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Chimpanzees surviving in a fragmented high-altitude forest landscape of the Congolese Albertine Rift

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Abstract

This paper documents a community of eastern chimpanzees (*Pan troglodytes schweinfurthii* Giglioli, 1872) inhabiting three relict forest fragments situated on the Lake Albert escarpment, down the Ituri highlands, of eastern Democratic Republic of the Congo (DRC). The area explored had a combined forested surface of ±18.15 km^2 in 2017, shrinking by 1.2% per year between 2010 and 2015. Between 2015 and 2017, we found 160 chimpanzee nests along 37.6 km of pilot walks, some up to 2,000 m altitude. Another 123 nests logged along 6.7 km transects led to an estimate of chimpanzee density of 4.62 weaned individuals per square kilometer of forest habitat. Camera-trap images and direct observations revealed that this community is comprised of a minimum of 42 weaned individuals, which translates into an estimated density of 2.3 chimpanzees per square kilometer. The increasing rate of forest degradation threatens to erode the cultural and genetic diversity of nonhuman primates in

Eleventh author name was updated to Thurston Cleveland Hicks.]

eastern DRC; the local people however exhibit willingness to establish a community managed reserve. We hope that this report will lead to the recognition of this site as a Chimpanzee Conservation Unit, facilitating further research in these "Relict Altitude Forests Fragments of the Albert Lake Escarpment" (or RAFALE landscape) and the Ituri highlands where other undocumented chimpanzee communities occur.

KEYWORDS

Albertine Rift, behavior, conservation, Democratic Republic of the Congo, Ituri, Mbudha community, *Pan troglodytes schweinfurthii*

1 | INTRODUCTION

Due to its relative isolation from other East African mountain ecosystems, the Albertine Rift has been recognized as a biodiversity hotspot (Plumptre et al., 2007). It hosts at least 1,779 terrestrial vertebrate species (mammals, birds, reptiles and amphibians), of which 140 are endemic and 78 have been classified as globally threatened on the International Union for Conservation of Nature (IUCN) Red List (Ayebare, Plumptre, Kujirakwinja, & Segan, 2018). The Rift covers 313,000 km^2 from the northern tip of Lake Albert and Murchison Falls National Park to the southern tip of Lake Tanganyika and encompasses the mountains on either flank of the Rift valley (Plumptre et al., 2007; Plumptre et al., 2010). About two-thirds of the Albertine Rift is situated in eastern Democratic Republic of the Congo (DRC). Over the last decades, dramatic human demographic growth—often exacerbated by the influx of local and foreign refugees—has resulted in drastic changes in land use due to the conversion of forest into agricultural land (Ayebare et al., 2018). The DRC hosts at least 49 species of primates (IUCN, 2020), but in some areas their populations are fragmented and in decline (Hicks et al., 2010). This is the case for the eastern chimpanzee *Pan troglodytes schweinfurthii*, which is threatened throughout their range (Hicks et al., 2010). It is estimated that in DRC alone there remain at least 100,000 eastern chimpanzees, with up to ±13,000 living in the Albertine Rift (Plumptre et al., 2010). Nevertheless, population estimates for the species remain uncertain in many areas of DRC, as political instability has hampered scientific explorations of vast areas especially in the Ituri province.

The forests of the Ituri highlands have been reduced to broken ribbons with fewer than 20 forest fragments scattered along the slopes of the Lake Albert escarpment. Although farther to the northwest of the country large areas of intact habitat suitable for chimpanzees and other wildlife remain (Hicks et al., 2014), these small forest fragments serve as last refugia for endangered species now swept up in the wave of development. While habitat fragmentation increases the risk of wildlife extinction, a substantial number of forest species—including chimpanzees—are able to survive for decades in disturbed and fragmented forests (McCarthy et al., 2015; Whitmore & Sayer, 1992). In order to protect chimpanzees as a species, it is necessary to know exactly where they occur. The presence of chimpanzees in relict forest fragments of the Congolese Albertine Rift region—determined in 2015 based on informal discussion with local inhabitants—was unexpected. Chimpanzees do not habitually occur in montane forests (highest record at 2,750 m elevation) (Matthews, Ridley, Niyigaba, Kaplin, & Grueter, 2019; Plumptre et al., 2010) and the closest known chimpanzee populations—either across the lake in Uganda or off the eastern limit of the Ituri-Epulu-Aru Central Africa Regional Program for the Environment (CARPE) landscape—are located ±75 km away. Moreover, the only written historical evidence of chimpanzees in the region dates back to 1886 from the notes of Emin Pacha (Meessen, 1951).

This paper documents the existence of a community of chimpanzees surviving in three fragments of the Congolese Albertine Rift. We named this chimpanzee community "Mbudha" which—in Bbaledha language—means the *water of the chimpanzees*. We provide a first assessment of the community size and density, and of their nest-building behavior within the surveyed habitat. The results of this study will provide the conservation authorities with a resource to help them classify this area as a Chimpanzee Conservation Unit (CCU), and, with the support of the local communities, will help inspire further research projects on the Congolese Albertine Rift and in the Ituri highlands, where other undocumented chimpanzee populations occur.

2 | METHODS

2.1 | Site description

We refer to the forest fragments located along the Congolese Albertine Rift slope as the RAFALE landscape ("Relict Altitude Forest Fragments of the Albert Lake Escarpment") to distinguish it from the Ituri highlands which have altitudes ranging from 1,700 up to 2,455 m at Mount Aboro (Meessen, 1951). No fragment within the RAFALE landscape is currently protected (Figure 1).

