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New Southernmost Limit for Chimpanzee Tool-making: Termite Fishing in the Loasi Forest Reserve (Tanzania)

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Abstract: Tool use by wild chimpanzees (*Pan troglodytes*) is well documented across the African continent, offering one of the best examples of chimpanzee technological and cultural variation. However, data from populations living at the species' biogeographical limits remain scarce and are currently limited to the northern edge of their range. Here, we present the first evidence of tool use by a chimpanzee community living under severe anthropogenic pressure in the savanna woodland of the Loasi Forest Reserve, southern Tanzania—at the southernmost limit of the species' distribution. We recovered thirteen termite-fishing probes from a single *Macrotermes* mound, made from grass and bark. The implements closely resemble those reported from other well-studied chimpanzee communities in Tanzania, suggesting commonality of probing technique used in the region. Our findings add a new east African chimpanzee community to use termite fishing probes and extends the known southern limit for *Pan* tool use by approximately 230 km. The study of Loasi chimpanzees offers new opportunities to investigate chimpanzee regional technological variation and contributes to ongoing discussions about integrating cultural traits into conservation efforts.

Key words: *Pan troglodytes schweinfurthii*, *Macrotermes*, tool use, chimpanzee range limit, conservation

INTRODUCTION

Chimpanzees (*Pan troglodytes*) have the widest distribution of all great apes due to their considerable ecological and behavioural flexibility (Kalan *et al.* 2020). Occupying a wide range of habitats and climates across Equatorial Africa, from forested and savanna environments to mosaic habitats (van Leeuwen *et al.* 2020), all studied populations exhibit some form of tool use, with extensive behavioural variation at both the local and regional scale (McLennan 2014; Kühl *et al.* 2019). This includes the use of tools for extractive foraging, which has

been argued to be culturally transmitted to produce group-specific social traditions (Hicks *et al.* 2019).

Tanzania represents the south-eastern limit of the distribution of the genus *Pan* in Africa (Humle *et al.* 2016). Most of the region's native population of approximately 2,500 chimpanzees (TAWIRI 2018) are concentrated within two distinct zones in the west of the country. These are the Greater Gombe Ecosystem (GGE) which contains the Gombe National Park in the north and nearby chimpanzee habitat outside the park (Wilson *et al.* 2020),

and the approximate 20,000 km² of the Greater Mahale Ecosystem (GME). The latter contains the Mahale Mountains National Park to the west and several primarily savanna-woodland (miombo) environments interspersed with small patches of riparian forest, swamp, bamboo and grassland outside the park (Piel *et al.* 2015).

Further south, Africa's most southerly documented chimpanzee population, the southern Tanganyika chimpanzees, survive under heavy anthropogenic pressure, with the Loasi Forest Reserve and adjacent unprotected areas constituting the southernmost continental limit of confirmed chimpanzee distribution (Ogawa *et al.* 1997; Davenport *et al.* 2010; Figure 1). While chimpanzees living in the GGE and GME have been the focus of attention of researchers and conservationists for decades, the southern Tanganyika population has remained comparably neglected (Davenport *et al.* 2007, 2010; Yoshikawa *et al.* 2008; Inoue *et al.* 2013). Given their geographical location, this is surprising. Lower genetic distances between Loasi and the GME compared with those between the GGE and GME, suggest that GME chimpanzees may have originated from the southern Loasi landscape, likely avoiding the Malagarasi River—a long-standing geographic barrier between the GGE and GME (Inoue *et al.* 2013; but see Piel *et al.* 2013 for evidence of possible chimpanzee crossings). Furthermore, reconstructions of historical chimpanzee distribution indicate that the species once occurred on both sides of Lake Tanganyika, extending up to Zambia (Barratt *et al.* 2021), though the current recognized range ends in Democratic Republic of Congo (DRC), north of the DRC-Zambia border (Bonnin *et al.* 2023). This raises the possibility that GME chimpanzee ancestors reached Tanzania from southern regions via Lake Tanganyika (Bonnin *et al.* 2023), highlighting the importance of Loasi chimpanzees for understanding the origin and expansion of chimpanzees in Tanzania—a current topic of controversy and debate (Inoue *et al.* 2013; Bonnin *et al.* 2023).

Chimpanzee termite fishing was first reported in Tanzania (and for the species as a whole) in the Gombe Stream Game Reserve by Jane Goodall, in what became the first well-documented evidence of tool use by a nonhuman great ape (Goodall 1964). Since then, the use of termite fishing probes has been documented at three other sites within the country: the Kasakati Basin (Suzuki 1966), the Mahale Mountains National Park (Nishida & Uehara 1980), and most recently, in the Issa Valley (Stewart & Piel 2014) (Figure 1). While the use of

probes is ubiquitous across all reported termite-fishing communities in the country, researchers have now documented cross-community variation in the material used to manufacture tools and the distance travelled by the apes to obtain raw materials, with differences attributed to a combination of social and ecological factors (Pascual-Garrido & Almeida-Warren, 2021).

As with most communities across Africa, the survival of the Loasi chimpanzees is now threatened by increasing levels of anthropogenic activities (Davenport *et al.* 2010). Documenting local chimpanzee traditions is urgent, as populations with unexplored cultural traits such as Loasi may be locally extirpated before they can be described. From a purely scientific perspective, documentation of such diversity is essential for the debate on cultural diversity in nonhumans (Hicks *et al.* 2019) but can also assist in arguing for cultural traits that require protection and the environments in which they are exhibited (Izar *et al.* 2025; Wessling *et al.* 2025). Furthermore, our study may help highlight the positive effect of field research in supporting conservation efforts (Tagg *et al.* 2015).

