International Journal of Primatology (2022) 43:867–884
https://doi.org/10.1007/s10764-022-00303-0

Forest Landscape Restoration Contributes to the Conservation of Primates in the Gishwati-Mukura Landscape, Rwanda

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Received: 23 October 2021 / Accepted: 17 May 2022 / Published online: 7 June 2022

Abstract

Land-use change is the main driver of habitat loss and fragmentation for primates, resulting in declines in species diversity and population size. The Gishwati-Mukura landscape in Rwanda, home to endemic and threatened primate species, is characterized by heavily degraded and fragmented forest fragments, including one remnant tropical montane forest, one restored forest, and several forests planted in the mid-1980s with exotic species. A landscape restoration project was launched in 2014 to restore and protect this landscape and improve human wellbeing. From June to August 2019, we assessed the use of remnant, restored, and exotic forest patches by primates in this landscape. Using 15 line transects and 7 reconnaissance surveys, we compared distribution and abundance of Endangered golden monkeys (*Cercopithecus mitis kandti*), Vulnerable L'Hoest's monkeys (*Allochrocebus lhoesti*), and Endangered eastern chimpanzees (*Pan troglodytes schweinfurthi*) between remnant tropical montane forest and restored forest and ascertained the presence of primates in planted forest patches in the Gishwati-Mukura landscape. We interviewed farmers (N = 97) to assess the frequency of human-primate conflicts associated with the remnant and restored forests. We found that all three primate species occupied the remnant tropical montane forest, chimpanzees and golden monkeys occurred in the restored forest, and only golden monkeys inhabited the exotic planted forest fragments. For all three species, encounter rates were higher in the remnant tropical montane forest than in the restored and planted forest fragments. The restored forest provided additional habitat for primates, and efforts to restore degraded forest appear to have reduced conflicts between communities and primates.

Keywords Crop foraging · Primate distribution · Forest fragments · Landscape restoration

Handling Editor: Joanna Setchell.

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Introduction

Ongoing land-use change is leading to loss and fragmentation of habitat for primates worldwide (Cowlishaw, 1999; Estrada et al., 2017; Fahrig, 1997; Marsh & Chapman, 2013; Schwitzer et al., 2011). Land use change results in small and isolated forest fragments, and declines in species diversity and population size (Fahrig, 1997, 2003; Ickes et al., 2012; Irwin, 2006; Laurance et al., 2002). With more than 75% of the populations of nonhuman primate species declining due to human activities, and approximately 60% of all primate species in danger of extinction (Estrada et al., 2017; Rylands et al., 2008), land use change is an especially critical issue for primate conservation. Land use and land cover changes can cause primate populations to be more exposed to hunting activity for bushmeat (Bicca-Marques, 2003) and conflicts with humans (Hill, 2000; Mekonnen et al., 2018; Ukizintambara, 2008). Some primate populations have adopted crop foraging behaviors when the surrounding landscape is dominated by agricultural crops or when there are limited food resources available, such as fruit (Baranga et al., 2012; Campbell-Smith et al., 2010; Hill, 2018; Naughton-Treves, 1998; Newton-Fisher, 1999). Indeed, primates must adapt quickly to changing landscape conditions or their populations will decline and eventually go extinct (Estrada et al., 2017; Schwitzer et al., 2011). Forest-associated primates that have the ability to use small fragments of forest and nonforest habitats (e.g., anthropogenic habitats, such as cropland and plantation), are more likely to persist following land use and other environmental changes (Arroyo-Rodríguez et al., 2013; Onderdonk & Chapman, 2000).

Forest landscape restoration is a key approach to return ecological function in deforested or degraded forest landscapes, while also improving human well-being. Through emerging global restoration efforts, such as the Bonn Challenge (https://www.bonnchallenge.org/), tropical forest cover is being restored as part of national forest landscape restoration initiatives (Chazdon & Uriarte, 2016). These restoration efforts aim to provide ecological and social benefits, as well as mitigate the effects of climate change, with a common goal of restoring 350 million hectares of forest globally by 2030 (Chazdon & Uriarte, 2016; Mansourian et al., 2017). Since 2011, 74 countries (including 31 African countries) pledged to provide more than 200 million hectares into the forest and landscape restoration efforts (IUCN and WRI, 2014). Forest and landscape restoration initiatives have the potential to support the conservation and recovery of primate populations. Restoring forest functions has already created new opportunities for people and primates (Chazdon et al., 2020; Hanya et al., 2005; Merker et al., 2005). For example, *Cercopithecus* species from Kibale National Park in Uganda and Kakamega forest in Kenya (Chapman et al., 2000; Fashing et al., 2012; Twinomugisha et al., 2007; Vié et al., 2009), chimpanzees (*Pan troglodytes schweinfurthii*) from Gombe National Park, Tanzania (Goodall, 2015), and black-and-white colobus monkey (*Colobus angolensis palliates*) from Diani forest in Kenya (Dunham, 2017) use regenerating or secondary forests and planted forests. Forest restoration also has helped with the recovery of six primate species, including

redtail monkeys (*Cercopithecus ascanius*), mangabeys (*Lophocebus albigena*), olive baboons (*Papio anubis*), blue monkeys (*Cercopithecus mitis*), red colobus (*Procolobus rufomitratus*), and black-and-white colobus (*Colobus guereza*) in the Kibale forest in Uganda (Chapman et al., 2018).