The RAFALE landscape consists of a mosaic of 20 semi-deciduous montane forest fragments (>0.5 km^2 each) comprising a total forested surface area of ±70 km^2 (see Ponce-Reyes et al., 2017 for Albertine Rift habitat description). They form a string, which is oriented southwest-northeast along 80 km of steep slopes on the western side of Lake Albert, ranging from an elevation of 620 m at Lake Albert to 2,020 m above sea level on the highest ridge. Depending on the altitude, the average daily temperature varies from 17 to 25°C and the annual average precipitation ranges from 1,200 to 1,700 mm. A short rainy season, characterized by heavy rainfall, occurs between March and the end of May, and a long rainy season occurs between August to mid-November (Meessen, 1951).

We selected three forest fragments, named locally the Tsili-Bai, Zalu-Rogo and Dolokpa-Dzoo forests and labeled them, respectively, FG1, FG2, and FG3 (FG, gallery forest; Figure 2) situated on the border of two administrative territories (Djugu and Mahagi) of Ituri Province, both of which are densely populated, with an average of ±300 habitants per km^2 (Dadzie, 2012). Slash-and-burn agriculture for the subsistence of local populations has converted the plateau and the slopes of the escarpment into agricultural land used to grow cassava, groundnuts, beans, maize and sorghum. Each of the fragments is a riverine gallery forest surrounded by open grassland savannah, fallow land and crop fields, with streams that flow into a central river that empties into Lake Albert. These forest fragments are characterized as high-altitude closed-canopy strips with a moderately dense understory (10–50 m horizontal visibility). FG1 is predominantly a secondary forest due to the extensive human activities and forest degradation for charcoal production and agriculture. FG2 and FG3 are a mixture of secondary,

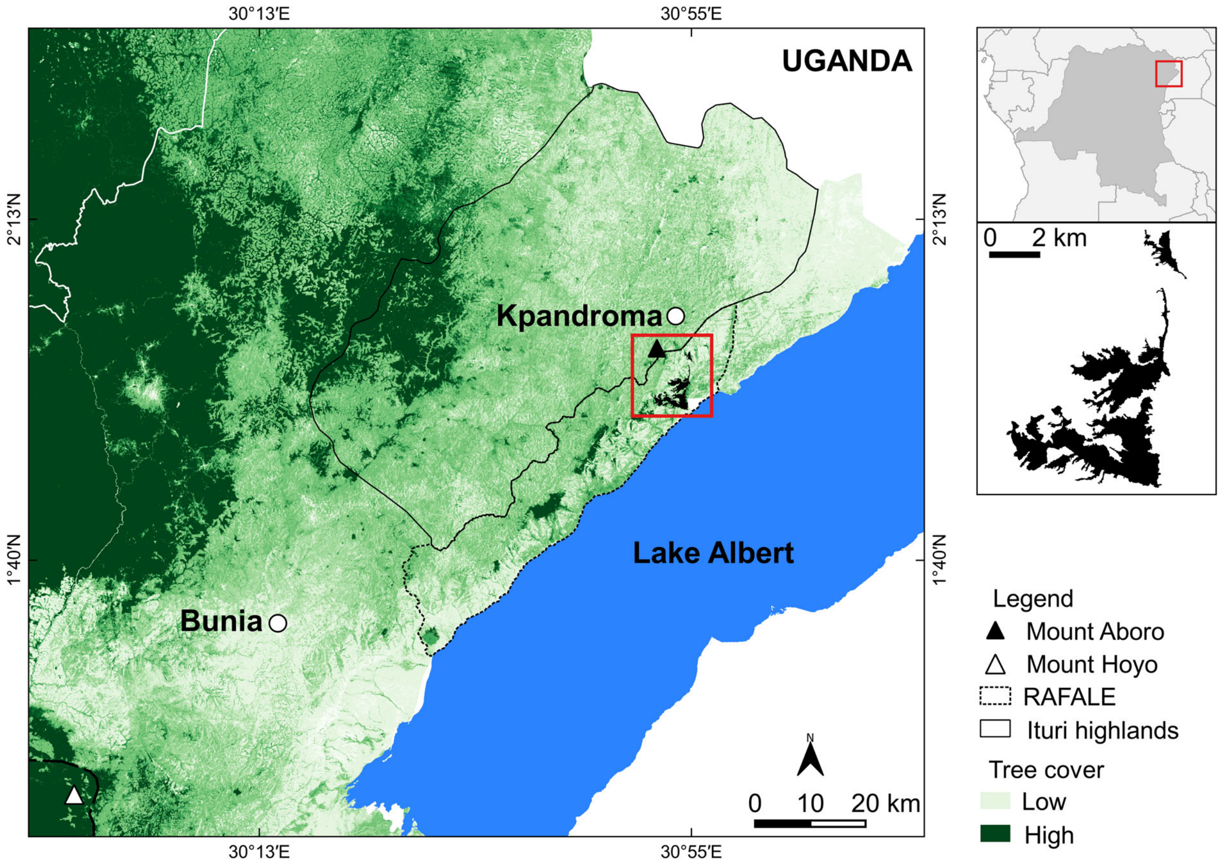

FIGURE 1 General location of the study site labeled RAFALE in eastern DR Congo, the Ituri highlands and Mount Aboro of the Blue Mountains with inset map of the study site with the contours of the three studied fragments as shown in Figure 2