In this study we present the first evidence of the use of tools for termite predation by the Loasi chimpanzee community, extending by approximately 230 km the current southern distribution limit for tool-assisted foraging by chimpanzees on the continent, and adding to the chimpanzee ethogram the first evidence of termite fishing in the far south of Tanzania.

METHODS

Study site and Subjects

The Loasi Forest Reserve (S08.18062, E31.12708) and adjacent unprotected areas currently represent the southernmost continental limit of confirmed chimpanzee distribution (Figure 1) (Ogawa *et al.* 1997; Davenport *et al.* 2010). The presence of chimpanzees in the area is evidenced by nests and camera trap images (Figure 2). Like the majority of wild chimpanzees in Tanzania, the Loasi chimpanzees are unhabituated and reside outside of any national park (Wilson *et al.* 2020), on land managed by the Tanzania Forest Services Agency (TFS). The habitat consists mostly of savanna woodland (miombo) dominated by *Brachystegia* and *Julbernardia* interspersed with grassland (Ogawa *et al.* 1997), thus more closely resembling the more open miombo woodland habitats inhabited by the

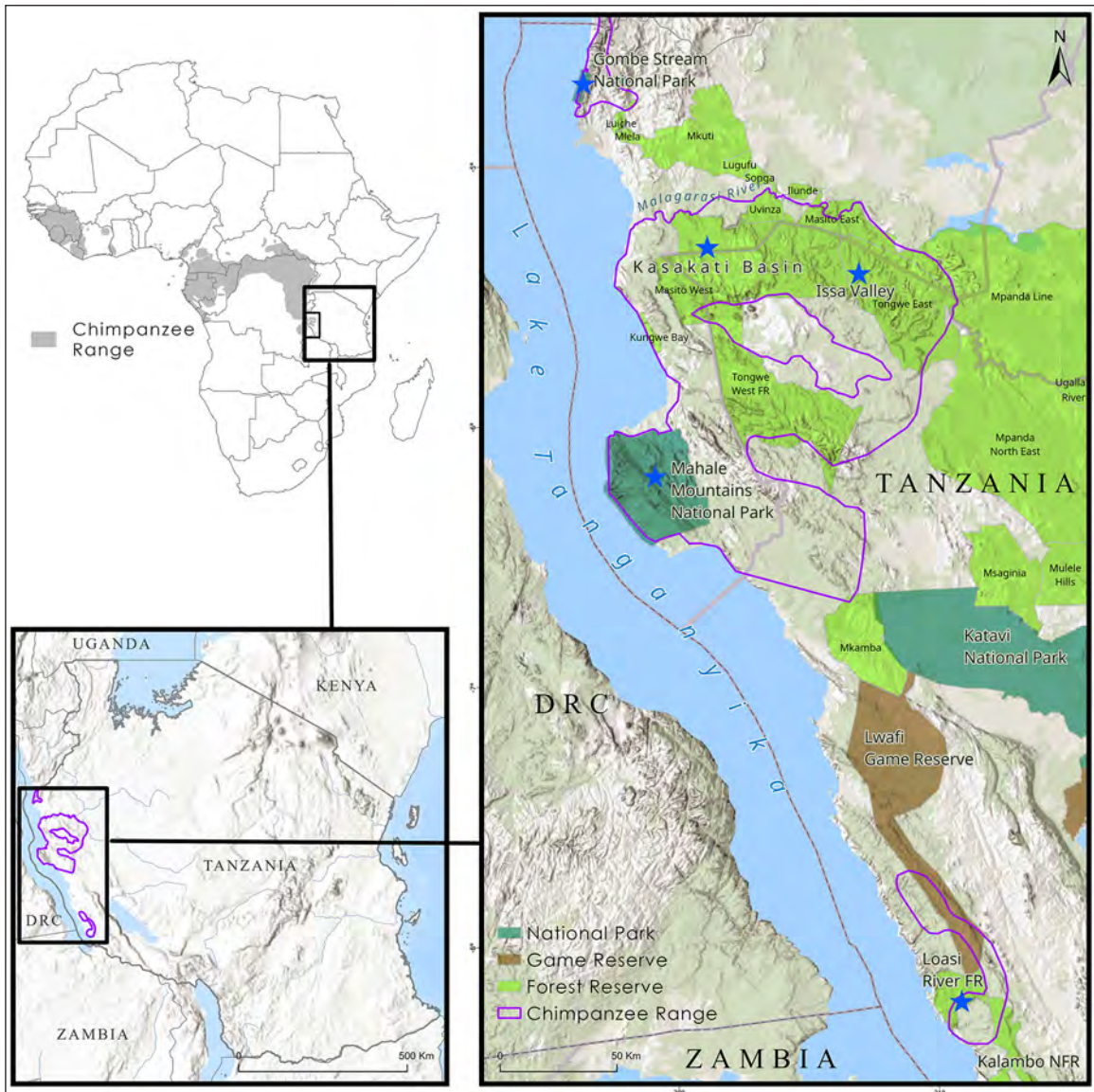


Figure 1. Map of western Tanzania indicating the Loasi Forest Reserve, other protected areas and the chimpanzee range (adapted from Bonnin *et al.* 2020). Documented termite-fishing communities are indicated with a star. Map created by Joseph Mtenga, Wildlife Conservation Society.

termite-fishing chimpanzee communities of the Issa valley (Stewart & Piel 2014) and the Kasakati Basin (Suzuki 1966). Relatively dense forests are found in valleys where rivers bisect the escarpment. The elevation ranges between 1,200–1,500 m (Ogawa *et al.* 1997). The region's climate consists of a dry season which starts in June and ends at the beginning of November, and a wet season from late November until May, with two major peaks in rainfall during the wet season (Davenport *et al.* 2007).