In the Albertine Rift region of Central and East Africa, forest loss and fragmentation threaten several primate species, especially endemic species or those that range in small, isolated high-elevation montane forests (Ayebare et al., 2018; Plumptre et al., 2007; Ponce-Reyes et al., 2017; Salerno et al., 2018). These threats are particularly strong in western Rwanda, which has experienced significant forest cover loss due to agricultural transformation (e.g., tea, *Pyrethrum*, pine plantations, pasture land) and pressure due to the very high human population density in this region, with of 458 people per km^2 and up to 1,000 people per km^2 around protected areas (NISR, 2012). The Gishwati Forest in western Rwanda has suffered substantial forest cover loss and fragmentation, initially due to animal husbandry and pine plantation projects funded by the World Bank in the early 1980s, followed by further forest conversion to farm land in the 1990s (Plumptre et al., 2001). As a result, Gishwati Forest cover dropped dramatically from 280 km^2 in the 1970s to ~174 km^2 in early 1980s; forest conversion in the 1990s resulted in further forest cover loss leaving 9.6 km^2 in 2003 (Arakwiye et al., 2021; Nyandwi & Mukashema, 2011). The Government of Rwanda has pledged to restore two million hectares under the Bonn Challenge (MINIRENA, 2014). To reverse fragmentation and forest cover loss of Gishwati Forest, the Government and conservation partners initiated a program in 2014 to restore degraded tropical montane forest (Clay, 2019). This restoration project has the potential to help protect the threatened primate populations residing in the Gishwati Forest, but an evaluation is needed to understand how primates use this rehabilitated landscape. A recent study found out that tree species richness, tree density, proportion of native tree species, and diameter at breast height in the montane forest fragment are higher than in the restored forest fragment (Arakwiye, 2020).

In this study, we investigated how primates are responding to landscape restoration in the Gishwati-Mukura landscape of Rwanda and whether the restoration is benefiting conservation of primates. Specifically, we assessed the distribution of three diurnal primate species, the Endangered and endemic golden monkey (*Cercopithecus mitis kandti*, synonyms: *Cercopithecus kandti*), L'Hoest's monkey (*Allochrocebus lhoesti*), and the Endangered eastern chimpanzee (*Pan troglodytes schweinfurthii*), one remnant tropical montane forest fragment, one restored forest fragment, and several forests fragments planted with exotic species following restoration and conservation initiatives. We addressed the following questions: (i) how do primates respond to forest restoration in the Gishwati-Mukura landscape, and (ii) what is the relationship between forest restoration and crop foraging around the Gishwati-Mukura National Park? We hypothesized that primates would colonize restored forest and that efforts to restore the degraded forests would increase suitable habitat for primates, leading to a decrease in conflicts between local communities and primates. We predicted that primates would have started using the restored forest fragment.

Methods

Study Site and Species

The Gishwati-Mukura landscape includes one remnant tropical montane forest fragment, one restored forest fragment with predominantly native tree species which was previously degraded forest, and several forest fragments planted with exotic species in mid-1980s in areas that had been deforested in early 1980s (Arakwiye et al., 2021; Nyandwi & Mukashema, 2011) (Figure 1). These forest fragments are located between 2000 m and 2500 m of elevation, where average annual rainfall is 1,884 mm, and temperature ranges between 15.7 °C and 24.2 °C (Chancelloret al., 2012a). The remnant tropical montane forest fragment and restored forest fragment were gazetted as the Gishwati-Mukura National Park in 2016 due to their international importance for a number of threatened and endemic species.