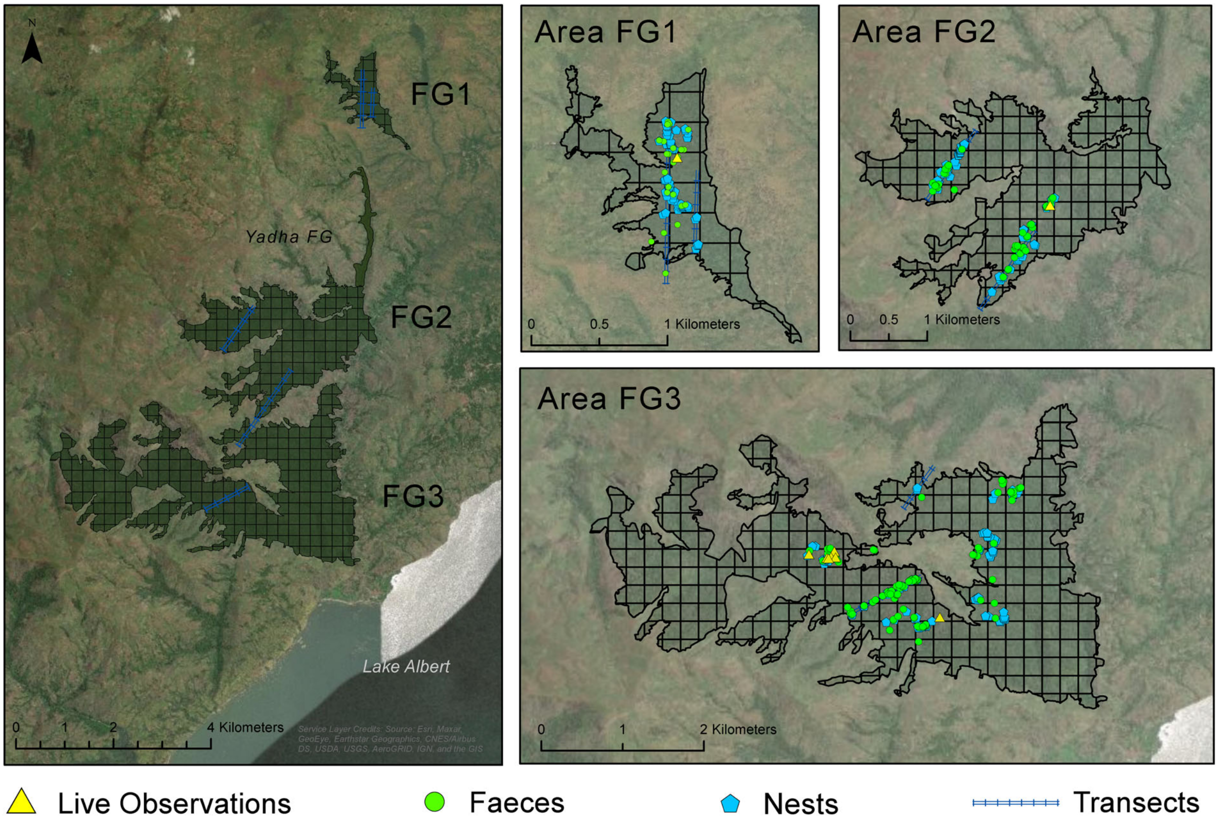

FIGURE 2 Location of transects, chimpanzees and their nests in FG1 (Tsili-Bai forest), FG2 (Zalu-Rogo forest), and FG3 (Dolokpa-Dzoo forest)

primary and near-primary semi-deciduous forests containing numerous tree species of the families Myristicaceae, Sapotaceae, Annonaceae, Apocynaceae and Euphorbiaceae. The RAFALE landscape is crisscrossed by human-made trails used for carrying food and other necessities to the villages on the slopes, and to trade fish with the lake dwellers below.

2.2 | Mapping of the forest surface and deforestation rate estimate

We drew the boundaries of the three forest fragments by hand in Google Earth Pro (ver. 7.3) (Google Earth Pro, 2017) using the visual difference between forest and non-forest vegetation types. These polygons were converted to Keyhole Markup Language (KML) files and imported in ArcGIS (Environmental Systems Research Institute, 2011) together with a topographical polygon-shape file (Digital Elevation Model or DEM) provided by the *Observatoire Satellital des Forêts d'Afrique Centrale*, OSFAC, Kinshasa) with an accuracy of 30 m. The topographical shape-file was converted to a raster-file. We converted the imported KML-files to polygon shape-files of the forest fragments and used it as masks to cut out the forest fragments from the topographical raster-file.

We calculated the forest cover of the three fragments at three time points (2010, 2012, and 2015), taking into account the topography (DEM), based on historical imagery freely available in Google Earth (Landsat 7 and 8). We calculated the fragment forest area to estimate the rate of deforestation over this period. We created our maps using Google Earth Pro (ver. 7.3) (Google Earth Pro, 2017) and our images using ArcGIS (ver. 2.14) and QGIS (ver. 3.10.2) (GIS Development Team, 2018) and performed all statistical analyses using the program R (ver. 3.5.3) (R Core Team, 2018).