Since the first documentation of the Loasi chimpanzee community in 1996 by Ogawa *et al.* (1997), nest count surveys have indicated a

low population density (0.01 individuals/km²) (Yoshikawa *et al.* 2008), with an estimated 40–50 chimpanzees in the area (Moyer *et al.* 2006). This is a cause for concern, as small, isolated populations face increased extinction rates (Davies *et al.* 2000). The Loasi area is heavily impacted by human activities, including selective logging, agro-pastoralism and hunting, and some of the last surviving riverine forests have been recently cleared (Davenport *et al.* 2010). Consequently, chimpanzees in Loasi remain largely restricted to a few km of riparian woodland (WCS, unpublished data) and are at severe risk of local extinction.



Figure 2. (a) A fresh chimpanzee nest recorded during the study (02 February 2021). Photograph by Aaron Nicholas.

(b) Image of a Loasi chimpanzee captured by a video triggered camera trap in the study area (15 November 2023).



Data collection

To document the potential use of tools for termite predation by Loasi chimpanzees, we conducted two reconnaissance surveys within the termite fishing season reported for other Tanzanian communities (Teleki 1974; McGrew & Collins 1985; Stewart & Piel 2014): 19-26 November 2020 and 20 January-04 February 2021. The aims of these surveys were to: a) examine if Loasi chimpanzees use tools to gather

termites, and b) if so, how do the implements compare with those described for other well-studied termite fishing communities in the country. While Loasi chimpanzees may also engage in other forms of tool-assisted foraging, we exclusively focused on searching for evidence of termite fishing given that termites are sedentary and thus easier to detect compared to other type of insects (i.e., army ants) commonly predated by chimpanzees with tools which are nomadic (Pascual-Garrido *et al.* 2013).

During reconnaissance surveys, we searched for the characteristic large *Macrotermes* mounds (McGrew & Collins 1985) that, albeit with a few exceptions (Andres-Bray *et al.* 2024), constitute the most common termite prey harvested with tools by chimpanzees (Lesnik 2014). A total of 32 mounds were recorded. At each mound, we used well-established primate archaeological methods to detect indirect evidence of chimpanzee termite fishing activities (Pascual-Garrido 2018) including: a) abandoned tools, b) tool source plants identified by the presence of scars left on their stems or branches during the process of tool material sourcing, c) refitting of abandoned artefacts to sources, d) presence of discarded termite heads as a result of chimpanzee foraging, and e) other signs of chimpanzee activity on top of the mound such as fresh leaves or discarded raw material as a result of the tool manufacture process. We recorded a twig, vine, piece of grass or bark as a tool if two or more of the following criteria applied: the implement was found on top of or < 1 m from the mound, was projecting from a termite exit or alate hole, showed evidence of modification (i.e., reduction, stripping of bark or leaves), had one or both soiled ends, was refitted to a source (Hicks *et al.* 2019), and/ or was found associated with one or more of the criteria described previously as evidence of termite fishing. When we found potential tools, we recorded the following parameters: a) type of raw material (i.e., grass, bark, twig, vine, etc.); b) age according to the physical characteristics of the implements, including colour and pliability (McGrew & Collins 1985); and c) length and width. If tool sources were found, samples were collected and curated in camp using a plant drier for later identification by Frank Mbago.

RESULTS

On 22 January 2021 at 10:13 am we found an active *Macrotermes* mound in the miombo woodland at the edge of riverine forest associated with tools (Table 1) (Figure 3a). All implements were found abandoned

on top of the mound. Two of the implements were made of grass and five were made of bark. All bark tools were sourced from one species located two to three meters from the center of the mound identified as *Markhamia obtusifolia*, a native shrub or small tree belonging to the family Bignoniaceae, with one bark tool refitted to this source (Figure 3b). Two fragments and fresh leaves of *Markhamia obtusifolia* were also found in association with the manufacture process of the bark tools (Figure 4a). Based on the conditions of the tools (e.g., pliability, bright colour of the cambium layer of the tools), the associated debris resulting from the manufacture process (i.e., degree of wilting of stripped leaves), the fishing holes (i.e., recently sealed by termites), and of the tool material sourced (i.e., scar with cambium layer still fresh and green) (Pascual-Garrido 2018), tools were most likely manufactured earlier on that same date or the day before they were found.

When we revisited the site on 04 February 2021 at 2:01 pm, we found another six tools, four made from grass and two made from bark. By the conditions of the implements (i.e., level of moisture, colour of the cambium layer, pliability, etc.), these were probably manufactured and used on different dates. While the grass tools were likely older (> 1 week), the bark tools appeared to be most likely less than one week old. Both bark tools were made from the same plant species (unidentified), and one of them was left inserted into an open (alate) termite hole (Figure 4b). Eleven grass fragments resulting from the manufacture process, and seven heads of termites identified as *Macrotermes* by the characteristic colour, size, and shape, were also found associated with the grass implements (Figure 4c).

When measured, the overall mean length of the tools was 43.0 cm (SD = 16.6, range: 23.2-82.1, $n = 13$), while the mean diameter measured at mid-point was 2.4 mm (SD = 1.5, range: 0.5-4.5, $n = 13$) (Table 1). When split according to material types, grass tools were on average significantly longer than tools made from bark (grass tools: $\bar{x} = 56.2$, SD = 15.1, range = 38.2-82.1, $n = 6$; bark tools: $\bar{x} = 31.7$, SD = 6.0, range = 23.2-37.9, $n = 7$; $t = (6.36) =$

Table 1. Date, number, length, width, and raw material type of fishing probes recovered during this study. For raw material type, the number in brackets indicates the total number of tools per tool material class.