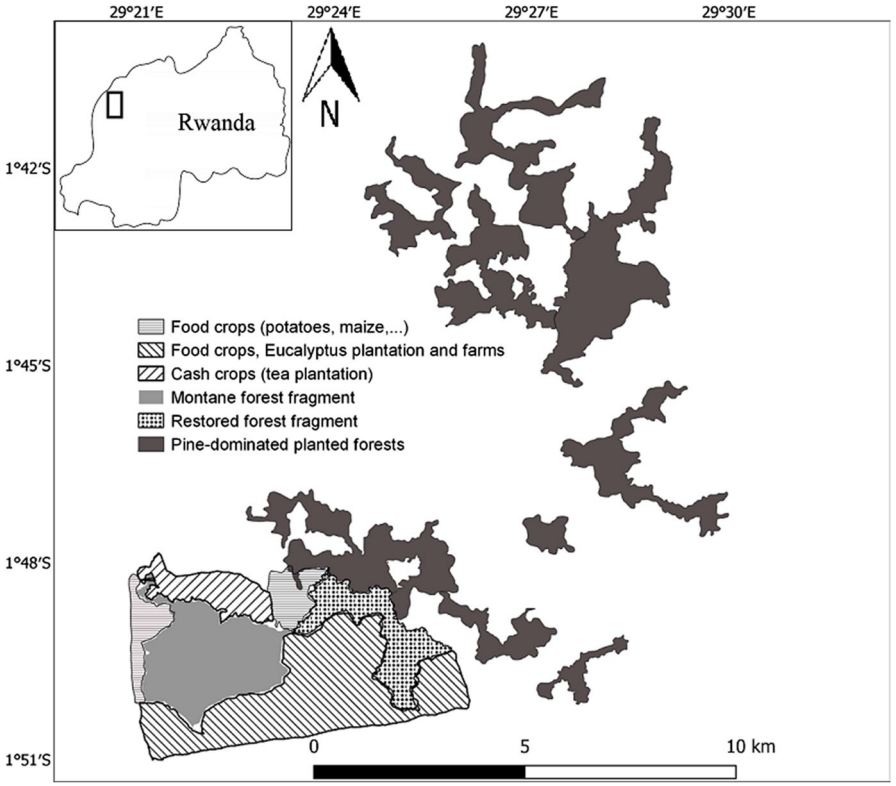

Figure 1 Location of the study areas in the Gishwati-Mukura landscape with one remnant tropical montane forest fragment (grey) and one restored forest fragment (dotted), and several pine-dominated planted forests initiated in mid-1980s (black); both remnant montane and restored forest fragments are surrounded by agriculture crops (food and cash crops), whereas the planted forests are surrounded by pasture lands (white).

The remnant montane forest (9.6 km^2) is characterized by fruit producing tree species typical of afromonontane forest, mainly *Symphonia globulifera*, *Alangium chinense*, *Polyscias fulva*, *Maesa lanceolata*, *Albizia gummifera*, and *Ilex mitis.* The restored forest (5.6 km^2) is connected to the remnant tropical montane forest by a narrow corridor of ~500 m in length and ~50-170 m in width, composed of bamboo stands (*Yushania alpina)* mixed with *Xymalos monospora*, *Maesa lanceolata*, and *Polyscias fulva*, and a few exotic tree species including *Acacia mearnsii* (Arakwiye, 2020; REMA, 2015). The planted forest fragments were established in the mid-1980s (~40 km^2) after clearing the native forest in early 1980s. These planted forest patches are dominated by introduced tree taxa, mostly *Pinus* spp., a few *Eucalyptus* spp. and *Cupressus* spp. (Arakwiye, 2020; Ngabikwiye, 2019). All forest fragments are separated by farm and pasture lands (Figure 1).

The remnant tropical montane forest (the Gishwati Forest) hosts three diurnal primate species, the golden monkey, the L'Hoest's monkey, the eastern chimpanzee, and an unidentified nocturnal bushbaby species (*Galago* sp.) (Chancellor et al., 2012a). Only one of several golden monkey groups in the Gishwati population is habituated to human presence (~30 individuals) and had an estimated home range of up to ~151 ha (Tuyisingize et al., 2022). A L'Hoest monkey group (~29 individuals) used a home range of ~117 ha (Kaplin, 2001) and a chimpanzee community used a home range of ~4,000 ha (~67 individuals) in a neighboring forest, Nyungwe National Park (Green et al., 2020). Studies from 2009 showed that primates were the main crop foraging animals around the Gishwati natural forest (McGuinness & Taylor, 2014).

Data Collection

We collected data from June to August 2019. Following the distance sampling method (Buckland et al., 2010a), we surveyed a total of 15 line transects (between 0.75 and 3.2 km in length) three times each during this time period, including nine line transects located at 400-m intervals in the remnant tropical montane forest and six line transects placed at 600-m intervals located in the restored forest (Figures 2a, b). In the planted forests, we surveyed primates using seven existing trails (2-7 km of length) called reconnaissance surveys or recce trails (White & Edward, 2000) as a quick method for covering large areas with minimal disturbance (Figure 2c); each of these existing trails was visited three times during the study period.

We moved along transect lines and recce trails at 1 km/hour (Peres, 1999), recording the presence of each primate species encountered. At each encounter of a monkey (golden monkey or L'Hoest's monkey), we recorded the GPS location, the detection angles using a Meridian PRO Sighting Compass, the sighting distance from the observer to the individual or the center of the group using a Bushnell 7x26 laser rangefinder, the number of individuals in a group and the vegetation type (Buckland et al., 2010b; Peres, 1999). We identified monkeys based on direct sightings and on the golden monkey's "pyow" call, which is not made by the L'Hoest's monkey.