2.3 | Chimpanzee surveys

2.3.1 | Preliminary surveys

For our preliminary chimpanzee surveys, we selected fragments and forest sections based on their accessibility (Table S1, Supporting Information). The objective of each pilot walk was to confirm the presence of chimpanzees and estimate the nest encounter rates in each forest fragment. In March, June, August, October and September 2016, and in April–May 2017, we conducted a total of 14 unplanned pilot walks following the path of least resistance (Walsh & White, 1999) (Table S2). We carried out our pilot walks at an average speed of 2.7 km/hr and covered an overall total distance of 37.6 km. For each chimpanzee nest site found on pilot walks, we assigned a binary category (old/recent; as the team had not yet been trained to recognize precise nest categories), and described the nest tree (diameter at breast height or DBH, height, species) and nest arrangement (single/multiple nests in one tree). We recorded the GPS location, altitude and the general habitat type of the forest fragment. We defined nest sites as a group of nests of the same age separated from other nests by a maximum distance of 20 m (Dupain, Guislain, Nguenang, De Vleeschouwer, & Van Elsacker, 2004); we categorized all nests below 0.5 m as ground nests (Hicks, 2010).

2.3.2 | Population density estimates and nesting behavior

In August 2016 and April 2017, we carried out a structured investigation to estimate the density of chimpanzees in three forest fragments and the nest encounter rates. We walked once covering a total of 6.7 km systematic pre-planned line transects using a handheld GPS (Garmin 62cs) at an average speed of 1.0 km/hr (6 transects; Table 1). We recorded the GPS coordinates of signs of chimpanzee activity—detected whilst walking the transects—such as feeding remains, nest sites, tracks and dung; the latter were placed in vials and stored for further analysis.

Whenever we found a nest whilst walking the transects, we searched the surrounding forest to locate any other nests from the same nest group (i.e., of the same age and within 20 m; Dupain et al., 2004). For each nest, we recorded age category as follows: (a) fresh nest, very recent (a few days old), with presence of fresh dung, hair, urine, and/or odor, (b) fresh nest with all leaves remaining green, no odor, if present, dung was dry or degraded, (c) intermediate state of decomposition, with a mixture of green and brown leaves, (d) nest with completely brown foliage, but structure was still intact, (d) nest with completely brown foliage, deformed structure, and/or perforated, and (e) almost completely decomposed and hardly recognizable (J. Willie, pers. comm.). We also recorded the nest height, position on the tree or vine, which was divided into 3 major classes: side (S), top (T) and vine (L) and several combinations (SS, SL, TS, TL, TT, TSS, TTS) when a nest was built on >1 tree or support (J. Willie, pers. comm.). The GPS coordinates and location along the transect line, the perpendicular distance from the nest to the transect, and characteristics of the nesting tree (species, DBH, height using the Nikon Forestry Pro II Laser Rangefinder/Hypsometer) were also recorded.

2.3.3 | Distance analysis

Chimpanzee nest survey data were used to estimate nest density, and ultimately density of weaned chimpanzee nest-makers, using DISTANCE (version 6.2) based on four detection models (half-normal, hazard-rate, uniform and negative exponential) and three adjustment functions (cosine, simple polynomial and hermite polynomial), resulting in 12 models (Buckland et al., 2001;

TABLE 1 Overall nest encounter rates per fragments on pilot walks, total pilot and transect walk length per fragment with number of nests counted, nest encounter rate, average slope along transects and estimated surface area of each forest fragment

Forest fragment	Surface area (km^2)	Length of pilot walk covered (km)	Number of nests on pilot walks	Nest encounter rate per km during pilot walks	Length of transect walked (km)	Number of nests along transects	Nest encounter rate per km along transects	Average slope (%)
FG1	0.96	12.4	48	3.9	1.3	33	25.4	22.7
					0.5	8	16.0	22.3
FG2	5.94	13.1	51	3.9	2.0	19	9.5	25.0
					1.1	39	35.5	22.8
FG3	11.30	12.1	61	5.0	1.1	22	20.0	21.0
					0.7	2	2.9	18.1
Total	18.15	37.6	160	4.3[a]	6.7	123	18.4a	

[a] Total nests encountered/total number of kilometers walked on a single walk.

Thomas et al., 2010). We considered the model with the lowest Akaike Information Criterion (AIC) and lowest coefficient of variation as the most accurate (Waltert, Chuwa, & Kiffner, 2009). We performed our analyses on the truncated data set. We used this approach because observations of the nests furthest from the transects are less important for the detection function; these outliers can have a major influence on the selected model which may increase the variance in the estimated abundance/density (Buckland et al., 2001). Thus, we discarded the largest 5% of distances which resulted in 117 nests for analysis. We selected the model with the best fit using the truncated data set for the entire survey region (nest counts from FG1, FG2 and FG3). Following Kouakou, Boesch, and Kuehl (2009), nest density was converted to chimpanzee density using the formula

$$\hat{D}_{chimpanzees} = \frac{\hat{D}_{nests}}{\hat{r}*\hat{t}}$$

where $\hat{D}_{chimpanzees}$ is the estimated density of weaned chimpanzees, $\hat{D}_{nests}$ is the nest density, $\hat{r}$ is the daily nest production rate per individual, and $\hat{t}$ is the nest decay time (in days). Values of $\hat{r}$ and $\hat{r}$, taken from the literature, were 1.09 and 111, respectively (Kühl, Maisels, Ancrenaz, & Williamson, 2008; Plumptre & Cox, 2006).