Date	Tools (n)	Mean Length (cm)	SD	Mean Width (mm)	SD	Tool Materials
22 Jan 2021	7	41.8	19.0	2.5	1.4	bark (5), grass (2)
04 Feb 2021	6	44.4	15.0	2.2	1.8	bark (2), grass (4)



Figure 3. (a) *Macrotermes* mound with recently abandoned termite fishing probes by the Loasi chimpanzees and associated detached material (indicated with white arrow) (22 January 2021). Photograph by Alejandra Pascual-Garrido. (b) Alejandra Pascual-Garrido refits a bark tool to its source plant (22 January 2021). Note the bright colour of the stem as a result of chimpanzees recently removing the bark for tool material. Photograph by Aaron Nicholas.

3.7116, $p < 0.05$). However, given the small sample size, this difference must be treated with caution. No significant difference between average mean diameter across tool material types was found (grass tools: $\bar{x} = 1.9$ mm, $SD = 2.00$, range = 0.4–4.5, $n = 6$; bark tools: $\bar{x} = 2.7$ mm, $SD = 1.00$, range = 1.2–3.9, $n = 7$; $W = 14$, $p = 0.3511$).

DISCUSSION

Our study adds a new East African chimpanzee community to the list of Tanzanian chimpanzees that use probes to gather termites and extends the southernmost known limit of termite fishing chimpanzees on the continent by approximately 230 km. While we did not directly observe the chimpanzees using the implements, we found clear evidence of their use. For example, one tool was left inserted into an open (alate) hole of the termite mound (Figure 4b), a behaviour recorded in other termite fishing communities (Suzuki 1966; McGrew *et al.* 1979; McGrew & Collins 1985). We also documented the presence of termite soldier heads, discarded fresh material resulting from the tool manufacture process, and scars on tool sources after tool material removal, which are also elsewhere associated with signs of chimpanzee termite-fishing activity (Almeida-Warren *et al.* 2017; Pascual-Garrido 2017). Furthermore, the tool dimensions

and materials used were within the parameters of implements reported from other well-studied Tanzanian termite fishing communities (Table 2).

When compared across material types, grass tools were significantly longer than those made from bark, however the average diameter did not differ significantly between the two. It should be cautioned here, though, that the sample size is small and the tools all came from one mound. We need more data to draw broader conclusions.

Plant materials used in the manufacture of tools by the Loasi chimpanzees (i.e., grass and bark) are also utilised by other Tanzanian communities; bark and grass tools are extensively used by Gombe and Mahale chimpanzees (McGrew *et al.* 1979; Nishida & Uehara 1980; McGrew & Collins 1985; Pascual-Garrido 2017, 2018). Chimpanzees living in the Kasakati Basin have been reported using bark tools (Suzuki 1966), while Issa chimpanzees exclusively use bark for tool manufacture (Almeida-Warren *et al.* 2017). That we failed to document other plant materials in our study may be a result of our small sample size ($n = 13$) compared to the other three more extensively studied communities of Gombe, Mahale, and Issa (McGrew *et al.* 1979; Nishida & Uehara 1980; McGrew & Collins 1985; Almeida-Warren *et al.* 2017). Although a larger dataset is needed to compare implements used across the region, the tool sizes and materials used by the Loasi apes more closely resembled those at the nearer



Figure 4. (a) Fresh fragments and leaves of *Markhamia obtusifolia* as a result of the tool manufacture process. White arrow indicates a recently abandoned bark tool (22 January 2021). (b) Bark tool left inserted into an open (alate) termite hole, with white arrow indicating the point of insertion (04 February 2021). (c) Termite heads left on the surface of the *Macrotermes* mound, indicated with white arrows, after termite predation with tools by chimpanzees (04 February 2021). Photographs by Alejandra Pascual-Garrido.

sites of Mahale, the Issa Valley, and the Kasakati Basin than those at the more distant Gombe, where implements tend to be shorter and made from a wider range of materials. The identified source species for all bark tools recorded on the first date, *Markhamia obtusifolia*, represents, however, the first record as a tool source for termite-fishing tools.

That tools manufactured by the Loasi chimpanzees were similar in material and form to those described from other study sites in the region, suggests commonality of the termite-fishing probing technique in Tanzanian chimpanzees (Suzuki 1966; Teleki 1974; McGrew & Collins 1985; Stewart & Piel 2014). Lonsdorf (2006) has confirmed termite fishing as a socially learned behaviour passed down across generations by mothers to infants. If passed between chimpanzee communities through female dispersal (O'Malley *et al.* 2012), given the historical chimpanzee connectivity in the landscape (Kano 1971; Yoshikawa *et al.* 2008; Bonnin *et al.* 2020), chimpanzee termite fishing in Tanzania in places where the apes and *Macrotermes* overlap could be more widespread than currently recorded. This could be a fruitful avenue for future research, in particular to test the potential of a 'behavioural realm' in the use of termite fishing probes by Tanzanian chimpanzees (Hicks *et al.* 2019) or, alternatively, an ecological or termite-behaviour explanation (Uehara 1982; Sanz *et al.* 2014).