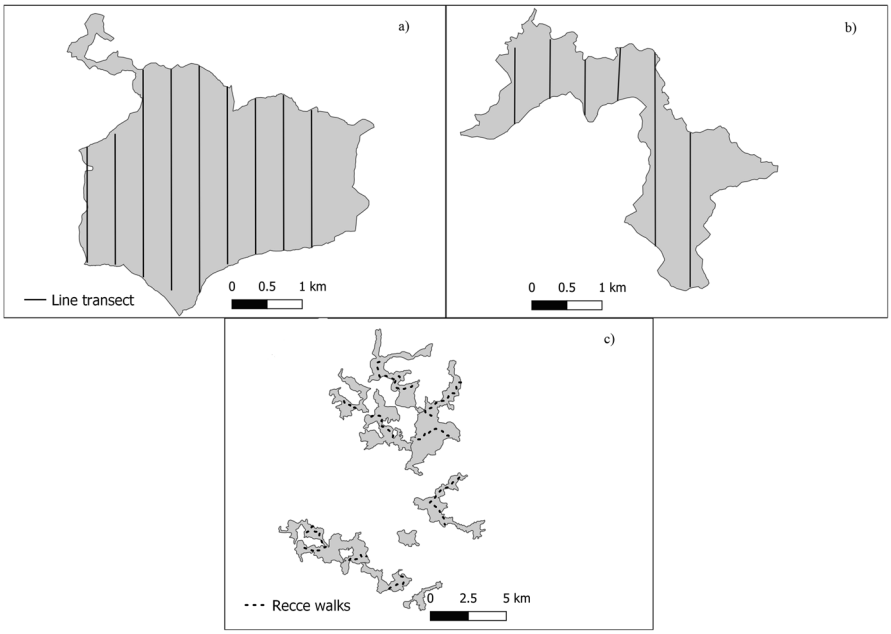

Figure 2 Location of line transects and recce walks in (**a**) the tropical montane forest, (**b**) the restored forest, (**c**) the pine-dominated forest planted in mid-1980s in Gishwati-Mukura landscape, Rwanda.

To collect data on the distribution of chimpanzees, we counted all nests (individual nests) and marked them to avoid recounts (Tutin & Fernandez, 1984). We also recorded GPS coordinates for all nests. We measured the perpendicular distance from the transect line to the tree trunk hosting each nest. For any direct observations of chimpanzees during transect walks, we counted the observed individuals and collected GPS coordinates.

Crop Foraging Incidences

As previous studies on crop foraging around the montane and restored forest fragments found that most crop foraging occurs within 200 m of the forest edge (McGuinness & Taylor, 2014; Naughton-Treves, 1998), we collected data about crop foraging incidences (direct observation of presence and absence of primates in people's fields) within 200 m from the remnant tropical montane forest and restored forests. We did not collect crop foraging data around planted forests, because no crop foraging incidences were reported near this type of forest (anonymous pasture owners, personal communication). Pasture lands, the dominant land-use type around the planted forests, act as a buffer between planted forests and crop fields (Hill, 1997).

To collect crop foraging incidence data, we walked ~31 km around the remnant tropical montane forest and the restored forest counterclockwise starting from the south (at 1° 71´ S, 29° 35´ E) (Figure 1). We interviewed any landowners encountered during these walks (older than age 21 years). Landowners could decide whether or not to participate and to which question they wanted to respond. If both a man and woman were encountered together, we allowed them to decide who would respond. We asked whether any primate species had been observed in the field or farm. If any crop foraging incident had occurred during the past 12 months (from July 2018 to June 2019), we asked what species foraged on their crops, if the owners engaged in crop foraging mitigation activities, and how the intensity of crop foraging (high = >60%, medium = between 20-50%, and low = <10%) compared with the previous 3 years (between July 2017- June 2018, and between July 2015-June 2017). Because respondents remembered better the past 2 years, our analyses focused on the comparison between July 2017-June 2018 and July 2018-June 2019.

Data Analysis

We performed statistical analyses using R package "Distance" to fit detection functions and estimate the abundance and density of primates from measurements of perpendicular distances to the transect lines (Buckland et al., 2010c; Miller et al., 2019). We calculated density of chimpanzee nests based only on individual nests as we had enough field sightings (70 individual nests) to calculate reliable nest density (Buckland et al., 2010c; Furuichi et al., 2001; Plumptre & Reynolds, 1997). We used the "ds" function to fit detection functions. We compared and selected our best models (hazard rate and half-normal) using the Akaike information criterion (AIC). We performed the unweighted Cramér-von Mises test to check whether our models fit the data well (Miller et al., 2019). We used forest type (montane and restored forests) as a covariate and allowed each forest type to have its own detection function. We only once encountered chimpanzees (5 individuals) along line transects in the remnant tropical montane forest, so chimpanzee direct sightings were not included in our analysis. Given that we had few observations of golden monkeys (19 observations) and L'Hoest's monkeys (12 observations), we only calculated encounter rates (number of groups/km walked) and mean group size.

When fitting the detection functions, we truncated the detections at 20 m for chimpanzee nests. As animal densities cannot be estimated from recce walks data, we only calculated encounter rates and mean group size for the primates living in planted forests.

To evaluate the incidence of crop foraging, we calculated the percentage of respondents reporting incidents for each species, along with the type of crop foraged on. We ran chi-square tests to determine whether there was a significant difference between participants reporting crop foraging incidences and those who did not report crop foraging incidences between July 2017 and June 2018 and between July 2018 and June 2019.