2.3.4 | Habitat description and botanical inventory along transects

We described the habitat and performed a botanical inventory by adapting methods and criteria described in White and Edwards (2000), Tagg and Willie (2013) and Willie, Petre, Tagg, and Lens (2018). Habitat description was based on the dominant plant species (trees, shrubs, lianas), horizontal visibility and canopy openness every 200 m. We distinguished 6 *terra firma* habitat types namely crop field, near primary forest (closed/open), old secondary forest (closed/open) and shrubby and herbaceous fallow land. For every 100 m increment along the transect line, we carried out a systematic botanical inventory (trees, shrubs, lianas, raffia and grass or herbs) and identified all vascular plant stems present in plots (20 × 5 m) and embedded subplots (4 × 4 m and 2 × 2 m). We counted and identified shrubs, raffia ($h \leq 1$ m) and grass or herbs in 2 × 2 m subplots; shrubs, raffia (DBH < 10 cm; $h > 1$ m) and vines (DBH < 5 cm) in 4 × 4 m subplots; and trees (DBH ≥ 10 cm), raffia (DBH ≥ 10 cm) and vines (DBH ≥ 5 cm) in 20 × 5 m plots. This allowed us to characterize the habitats and to assess whether or not chimpanzees favor particular tree species to build nests.

2.3.5 | Nesting tree selection

We adapted the approach of Jacobs (1974) to derive a "preference index" for each tree species. We calculated this index as the total number of nests built in each tree species minus the expected number of nests. To determine the expected number of nests for a tree species, we initially assessed the relative importance of the tree in the forest. For each tree species, we calculated the relative frequency (number of plots in which the tree species was found divided by the total number of occurrences of all tree species in plots), the relative density (number of stems of the tree species divided by the number stems for all tree species), and the relative dominance (basal area of the tree species divided by the combined basal area for all tree species), following Hamann, Barbon, Curio, and Madulid (1999). We then used the sum of these three parameters to determine the relative importance of each tree species in the forest.

2.3.6 | Direct and indirect observations of chimpanzees

Between March 2016 and May 2017, we placed 27 Bushnell camera-traps (No Glow Trophy cam) at 48 different locations 30-60 cm above the ground, initially at places where we had found traces of chimpanzees (Table S3). In May 2017, we recorded 2 hr of live observation in FG3 (Sony Alpha 7) that set the baseline for individual recognition. We also positioned five camera-traps on tree trunks (between 8 and 13 m high) to document the diversity of arboreal species (e.g., squirrels and primates) for our preliminary faunal inventory (Table S4).

From our analysis of direct observations, live footage and those of camera images, we attempted to identify each chimpanzee individual recorded. We adapted the age categorization from Goodall (1983) as we could not always strictly distinguish between age categories due to the limitations of available footage and the fact that this community is not habituated. We thus categorized all individuals into three age categories according to the following criteria: infant: 0–5 years (clinging or riding on the belly or back of a female or with attachment to a particular female); juvenile: 5–10 years (moving independently from a particular female, but showing attachment to her); adolescent/adult: over 10 years (Goodall, 1983). We could generally distinguish between male and female chimpanzees based on their body size, build, nipple and genital shape and size, and the presence of an infant chimpanzee. We used distinct individual features such as scars, injuries (e.g., snare mutilations), ear and face shape, face and hair color, and stature to avoid the double counting of individuals and to supplement the DISTANCE modelling estimate results.

3 | RESULTS

3.1 | Population size and density estimates

Between March 2016 and June 2017, we recorded 2 hours of live observation, 136 camera-trap video sequences and 155 camera-trap stills of chimpanzees (Table S3). We observed chimpanzees at 22 of our 48 camera-trap locations, totaling 1,987 trap nights with an average 20.0% trapping success or TS (number of triggers with a chimpanzee record). Based on the identifications of individuals made over the course of the study period (2016–2017), we determined the minimum size of the Mbudha community to be 42 weaned chimpanzees and 10 infants (Table 2). Based on the Mbudha community direct count estimates, the chimpanzee density in the forested area surveyed is at least 2.3 weaned individuals/km^2. Footage of chimpanzees patrolling, individual identification of chimpanzees and villagers' observations confirm their movement between the three forest fragments.

We recorded a total of 283 chimpanzee nests (123 along transects and 160 on the pilot walks). The mean number of nests per kilometer was 4.3 (min = 0 and max = 14.3) and 18.4 (min = 0 and max = 43.6) on pilot walks and transect surveys respectively without significant differences between the three fragments (Table 1).

Using the truncated dataset of 117 nests recorded along the six transects we surveyed between 1,100 and 1,700 m altitude (Figure 2), we estimated a density of 4.62 weaned chimpanzee individuals per km^2 (Uniform simple polynomial).

3.2 | Tree inventory and selection of nesting trees

In total, in our 180 plots (60 plots of 5 × 20 m, 4 × 4 m and 2 × 2 m) surveyed along the transects, we recorded 3,670 individual plant species of which 329 (9.0%) could not be identified (Table S5). The most frequently encountered families (>40 stems) were Myristicaceae (2 species), Sapotaceae (7 species), Rubiaceae (13 species), Annonaceae (6 species), Apocynaceae (6 species) and Euphorbiaceae (10 species). We recorded 795 trees and identified 740 stems belonging to at least 51 families of which 244 were trees with a DBH ≥ 10 cm. In Table 3, we present the most frequent tree species encountered (≥20 stems recorded); for comparative purposes, we have added references of their known use elsewhere by *Pan troglodytes* (Table 2).