In 2005, chimpanzee density at Loasi was estimated at 0.01 individuals/km² (Yoshikawa *et al.* 2008), which is much lower than the overall mean density of 0.05 individuals/km² reported for chimpanzees living in unprotected areas in Tanzania (Piel *et al.* 2015). Chimpanzee densities decline with increasing proximity to their range limit and with increases in habitat loss (Wessling *et al.* 2020). Furthermore, it is predicted that by the year 2100, due to the effects of global warming, chimpanzees will lose 10% of the habitat within their present biogeographical distribution, with communities

Table 2. Termite-fishing probes physical characteristics reported for chimpanzee termite-fishing communities in Tanzania in different field seasons.

Community and study site	Length (cm)	SD	# of tools measured for length	Width (mm)	SD	# of tools measured for width	Tool material						Reference	
							Bark	Twig	Vine	Grass	Palm frond	Bamboo		Sedge
Kasekela, Gombe	30.7	–	145	4.0	–	32	*	*	*	*	*			McGrew <i>et al.</i> 1979
Kasekela, Gombe	28.1	12.8	405	1.9	1.1	404	*	*	*	*				Pascual-Garrido 2019
Mitumba, Gombe	23.5	8.2	267	1.4	0.6	267	*	*						Pascual-Garrido 2019
B group, Mahale	–	–	133	–	–	–	*	*	*	*	*	*		Nishida & Uehara 1980
B group, Mahale	54.6	–	97	–	–	–								Uehara 1982
B group, Mahale	37.7	14.7	290	4.6	2.0	75	*	*	*			*	*	McGrew & Collins 1985
B group, Mahale	38.5	10.3	25	3.1	1.0	25	*							Pascual-Garrido 2017
K group, Mahale	51.5	–	16	–	–	–	*		*					Uehara 1982
Issa, Issa Valley	40.4	23.0	36	–	–	–	*							Stewart & Piel 2014
Kasakati, Kasakati Basin	45.0	–	2	–	–	–	*	*						Suzuki 1966
Loasi, Loasi Forest Reserve	43.0	16.6	13	2.4	1.5	13	*			*				This study

living at their biogeographical range limit such as Loasi no longer able to sustain a viable population size and thus suffering local extinction (Lehmann *et al.* 2010; Carvalho *et al.* 2021).

Chimpanzee behavioural diversity and flexibility enable them to occupy a wide range of habitats, including those experiencing high levels of anthropogenic disturbance (Hockings *et al.* 2015). However, increasing human disturbance has been shown to erode this diversity, including culturally transmitted behaviours (Gruber *et al.* 2019). Consequently, conservation efforts are beginning to recognize the importance of protecting both these cultural behaviours and the environments in which they occur (Wessling *et al.* 2025). Our finding that the Loasi chimpanzees—living at the biogeographical limit of their range—use technology to access food has implications not only for understanding human impacts on the expression of chimpanzee cultural behaviours and the constraints associated with life at the species' range edge (Hockings *et al.* 2015; Gruber *et al.* 2019; Köhl *et al.* 2019; Wessling *et al.* 2020), but also for informing current debates on how cultural diversity in nonhumans can support and enhance chimpanzee conservation policies (Izar *et al.* 2025; Wessling *et al.* 2025). Our results pave the way for future studies aimed at understanding the species' flexible responses to anthropogenic change (Hockings *et al.* 2015) and promoting the integration of specific cultural traits (e.g., termite fishing) and the local ecological features that support them (e.g., termite mounds and tool material) into conservation strategies (Izar *et al.* 2025; Wessling *et al.* 2025). Ultimately, we hope these efforts will help ensure that our close cousins persist into the increasingly unstable Anthropocene (Hockings *et al.* 2015; Mitani *et al.* 2024).

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REFERENCES

- Almeida-Warren, K., V. Sommer, A.K. Piel & A. Pascual-Garrido. 2017. Raw material procurement for termite fishing tools by wild chimpanzees in the Issa valley, Western Tanzania. *American Journal of Physical Anthropology* 164(2): 292–304.
- Andres-Bray, T.C., J. Smith, I. Nichols, E.E. Abwe & M.K. Gonder. 2024. Ecological correlates of chimpanzee termite fishing behavior in Mbam & Djerem National Park, Cameroon. *Ecology and Evolution* 14: e70080.
- Barratt, C. D, J.D. Lester, P. Gratton, R.E. Onstein, A.K. Kalan, M.S. McCarthy, G. Bocksberger, L.C. White, L. Vigilant, P. Dieguez, B. Abdulai, T. Aebischer, A. Agbor, A.K. Assumang, E. Bailey, M. Bessone, B. Buys, J.S. Carvalho, R. Chancellor, H. Cohen, E. Danquah, T. Deschner, Z.N. Dongmo, O.A. Doumbé, J. Dupain, C.S. Duvall, M. Eno-Nku, G. Etoga, A. Galat-Luong, R. Garriga, S. Gatti, A. Ghiurghi, A. Goedmakers, A.C. Granjon, D. Hakizimana, J. Head, D. Hedwig, I. Herbinger, V. Hermans, S. Jones, J. Junker, P. Kadam, M. Kambi, I. Kienast, C.Y. Kouakou, K.P. N'Goran, K.E. Langergraber, J. Lapuente, A. Laudisoit, K.C. Lee, F. Maisels, N. Mirghani, D. Moore, B. Morgan, D. Morgan, E. Neil, S. Nicholl, L. Nkambi, A. Ntongho, C. Orbell, L.J. Ormsby, L. Pacheco, A.K. Piel, L. Pintea, A.J. Plumptre, A. Rundus, C. Sanz, V. Sommer, T. Sop, F.A. Stewart, J. Sunderland-Groves, N. Tagg, A. Todd, E. Ton, J. Schijndel, H. VanLeeuwe, E. Vendas, A. Welsh, J.F.C. Wenceslau, E.G. Wessling, J. Willie, R.M. Wittig, N. Yoshihiro, Y.G. Yuh, K. Yurkiw, C. Boesch, M. Arandjelovic & H. Köhl. 2021. Quantitative estimates of glacial refugia for chimpanzees (*Pan troglodytes*) since the Last Interglacial (120,000 BP). *American Journal of Primatology* 83(10): e23320.
- Bonnin, N., F.A. Stewart, S.A. Wich, L. Pintea, S.M. Jantz, R. Dickson, J. Bellis, A. Chitayat, R. Ingram, R.J. Moore & A.K. Piel. 2020. Modelling landscape connectivity change for chimpanzee conservation in Tanzania. *Biological Conservation* 252: 108816.
- Bonnin, N., A.K. Piel, R.P. Brown, Y. Li, A.J. Connell, A.N. Avitto, J.P. Boubli, A. Chitayat,

