements.

Conservation management

The study site is important for apes and also elephants *Loxodonta africana* and other primates including red colobus *Piliocolobus oustaleti* (data collected simultaneously with this study; Malanda et al., 2007). More than 15 years after the survey of Fay & Agnagna (1992) the gorilla population in Batanga swamp remains high, perhaps because the site is inaccessible and remote. The Likouala swamps are the only remaining forest in the Congo Basin > 70 km from roads and the sole unprotected area > 50 km from roads (Blake et al., 2007). However, data from 2008 suggest that the remaining *Raphia* swamp may be affected by human activities (G.-A.F. Malanda & F.C. Iyenguet, pers. obs.). The caveat of Blake et al. (2007) that, in some areas, rivers may confound the effect of roads as a proxy for isolation may therefore be correct. Currently, most *Raphia* swamp in northern Congo is found outside existing protected areas (Appendix). As the habitat is difficult to penetrate and gorillas are threatened by ebola and hunting elsewhere (Walsh et al., 2003, 2005; Leroy et al., 2004; Tutin et al., 2005; Bermejo et al., 2006; Rizkalla et al., 2007), this *Raphia* swamp should be protected. There is potential to enlarge the limits of Lac Télé Community Reserve taking into account the year-round habitat requirements of gorillas.

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Appendix

The appendix for this article is available online at http://journals.cambridge.org

Biographical sketches

Hugo Rainey has studied African birds since 1996, was formerly Lac Télé Community Reserve project director and is a Wildlife Conservation Society (WCS) technical advisor in Cambodia. Fortuné Iyenguet has been an ecologist at the Reserve since 2001 and surveyed mammals in Odzala. Guy-Aimé Malanda has been an ecologist at the Reserve since 2001, surveying fish and mammals in the Ndoki-Likouala landscape. Bola Madzoké has monitored mammals and waterbirds in the Reserve and Ndoki-Likouala landscape since 1998. Domingos Dos Santos has worked to conserve gorillas for 16 years and is now conservator in Nouabalé-Ndoki National Park. Emma Stokes worked for 10 years on African ape research and conservation, coordinating monitoring in Congo, and now coordinates monitoring for the WCS tiger programme. Fiona Maisels is Monitoring Coordinator for WCS Central Africa and has worked in this region's forests since 1988. Samantha Strindberg provides conservation planning and statistical assistance to WCS field programmes.