Ethical note

Field research permits were provided by Rwanda Development Board. The research proposal was approved by the University of Rwanda. Participants in the interviews were briefed on the purposes of the study and given the opportunity to end their participation in the study at any time. We sought verbal consent from participants before the interviews, which lasted less than 10 min per person. Ethical considerations of anonymity, right of refusal, and clarity of outcomes were adhered to, and no names were recorded. We followed the International Primatological Society code of best practices for field primatology (Riley et al., 2014).

Data availability The data that support the statistical findings of this study are available from the corresponding author upon reasonable request.

Results

Primate Distribution

We surveyed a total of 88.25 km of line transects, including 63.55 km in the remnant tropical montane forest and 24.7 km in the restored forest. We also collected data along 57 km of reconnaissance walks in forests planted in the mid-1980s. We found all three primate species—chimpanzees, golden monkeys, and L'Hoest's monkeys—in the remnant tropical montane forest. We observed only golden monkeys and chimpanzees in the restored forest, and golden monkeys were the only species found in the *Pinus*-dominated planted forest patches (forests planted in the mid-1980s) (Figure 3).

Golden monkey and chimpanzee encounter rates were higher in the remnant tropical montane forest than in the restored forest (Table I). The unweighted Cramer-von Mises test indicated that the half-normal detection function with forest type as a covariate fitted best chimpanzee nest data (test statistic = 0.05, $p = 0.9$). The associated mean individual detection probability was 0.359 (0.48 in montane forest and 0.1 in restored forest; Figure 4). The individual nest density in the montane forest overlapped with individual nest density in restored forest (Table I). In forests planted in mid-1980s, we observed 15 golden monkey groups (range: 4-18 individuals) at an encounter rate of 0.26 per km; mean group size was 11.5 (4-18) individuals.

Crop Foraging Incidences

We interviewed 97 farmers (55 females and 42 males) around the tropical montane forest and restored forest fragments. Between July 2017 and June 2018, 72% of the farmers reported that primates had foraged on their crops in the previous 12 months. This percentage declined to 43% between July 2018 and June 2019 ($\chi^2 = 4.41$, $p = 0.03$). Crops grown within 200 m of the tropical montane forest and restored forest

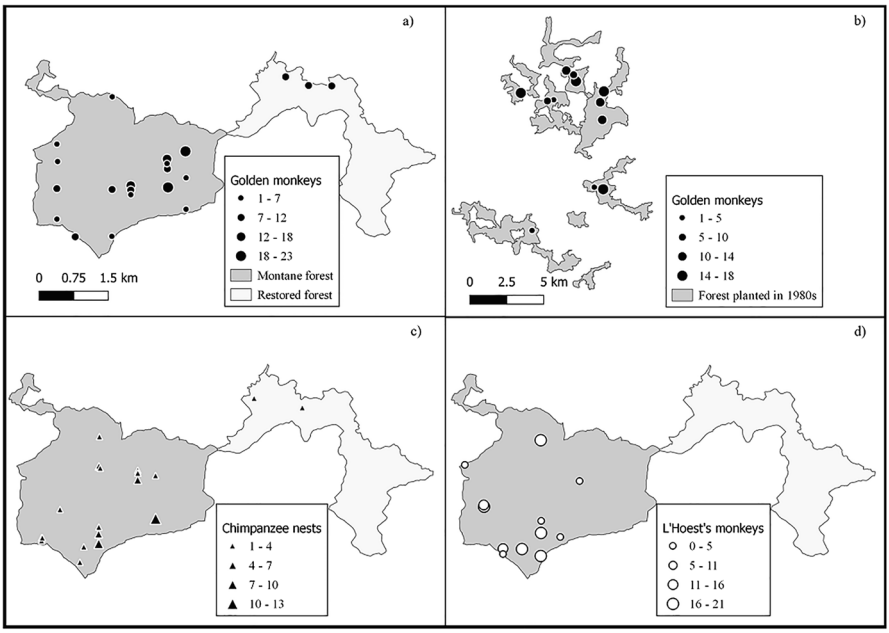

Figure 3 Location of direct observations of golden monkeys (**a**), the distribution of golden monkey sightings in planted forests (**b**), and (**c**) chimpanzee nests in the remnant tropical montane forest and the restored forest in Gishwati-Mukura landscape, Rwanda. (**d**) Direct observations of L'Hoest's monkeys.