We characterized 113 chimpanzee nests. Most nests encountered along transects were a few weeks to several months old (68.1% Categories 4–6 and 22.1% Categories 2 and 3) and only 9.7% were fresh (Category 1). In five nesting sites (two in FG1 and FG3, one in FG2), we found nests of different ages which suggests that these sites were used repeatedly by chimpanzees. Most of the nests were built on protruding lateral branches (88.5%), while the remaining nests were built on the top and upper branches of the trees. Nest height along transects ranged between 1.5 m and 27 m (mean height = 10.31 m; SD ± 5.04). Yet, the highest and lowest nests were recorded at 39 m on a *Pouteria altissima* tree and at 0.5 m on a *Rothmania talbotii* tree in pilot walks. The latter is considered a ground nest by the criterion of Hicks et al. (2010). The ground nests encounter rate (1) and the ratio of ground nests (Gn) to tree nests (Tn) were low (Gn = 1:Tn = 282).

We found 42 nests in trees of the Annonaceae family (e.g., *Monodora* sp.), 21 nests in trees of the Sapotaceae family (e.g., *Chrysophyllum africanum*) and 12 in trees of the Strombosiaceae family (*Strombosia scheffleri*). The remaining nests were built in trees from 18 other families. The Mbudha community chimpanzees preferred to build nests in particular tree species (Table 4). Overall, *Monodora myristica* (30.365) was the most popular species for nest building, followed by *Strombosia scheffleri* (9.577) and *Chrysophyllum gorungosanum* (4.970). Chimpanzees were significantly less likely to build nests in *Pycnanthus angolensis*, *Piptadeniastrum africanum* and *Dracaena mannii*.

TABLE 2 Numbers of individuals from the Mbudha community observed between 2016 and 2017 (M = male, F = female,? = unknown sex)

	Adult or adolescent >10 years				Juvenile 6–10 years		Infants 0–5 years	
Forest	M	F	?	M	F	?		Total
FG1	0	5	0	1	0	0	1	7
FG2	4	7	0	0	2	0	3	16
FG3	7	8	4	1	2	1	6	29
Total	11	20	4	2	4	1	10	52

TABLE 3 Most frequent trees species encountered (20 or more stems of the species) in the three surveyed forest fragments and their known use by chimpanzees (*Pan troglodytes* spp.) *across* Africa

N	Species	Number of stems	Known use	References
1	*Celtis tessmannii*	20	Food—nesting	Tédonzong et al. (2019)
2	*Vernonia amygdalina*	22	Antihelminthic	Koshimizu, Ohigashi, and Huffman (1994)
3	*Tabernaemontana stapfiana*	23	Food—nesting	Gross-Camp et al. (2009(
4	*Piptadeniastrum africanum*	28	Nesting	McCarthy, Lester, and Stanford (2017)
5	*Pseudospondias microcarpa*	28	Food—nesting	Samson and Hunt (2014)
6	*Chrysophyllum gorungosanum*	34	Food—nesting	Stanford and O'Malley (2008)
7	*Trilepisium madagascariense*	51	Antimicrobial	Krief et al. (2006)
8	*Monodora myristica*	56	Food	Wrangham, Conklin, Chapman, and Hunt (1991)
9	*Chrysophyllum africanum*	74	Nesting	Ndiaye, Badji, Lindshield, and Pruetz (2018)
10	*Pycnanthus angolensis*	100	Food—nesting	Nakamura and Itoh (2015)

3.3 | Habitat loss

We estimated the total combined area of the three forest fragments studied to be ±18.15 km^2 (FG1 = ±0.96 km^2, FG2 = ±5.89 km^2 and FG3 = ±11.30 km^2) in 2017. We estimated the rate of forest loss between 2010 and 2015 as 6.11% for the three forest fragments combined. We observed the highest deforestation rate in FG2 as it has lost 12.40% of its forest cover during that period, versus 4.70% in FG1 and 2.88% in FG3. These three forest fragments are threatened by an accelerating rate of land conversion, beginning with logging and ending as agricultural fields and a source of charcoal production.

4 | DISCUSSION

4.1 | The Mbudha community compared to other isolated chimpanzee populations

In the three explored RAFALE fragments, our analysis of the truncated data set, led us to estimate chimpanzee density at 4.62 weaned individuals per km^2 of forested area (±18.15 km^2). An average of 1.12 chimpanzees/km^2 has been proposed for high altitude forests in other regions of DRC (Plumptre et al., 2010); the estimated chimpanzee density in RAFALE is 4.1 times higher. It is comparable to certain sections of Kibale in Uganda (1.5–5.1 individuals/km^2) (Plumptre et al., 2010)—the highest densities known for the species—Sebitoli in Uganda (2.5–4.9 individuals/km^2) (Bortolamiol, Cohen, Palibrk, & Krief, 2012) and Virunga National Park (3.66 individuals/km^2) (Plumptre et al., 2010). Based on direct observations, we estimated the Mbudha community to comprise at least 42 weaned and 10 unweaned chimpanzees (<5 years old), which give a total density of 2.3 weaned individuals/km^2. This is two times lower than that density estimation obtained through indirect distance sampling but we cannot exclude that additional—probably smaller—groups remained undetected as we only surveyed 15% of the forested area. Given the limited area we were able to survey during this pilot study, the total size of the RAFALE landscape chimpanzee population and its possible connection with communities present in other western forest fragments (±70 km^2 of forested area) remain unknown.