- J. Giles, M.S. Gundlapally, I. Lipende, E.V. Lonsdorf, D. Mjungu, D. Mwacha, L. Pintea, A.E. Pusey, J. Raphael, S.A. Wich, M.L. Wilson, E.E. Wroblewski, B.H. Hahn, & F.A. Stewart. 2023. Barriers to chimpanzee gene flow at the south-east edge of their distribution. *Molecular Ecology* 32(14): 3842–3858.
- Carvalho, J. S., B. Graham, G. Bocksberger, F. Maisels, E.A. Williamson, S. Wich, T. Sop, B. Amarasekaran, B. Barca, A. Barrie, R.A. Bergl, C. Boesch, H. Boesch, T.M. Brncic, B. Buys, R. Chancellor, E. Danquah, O.A. Doumbé, S.Y. Le-Duc, A. Galat-Luong, J. Ganas, S. Gatti, A. Ghiurghi, A. Goedmakers, N. Granier, D. Hakizimana, B. Haurez, J. Head, I. Herlinger, A. Hillers, S. Jones, J. Junker, N. Maputla, E.-N. Manasseh, M.S. McCarthy, M. Molokwu-Odozi, B.J. Morgan, Y. Nakashima, P.K. N’Goran, S. Nixon, L. Nkambi, E. Normand, L.D.Z. Nzooh, S.H. Olson, L. Payne, C.-A. Petre, A.K. Piel, L. Pintea, A.J. Plumptre, A. Rundus, A. Serckx, F.A. Stewart, J. Sunderland-Groves, N. Tagg, A. Todd, A. Vosper, J.F.C. Wenceslau, E.G. Wessling, J. Willie, & H.S. Kühl. 2021. Predicting range shifts of African apes under global change scenarios. *Diversity & Distributions* 27(9): 1663–1679.
- Davenport, T.R.B., N.E. Mpunga, G. Picton Phillips, S.J. Machaga, D.W. De Luca, O. Kibure & Y. Abeid. 2010. The conservation status of the chimpanzees *Pan troglodytes schweinfurthii* in ‘Southern Tanganyika’. Unpublished report of the Wildlife Conservation Society.
- Davenport, T.R.B., G. Picton Phillips, N.E. Mpunga, S.J. Machaga & D.W. De Luca. 2007. Developing a conservation strategy for the chimpanzees of Southern Tanganyika. Unpublished report of the Wildlife Conservation Society.
- Davies, K.F., C.R. Margules & J.F. Lawrence. 2000. Which traits of species predict population declines in experimental forest fragments? *Ecology* 81(5): 1450–1461.
- Goodall, J. 1964. Tool-using and aimed throwing in a community of free-living chimpanzees. *Nature* 201: 1264–1266.
- Gruber, T., L. Luncz & J. Mörchen. 2019. Cultural change in animals: a flexible behavioural adaptation to human disturbance. *Palgrave Communications* 5: 64.
- Hicks, T.C., H.S. Kuehl, C. Boesch, P. Dieguez, A.E. Ayimisin, R.M. Fernandez, D.B. Zungawa, M. Kambere, J. Swinkels, S.B.J. Menken, J. Hart, R. Mundry & P. Roessingh. 2019. Bili-Uére: a chimpanzee behavioural realm in northern Democratic Republic of Congo. *Folia Primatologica* 90(1): 3–64.
- Hockings, K. J., M.R. McLennan, S. Carvalho, M. Ancrenaz, R. Bobe, R.W. Byrne, R.I.M. Dunbar, T. Matsuzawa, W.C. McGrew, E.A. Williamson, M.L. Wilson, B. Wood, R.W. Wrangham & C.M. Hill. 2015. Apes in the anthropocene: flexibility and survival. *Trends in Ecology & Evolution* 30(4): 215–222.
- Humle, T., F. Maisels, J.F. Oates, A. Plumptre & E.A. Williamson. 2016. *Pan troglodytes*. 2016. *The IUCN Red List of Threatened Species* 2016.
- Inoue, E., Y. Tashiro, H. Ogawa, M. Inoue-Murayama, T. Nishida & O. Takenaka. 2013. Gene flow and genetic diversity of chimpanzees in Tanzanian habitats. *Primate Conservation* 26(1): 67–74.
- Izar P., E. van de Waal & M.M. Robbins. 2025. Integrating culture into primate conservation. *Philosophical Transactions of the Royal Society B* 380: 20240135.
- Kalan, A., R. Mundry, P. Dieguez, C. Coupland, M. Fay, D. Fine, D. Morgan, E. Neil, S. Nicholl, L. Ormsby, O. Robinson, L. Pacheco, A. Piel, F. Stewart, E. Wessling, W. Jacob & H. Kühl. 2020. Chimpanzee ethnography reveals unexpected cultural diversity. *Nature Human Behaviour* 4(9): 910–916.
- Kano, T. 1971. Distribution of the primates on the eastern shore of Lake Tanganyika. *Primates* 12(3–4): 281–304.
- Kühl, H.S., C. Boesch, L. Kulik, F. Haas, M. Arandjelovic, P. Dieguez, G. Bocksberger, M.B. McElreath, A. Agbor, S. Angedakin, E.A. Ayimisin, E. Bailey, D. Barubiyo, M. Bessone, G. Brazzola, R. Chancellor, H. Cohen, C. Coupland, E. Danquah, T. Deschner, O. Diotah, D. Dowd, A. Dunn, V.E. Egbe, H. Eshuis, R. Fernandez, Y. Ginath, A. Goedmakers A.-C., J. Head, D. Hedwig, V. Hermans, I. Imong, K.J. Jeffery, S. Jones, J. Junker, P. Kadam, M. Kambere, M. Kambi, I. Kienast, D. Kujirakwinja, K. Langergraber, J. Lapuente, B. Larson, K. Lee, V. Leinert, M. Llana, G. Maretti, S. Marrocoli, T.J. Mbi, A.C. Meier, B. Morgan, D. Morgan, F. Mulindahabi, M. Murai, E. Neil, P. Niyigaba, L.J. Ormsby, L. Pacheco, A. Piel, J. Preece, S. Regnaut, A. Rundus, C. Sanz, J. van Schijndel, V. Sommer, F. Stewart, N. Tagg, E. Vendras, V. Vergnes, A. Welsh, E.G. Wessling, J. Willie, R.M. Wittig, K. Yurkiw, K. Zuberbühler, & A.K. Kalan. 2019. Human impact erodes chimpanzee behavioral diversity. *Science* 363: 1453–1455.
- Lehmann, J., A.H. Korstjens & R.I.M. Dunbar. 2010. Apes in a changing world - the effects of global warming on the behaviour and distribution of