Table I Results of primate (chimpanzee, golden monkey, L'Hoest's monkey) transect surveys conducted in the tropical montane and restored forests of Gishwati, part of Gishwati-Mukura National Park, Rwanda between June and August 2019

	Golden monkey	L'Hoest's monkey	Chimpanzee nests
Montane forest			
# Observations	19	12	70 (19 clusters)
Encounter rate (groups per km)	0.3	0.19	1.1
Group size range	2-23	4-21	2-13
Mean group size (95% CI)	11.8 (2-23)	13.4 (4-21)	4.2 (2-13)
Individual nest density (95% CI)	NA	NA	0.54 (0.21-1.39)
Restored forest			
# Observations	3	0	8 (3 clusters)
Encounter rate (groups per km)	0.12		0.32
Group size range	8-11	0	2-4
Mean group size (95% CI)	9.7 (8-11)	0	2.7 (2-4)
Individual nest density (95% CI)	NA	NA	0.77 (0.17-3.52)

NA, not applicable

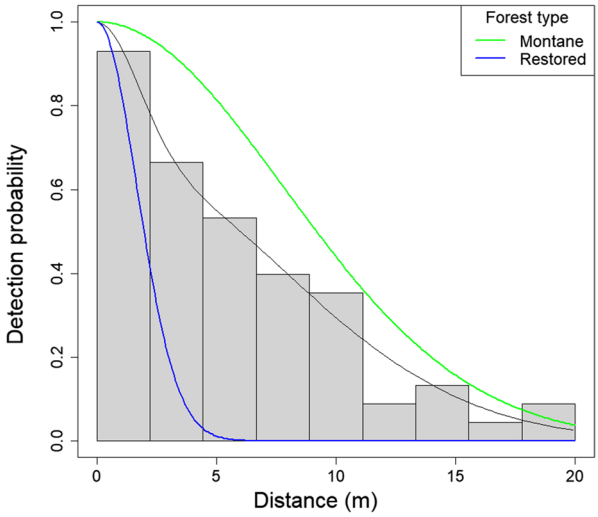

Figure 4 Detection probability of chimpanzee nests in the montane and restored forests in Gishwati-Mukura National Park, Rwanda, between June and August 2019. Black line denotes mean detection probability. Blue line denotes detection probability in restored forest. Green line denotes detection probability in montane forest.

included corn (*Zea mays*) also known as maize, potatoes (*Solanum tuberosum*), beans (*Phaseolus vulgaris*), peas (*Pisum sativum*), and sweet potatoes (*Ipomoea batatas*). The proportion of farmers that identified corn-foraging was the largest (64% of farmers mentioned this crop) followed by potatoes (20%) and peas (11%). All respondents reported having lost crops to L'Hoest monkeys, golden monkeys, and chimpanzees in previous years, mainly between July 2015 and June 2017 and between July 2017 and June 2018. Respondents perceived a decline in crop foraging incidences by primate species, especially by chimpanzees and golden monkeys. All of the reported incidents due to chimpanzees and golden monkeys occurred before July 2018. After that date, all incidents were due to L'Hoest's monkeys, and less than 10% of the interviewed farmers reported having observed chimpanzees and golden monkeys at the edge of the forest and never on people's farmland (Figure 5). To deter crop foraging, 89% of the farmers said that they protected their crops by guarding them during the day.

Discussion

The primate populations in the remnant tropical montane forest fragment, newly gazetted as part of the Gishwati-Mukura National Park, appear to be relatively stable or possibly increasing. The density of chimpanzee nests estimated in this remnant montane forest fragment is similar to previous estimates in Gishwati Forest (range: 1.01 and 2.15/km^2) (Barakabuye et al., 2007). In the montane forest, the golden monkey encounter rate (0.3 sightings/km) was greater than (0.16 sightings/km) previously reported from a study conducted between 2017 and 2018 (Tuyisingize et al., 2022), but this difference might be related to small sample size. Furthermore, encounter rates for L'Hoest's monkeys were high compared to estimates from the nearby Nyungwe National Park (0.01-0.14 sightings/km), while encounter rate for

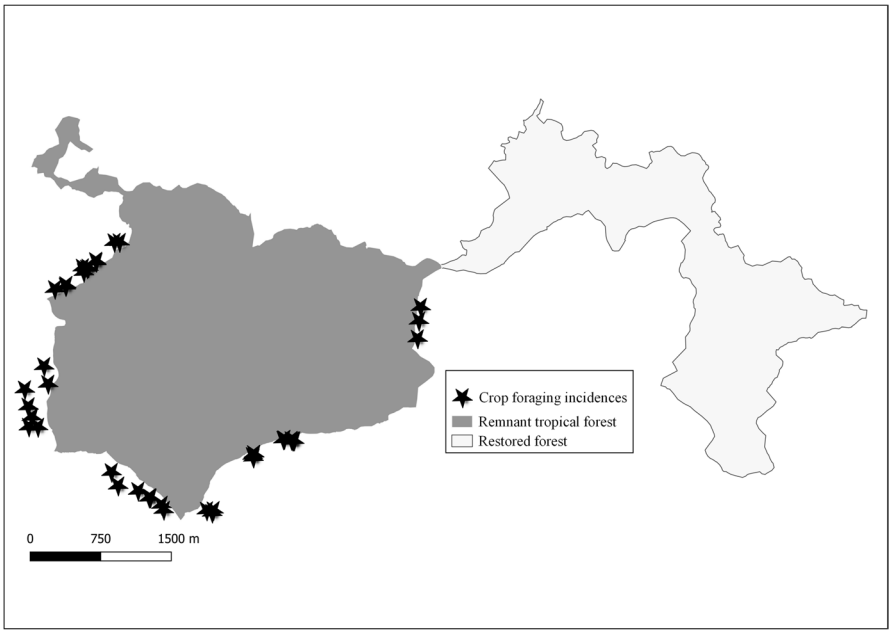

Figure 5 Distribution of crop foraging incidences by primates around the remnant montane forest fragment and the restored forest fragment of the Gishwati-Mukura landscape between July 2018 and August 2019. All of these incidents were due to L'Hoest's monkeys, which only occurred in the montane forest fragment.