In RAFALE, chimpanzees occur up to 2,000 m and according to locals they used to occur up to 2,455 m on Mount Aboro which has been completely deforested over the past 50 years (Dz'na, personal observation). This is among the highest-altitude populations of the species known. Researchers have documented the densities and maximum altitude for chimpanzees in Nyungwe National Park in Rwanda at 2,750 m (Gross-Camp & Kaplin, 2005) with ±0.4 chimpanzee/km^2 (Wildlife Conservation Society, unpublished data), Kibira in Burundi at 2666 m (Hakizimana & Huynen, 2013) with 0.98/km^2 (Plumptre et al., 2010), or the highlands of Kahuzi-Biega National Park in DR Congo at 2,600 m with 1.23 chimpanzee/km^2 (Plumptre et al., 2010). In terms of comparable isolated fragments, the density at RAFALE is 2.7 times higher than that of isolated forest patches of Gishwati forest in Rwanda (1.7 individuals/km^2) (Chancellor, Rundus, & Nyandwi, 2017). All sites exhibit much lower densities than in RAFALE. The high densities of chimpanzees observed in these forest patches may be due to the topography and concentration of nest building sites in narrow mountain forest slopes in which only one transect can fit, and to the unknown local nest decay rate. It is also likely that chimpanzees may occur more densely in these tiny patches of forest, but that their density over all habitat's types in RAFALE is considerably lower. All of these

TABLE 4 Tree species used for nesting by chimpanzees in the relict altitude forests fragments of the Albert Lake escarpment, Democratic Republic of the Congo

Name of the species	Total number of nests	Diameter range (cm)[a]	Relative importance in the forest	Preference index for nesting	Rank
Monodora myristica	36	7.6–68	4.858	30.365	1
Strombosia scheffleri	12	26–90	2.088	9.577	2
Chrysophyllum gorungosanum	12	4.5–26	6.060	4.970	3
Trichilia rubescens	3	3.7–28	0.359	2.584	4
Manilkara sp.	3	20–70	0.425	2.507	5
Monodora angolensis	4	13–38.5	1.311	2.479	6
Chrysophyllum sp.	3	13–18	0.942	1.908	7
Pseudospondias microcarpa	8	14–35	5.642	1.456	8
Tabernaemontana stapfiana	4	50–90	2.605	0.978	9
Unidentified tree sp. 1	1	43.5	0.378	0.561	10
Albizia sp.	1	46	0.421	0.511	11
Rothmannia sp.	1	21.3	0.587	0.320	12
Vepris heterophylla	1	70	0.600	0.304	13
Rothmannia talbotii	2	10.5–38	1.465	0.300	14
Coelocaryon preussii	1	13	0.622	0.278	15
Cola gigantea	1	33.4	0.783	0.091	16
Celtis tessmannii	7	10–27.1	6.638	−0.700	17
Trilepisium madagascariense	4	15.5–50	4.460	−1.174	18
Unidentified Trichilia sp. 1	1	19.5	1.988	−1.259	19
Phoenix reclinata	1	25	2.819	−2.270	20
Bridelia sp.	1	21	2.926	−2.394	21
Chrysophyllum africanum	3	10–28	5.527	−3.411	22
Alstonia boonei	1	105	3.927	−3.555	23
Dracaena mannii	1	30.9	4.906	−4.691	24
Piptadeniastrum africanum	1	95	4.997	−4.797	25
Pycnanthus angolensis	3	16–43.6	7.695	−5.927	26
Agelaea sp.	1	15	—	—	—
Entandrophragma congoense	1	37	—	—	—
Beilschmiedia sp.	1	50	—	—	—
Drypetes sp.	4	20–74	—	—	—
Ficus sp.	1	120	—	—	—
Landolphia owariensis	1	4	—	—	—
Uvariopsis congensis	2	5–6	—	—	—
Fagaropsis angolensis	1	32	—	—	—
Polyscias fulva	3	60	—	—	—
Pterygota sp.	1	49	—	—	—

Note: The higher the positive value of the preference index, the more preferred the species is. If a nest was built on more than one support (tree or vine) these were taken into account (123 nest recorded on 132 stems). The preference index for 10 species used for nesting could not be estimated because they did not occur in botanical inventory plots.

[a] Single value—single nest or several nests on the same stem).

parameters will likely introduce a bias that future surveys will take into account.

These differences may arise from lower fruit diversity at higher altitudes (Hakizimana & Huynen, 2013) or to the effects of elevation and steep slope on seed persistence and germination in montane forests (Gross-Camp & Kaplin, 2005). This may influence the repeated use of particular foraging and nesting sites and seasonal variation of suitable nesting and foraging sites. As such, the existence of this newly documented chimpanzee population thriving at high altitudes and on steep slopes provides an exceptional opportunity to conduct research to broaden our knowledge of the behavioral range of the species.