- African apes. *Journal of Biogeography* 37: 2217–2231.
- Lesnik, J.J. 2014. Termites in the hominin diet: A meta-analysis of termite genera, species and castes as a dietary supplement for South African robust australopithecines. *Journal of Human Evolution* 71: 94–104.
- Lonsdorf, E. 2006. What is the role of mothers in the acquisition of termite-fishing behaviors in wild chimpanzees (*Pan troglodytes schweinfurthii*)? *Animal Cognition* 9(1): 36–46.
- McGrew, W.C. & D.A. Collins. 1985. Tool use by wild chimpanzees (*Pan troglodytes*) to obtain termites (*Macrotermes herus*) in the Mahale Mountains, Tanzania. *American Journal of Primatology* 9(1): 47–62.
- McGrew, W.C., C.E.G. Tutin & P.J. Baldwin. 1979. Chimpanzees, tools and termites: cross-cultural comparisons of Senegal, Tanzania, and Rio Muni. *Man* 14: 185–214.
- McLennan, M.R. 2014. Chimpanzee insectivory in the northern half of Uganda's Rift Valley: do Bulindi chimpanzees conform to a regional pattern? *Primates* 55(2): 173–178.
- Mitani, J. C., E. Abwe, G. Campbell, T. Giles-Vernick, T. Goldberg, M.R. McLennan, S. Preuschoft, J. Supriatna & A.J. Marshall. 2024. Future coexistence with great apes will require major changes to policy and practice. *Nature Human Behaviour* 8(4): 632–643.
- Moyer, D., A.J. Plumptre, L. Pintea, A. Hernandez-Aguilar, J. Moore, F. Stewart, T.R.B. Davenport, A. Piel, S. Kamenya, H. Mugabe, N. Mpunga & M. Mwangoka. 2006. Surveys of chimpanzees and other biodiversity in Western Tanzania. Unpublished report of the Jane Goodall Institute and the Wildlife Conservation Society.
- Nishida, T. & S. Uehara. 1980. Chimpanzees, tools, and termites: another example from Tanzania. *Current Anthropology* 21(5): 671–672.
- Ogawa, H., M. Kanamori & H. Mukeni. 1997. The discovery of chimpanzees in the Lwazi river area, Tanzania: a new southern distribution limit. *Pan Africa News* 4(1): 1–3.
- O'Malley, R.C., W. Wallauer, C.M. Murray & J. Goodall. 2012. The appearance and spread of ant fishing among the Kasekela chimpanzees of Gombe: a possible case of intercommunity cultural transmission. *Current Anthropology* 53 (5): 650–663.
- Pascual-Garrido, A. 2017. Termite fishing by Mahale chimpanzees: revisited, decades later. *Pan Africa News* 24(2): 15–19.
- Pascual-Garrido, A. 2018. Scars on plants sourced for termite fishing tools by chimpanzees: towards an archaeology of the perishable. *American Journal of Primatology* 80(9): e22921.
- Pascual-Garrido, A. & K. Almeida-Warren. 2021. Archaeology of the perishable: ecological constraints and cultural variants in chimpanzee termite fishing. *Current Anthropology* 62: 333–362.
- Pascual-Garrido, A., B. Umaru, O. Allon & V. Sommer. 2013. Apes finding ants: predator-prey dynamics in a chimpanzee habitat in Nigeria. *American Journal of Primatology* 75: 1231–1244.
- Piel, A.K., N. Cohen, S. Kamenya, S.A. Ndimuligo, L. Pintea & F. Stewart. 2015. Population status of chimpanzees in the Masito-Ugalla ecosystem, Tanzania. *American Journal of Primatology* 77: 1027–1035.
- Piel, A. K., F.A. Stewart, L. Pintea, Y. Li, M.A. Ramirez, D.E. Loy, P.A. Crystal, G. H. Learn, L.A. Knapp, P.M. Sharp, & B.H. Hahn. 2013. The Malagarasi River does not form an absolute barrier to chimpanzee movement in Western Tanzania. *PLoS One* 8(3): e58965–e58965.
- Sanz, C.M., I. Deblauwe, N. Tagg & D.B. Morgan. 2014. Insect prey characteristics affecting regional variation in chimpanzee tool use. *Journal of Human Evolution* 71: 28–37.
- Stewart, F.A. & A.K. Piel. 2014. Termite fishing by wild chimpanzees: new data from Ugalla, western Tanzania. *Primates* 55(1): 35–40.
- Suzuki, A. 1966. On the insect-eating habits among wild chimpanzees living in the savanna woodland of western Tanzania. *Primates* 7(4): 481–487.
- Tagg, N., J. Willie, J. Duarte, C.-A. Petre & J.E. Fa. 2015. Conservation research presence protects: a case study of great ape abundance in the Dja Region, Cameroon. *Animal Conservation* 18: 489–498.
- TAWIRI. 2018. Tanzania Chimpanzee Conservation Action Plan 2018–2023. Tanzania Wildlife Research Institute (TAWIRI).
- Teleki, G. 1974. Chimpanzee subsistence technology: materials and skills. *Journal of Human Evolution* 3(6): 575–594.
- Uehara, S. 1982. Seasonal changes in the techniques employed by wild chimpanzees in the Mahale Mountains, Tanzania, to feed on termites (*Pseudacanthotermes spiniger*). *Folia Primatologica* 37(1–2): 44–76.
- van Leeuwen, K.L., R.A. Hill & A.H. Korstjens. 2020. Classifying chimpanzee (*Pan troglodytes*) landscapes across large-scale environmental gradients. *International Journal of Primatology* 41: 800–821.