chimpanzees nests in the Gishwati Forest overlaps (0.14-1.57 sightings/km) with the encounter rate of chimpanzee nests in Nyungwe National Park (Easton et al., 2011; Kaplin, 2014).

Compared with previous surveys in the study area (Barakabuye et al., 2007; Chancellor et al., 2012b; Tuyisingize et al., 2022), our findings show that primates are expanding their range from the remnant montane forest to the restored forest fragment in the Gishwati-Mukura landscape. Field staff reported seeing a few chimpanzees (~3 individuals) and a small group of golden monkeys (~9 individuals) crossing to the restored forest fragment from the montane forest fragment after 2016, and researchers observed a few chimpanzee nests in the restored forest fragment after 2018 (Chancellor, personal communication, 2021). We observed golden monkeys, L'Hoest's monkeys, and chimpanzees in the remnant tropical montane forest, but we also observed golden monkeys and chimpanzees in the restored forest fragment, whereas golden monkeys only used the exotic planted forest patches initiated in the mid-1980s. Furthermore, chimpanzee nest density did not differ significantly between the montane forest and the restored forest fragment. Most of chimpanzee nests were found in *Macaranga kilimandscharica* and *Symphonia globulifera* (D. Tuyisingize, personal communication, 2018-2019). Further studies on seasonality and availability of key food are needed to understand the capacity of the restored forest fragment to sustain primates. We also recommend additional studies with a larger sampling effort in both the montane and restored forest

fragments to generate accurate density estimates of all Gishwati primate species and to monitor trends over time.

The remnant tropical montane forest fragment is less disturbed and contains a greater diversity of native food plants than the restored forest fragment (Arakwiye, 2020; Bizuru et al., 2015; Chancellor et al., 2012b). The undergrowth vegetation is dominated by native perennial herbs and vines (e.g., ferns, *Sericostachys scandens*) in montane forest fragments and by ruderal plants (mostly Asteraceae family) in restored fragments (D. Tuyisingize, personal communication, 2019). In the montane forest fragment, chimpanzees and golden monkeys relied on fruiting trees and fed on fallback foods (leaves) during the low-fruit period (Chancellor et al., 2012b; Tuyisingize et al., 2021), while they are suspected to feed mainly on fallback food in the restored forest fragment. The golden monkey population living in the planted forests mainly feed on *Pinus* spp. and *Acacia* spp. trees, and a few other plant species available in these forests (Ngabikwiye, 2019).

Current and previous primate species distribution patterns suggest that the remnant tropical montane forest served as refuge site for primates during the periods of forest destruction in this Gishwati-Mukura landscape from the 1980s to 1990s. Our findings show that primates have dispersed to other forest patches in this landscape as it has been protected and restored. Golden monkeys occupied the forest planted in mid-1980s during the 1990s forest conversion period (local community, personal communication). As observed in golden monkeys in Mgahinga National Park, Uganda (Twinomugisha et al., 2007), and chimpanzees in the Taï National Park, Ivory Coast, and Gombe National Park, Tanzania (Goodall, 2015; Marchesi et al., 1995), the restored forest fragment may represent new habitat for primates in the Gishwati-Mukura landscape, benefiting from the new protection afforded by the recent gazettement of national park status. There was no evidence that L'Hoest's monkeys were present in the restored forest fragment. This species feeds on a larger proportion of terrestrial herbaceous vegetation typical of tropical montane forest than conspecific *Cercopithecus* monkeys (Kaplin & Moermond, 2000), which may have kept them in the remnant tropical montane forest rather than expanding to restored forest where the availability of terrestrial herbaceous vegetation may be limited.

This study provides evidence of the presence of Endangered golden monkeys in the pine-dominated planted forest fragments, composed mainly of exotic tree species, within the Gishwati-Mukura landscape. Individuals living in the vicinity of the forest fragments said that golden monkeys may have colonized the planted forest fragments bordering the remnant tropical montane forest fragment during forest conversion to farmland in the 1990s (personal communication, 24 July 2019). The remnant tropical montane forest declined from 280 km^2 to less than 10 km^2 between 1995 and 2000 (Nyandwi & Mukashema, 2011). We did not find signs of chimpanzees or L'Hoest's monkeys in planted forests. Compared with these other sympatric primate species (chimpanzees and L'Hoest's monkeys), golden monkeys may have greater ability and flexibility to adapt to new habitats (Chancellor et al., 2012b; Chapman et al., 2002; Kaplin, 2001; Tuyisingize et al., 2021), which enabled them to include exotic plant species in their diet. The restoration of the Gishwati-Mukura landscape may provide protection and connectivity for the primates that range

between the fragments comprising this landscape, and further studies are needed to document movements and use of the different fragments over time. Studies also are needed to understand factors limiting the chimpanzees and L'Hoest's monkeys from colonizing planted forests and to determine the demography and health of the golden monkey populations using forests planted with exotic species.