4.2 | Population isolation and its possible impact on group dynamics and material culture

Recent anthropogenic fragmentation and increased edge effects may ultimately force forest biodiversity to find a way to cope with these new environments, or to go extinct. Besides humans, chimpanzees have few or no predators in these fragments. Human pressure is high in this region, with large areas of potential habitat recently being degraded by loggers and encroached upon by slash-and-burn farmers. We calculated that an average 6.11% of habitat in the three RAFALE fragments has been lost between 2010 and 2015 and that at the current rate they will disappear within the next 60 to 80 years. We can predict that due to its small size, isolation and high pressure from humans, FG1 will likely not be inhabited for much longer by chimpanzees unless urgent action is taken to protect them and their habitat. Villagers identified Yadha forest gallery (Figure 2) as a corridor between FG1 and FG2, and footage of individual chimpanzees confirmed movement between the three fragments. We know that other communities live in the Wago forest, 40 km to the west of FG3. However, our data does not allow us to infer if they are geographically, genetically and culturally isolated or if they are connected—via the fragmented landscape—with the Mbudha community. Movement along the escarpment may have allowed the RAFALE chimpanzee population to have been connected in the past to chimpanzees' populations inhabiting the great Ituri lowland forest (Hicks, Menken, Laudisoit, & Hart, 2019) or even to Ugandan chimpanzee populations to the east of Lake Albert such as Bugoma and Budongo (Gruber, 2013).

As observed for chimpanzees from other study sites, the Mbudha chimpanzees used tree species in proportions that did not correspond to their abundance (Samson & Hunt, 2014), suggesting that they prefer particular tree species in which to build their nests. Although we only observed one ground nest, we suggest that future studies should investigate the frequency of ground nesting and ground nest features throughout this area. In depth studies of the local chimpanzee population material culture, the use of tools (or lack thereof) (McGrew, 1992), nest construction techniques including ground nesting, hunting techniques (Hicks, Menken, et al., 2019), and diet may fill in an intriguing gap in our understanding of the ecological and behavioral differences between chimpanzee populations from northern DRC and Uganda. Given the marked difference in levels of tool-assisted insectivory in northern DRC (Hicks et al., 2019) compared to northern Uganda (Gruber, 2013), it will be interesting to establish where the RAFALE chimpanzee population lies on this scale.

The forest patches we explored were dominated by plant families that are known to be part of the diet, pharmacopoeial kit or nest building traditions of chimpanzees in other forests (Krief et al., 2006; Tweheyo, Lye, & Weladji, 2004). Although plant species with known anti-malarial (*Vernonia amygdalina*) (Koshimizu et al., 1994), anti-microbial (*Trilepisium madagascariense*) and anti-parasitic (*Trichilia rubescens)* (Krief et al., 2006) bioactive components are common in the area, their potential use by the Mbudha community, and possibly throughout the RAFALE population remains to be determined.

4.3 | Prospects for the Mbudha chimpanzees and the greater RAFALE population

Local people living around the forest do not traditionally eat chimpanzees due to their human-like qualities, which is a major cultural asset for the conservation of this population. Although the local hunters claim they do not target chimpanzees, the snares and traps used to hunt other species may also wound or kill chimpanzees. In addition, the shrinking of these forests incurs the risk that the frequency of antagonistic encounters with humans will increase (McLennan, 2008) which may also lead to an increased exposure to anthropozoonotic pathogens (Guégan, Ayouba, Cappelle, & De Thoisy, 2020). Education and sensibilization are therefore key to maintaining healthy relationships between local people and primates in the area. Identifying corridors used by chimpanzees and restoring degraded corridors between adjacent fragments will be critical in ensuring their long-term survival along the escarpment. Hence, immediate actions must be taken to stop illegal logging, and to empower local communities to manage the area and pursue forest restoration. Local scientists, traditional leaders and village authorities are currently using community mapping to improve the management and protection of their resources. Unfortunately, recent political turmoil and the incursion of armed fighters makes planning difficult for this region (International Crisis Group, 2020).

The RAFALE chimpanzee population, including the Mbudha community, offers an excellent opportunity to achieve the conservation goals of the IUCN Primate Species Specialist Group because it (a) adds a new population on the map for eastern chimpanzees with possible site-specific behavior (nesting, hunting, tool use, diet), (b) is located outside current Chimpanzee Conservation Units (CCUs), and (c) represents a disjunct population living under unique ecological conditions (Plumptre et al., 2010). Moreover, the protection of these chimpanzees and the forests in which they occur would allow the conservation of the vulnerable Oustalet's red colobus monkey (*Piliocolobus oustaleti*; Hart et al., 2019) and endangered pangolins (*Phataginus* spp.) (Khwaja et al., 2019) as well as the 26 other mammal species recorded in this area. A more comprehensive assessment of the overall size of the chimpanzee population inhabiting this part of the Congolese Albertine Rift, the interconnectivity of their communities, their resilience to habitat fragmentation via the use of forest corridors, and the possibility that they may have developed characteristic cultural traits to adapt to their fragmented mountainous habitat is required to fully value the importance of this chimpanzee population. Such knowledge is essential to promote the conservation of these chimpanzees and their habitat and may help to develop a proposal declaring the RAFALE landscape a new Chimpanzee Conservation Unit (CCU) and to assist the local communities design a sustainable conservation plan for the benefit of people and wildlife alike.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICS STATEMENT

The study protocol has been approved by the scientific board of the University of Kisangani, which also issued the research permit and sampling authorizations and acknowledged our compliance with local guidelines. Because we only gathered non-invasive samples (faeces and hairs from nests), there was no need for additional ethical review. We observed the chimpanzees from a distance without making any attempts to contact them or to affect their behavior.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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