Farmers reported that crop-foraging had reduced, potentially owing to the ongoing efforts to protect and restore the Gishwati Forest, as suggested by some farmers. Previous studies reported both chimpanzees and monkeys (golden monkeys and L'Hoest monkeys) as crop foragers (McGuinness & Taylor, 2014; Rundus et al., 2022), but we found that L'Hoest's monkeys were the only crop foraging primate species. The recent landscape restoration initiatives, including the forest restoration, and the establishment of the Gishwati-Mukura National Park may have increased habitat availability for the primates, including fruiting trees and bamboo shoots preferred by the primates in this study, which may have reduced conflicts between primates and people. Given that the tropical forest remnant is very small, the incidence of crop foraging should be closely monitored as primate populations may grow due to improved protection, which may result in increasing crop foraging incidences. Climate change could also change or reduce food resource availability for the primates inside the park and force primates to adapt to and rely more on alternative food resources in the surrounding farmlands (Estrada et al., 2017; Graham et al., 2016). Crop-foragers are influenced by proximity of fields to their habitats or by the types of crops grown around the forest (Hill, 1997). It thus may be advantageous to encourage local farmers to plant alternative crops (nonpalatable plants for primates) or vegetation barriers (see Wallace & Hill, 2016, for crop foraging mitigation strategies in western Uganda) and to promote pasture lands near the forest and move palatable crops away from the park boundary to mitigate existing and future conflicts between agricultural crop production and the Gishwati primates (Rundus et al., 2022).

Conclusions and Recommendations

This study highlights the importance of forest landscape restoration to increase available habitat for primates and reduce human-wildlife conflicts. We found uneven distribution of primate species in the Gishwati-Mukura landscape most likely related to their species-specific adaptability to different habitats and food resources. Given that we found golden monkeys using the planted forests dominated by exotic tree species, further studies are needed to ascertain whether the planted forest fragments represent ecological "traps" or "sinks" for the primates in this landscape (Dias, 1996; Robertson & Hutto, 2006). Future studies are needed to investigate and compare birth rates and mortality, diet, activity budget, and energetic balance of primates inhabiting the different forest types to understand habitat effects on fitness, health, and survival. Given that L'Hoest's monkeys are semiterrestrial, forest-adapted monkeys (Kaplin & Moermond, 2000), a better understanding of their ecological niche and adaptive capacity in the remnant tropical montane forest is needed to understand why they are not using the restored forest in this landscape.

We show that forest landscape restoration efforts may contribute to the conservation of primates, particularly golden monkeys and chimpanzees. We propose that such forest restoration may also benefit those golden monkeys which currently range in pine-dominated planted forests owned by communities (Oldekop et al., 2016). For example, owners of planted forests could be encouraged to plant native tree species which can provide food resources for golden monkeys (see Tuyisingize et al., 2021, for a list of food plants in the Gishwati Forest), and all planted forest fragments could be connected to the Gishwati-Mukura National Park. Because the Gishwati primates, as frugivorous species, need relatively large ranges with adequate supplies of fruiting species and fall-back foods (Chancellor et al., 2017; Tuyisingize et al., 2021), it is important to continue the forest restoration actions using plants that are known primate foods, and consider future forest extension strategies that include adjacent peoples' rights and development needs (Nelson, 2010) and planting of appropriate montane tropical forest species.

Acknowledgements Much of the work was funded through a collaborative agreement between the Rwanda Environment Management Authority and the Center of Excellence in Biodiversity and Natural Resource Management at University of Rwanda which supported impact research in the Landscape Approach to Forest Restoration and Conservation (LAFREC) project. The authors are grateful to the University of Rwanda's Center of Excellence in Biodiversity and Natural Resource Management (UR-CoEB), which managed this project, organized, and coordinated the training and workshops, and managed the financial and reporting aspects with REMA. Further funding was provided by The Dian Fossey Gorilla Fund. They are grateful to field assistants namely Noel Turikumwe, and Rwamucyo Rudacogora who helped in making this study feasible. They thank Dr. Eric Rexstad for guidance on data analysis using DISTANCE software, and anonymous reviewers and editors of this revised manuscript.

Author contributions DT conceived and designed the study, helped in data collection, data analysis, interpretation, and manuscript writing; WE and DC helped in results interpretation, and manuscript writing; MN helped with field data collection and data entry; BAK contributed to the design of the study, helped in results interpretation, and manuscript writing. All authors provided comments and approved the final manuscript.

Declarations

Conflicts of interests No conflicts of interest reported by the authors.

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