- Wessling, E.G., P. Dieguez, M. Llana, L. Pacheco, J.D. Pruetz & H.S. Köhl. 2020. Chimpanzee (*Pan troglodytes verus*) density and environmental gradients at their biogeographical range edge. *International Journal of Primatology* 41(6): 822–848.
- Wessling, E. G., A. Whiten, S.K. Soiret, K. Scholfield, L. Samuni, C. Rutz, I. Redmond, L. Pintea, A. Lanjouw, K. Koops, S.A. Kamgang, A.K. Kalan, R.A. Ikemeh, T. Humle, C. Hobaiter, H. Frisch-Nwakanma, E. Freymann, O. Doumbe, P. Brakes, E. Abwe, & C. Sanz. 2025. Concerted conservation actions to support chimpanzee cultures. *Philosophical Transactions of the Royal Society B* 380: 20240143.
- Wilson, M.L, E.V. Lonsdorf, D.C. Mjungu, S. Kamenya, E.W. Kimaro, D.A. Collins, T.R. Gillespie, D.A. Travis, I. Lipende, D. Mwacha, S.A. Ndimuligo, L. Pintea, J. Raphael, E.R. Mtiti, B.H. Hahn, A.E. Pusey & J. Goodall. 2020. Research and conservation in the greater Gombe ecosystem: challenges and opportunities. *Biological Conservation* 252: 108853.
- Yoshikawa, M., H. Ogawa, T. Sakamaki & G. Idani. 2008. Population density of chimpanzees in Tanzania. *Pan Africa News* 15(2): 17–20.

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Perceptions and Primates: Exploring Local Attitudes toward Primate Conservation in the Mathews Range, Samburu, Kenya

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Abstract: The frequency and intensity of human-nonhuman primate interactions are on the rise due to increased demand for forest resources, climate change, and expansion of agricultural activities into forested landscapes. These interactions have played a critical role in shaping local attitudes, beliefs, and perceptions across many communities worldwide. Mathews Range Forest in Kenya is a southern part of a mountainous chain that crosses the savannah section of Samburu County and is home to a semi-nomadic Samburu pastoralist community. The forest holds five primate species: small-eared greater galago (*Otolemur garnettii*), De Brazza's monkey (*Cercopithecus neglectus*), northeastern vervet monkey (*Chlorocebus pygerythrus arenaria*), olive baboon (*Papio anubis*), and the endangered Mt. Uaraguess guereza (*Colobus guereza percivali*). To understand the Samburu community's perceptions of, and attitudes towards, nonhuman primates, we conducted qualitative research from September 2024 to June 2025. We administered 207 questionnaires in villages around the forest landscape. The majority of respondents reported a decline in primate populations within the Mathews Range Ecosystem due to habitat degradation. The respondents indicated that the endangered guereza population may have decreased significantly, as they are rarely seen. When they are spotted, they are elusive, wary, and exist in small groups compared to past years. The respondents raised issues contributing to the primates' decline, including deforestation, diseases, prolonged droughts, and hunting for primate skins. More than half of the respondents (65.4%) reported incidents of primate hunting. Deforestation was reported as the most common threat across all the villages interviewed, with the most targeted fodder plant species being *Craibia laurentii* (48.8%). In addition, the local community perceived baboons as the most problematic animals (99%), with vervets listed as a distant second (1%). These research findings may inform the local stakeholders of the need to strengthen primate conservation and regular population monitoring in the Mathews Range Forest to highlight the impact of threats facing the primates and their habitat and develop effective mitigation plans.

Key words: habitat threats, Mathews Range, perceptions, primates, Samburu

INTRODUCTION

Humans have come to terms with reality as we face the sixth mass extinction of species, considered “biological annihilation” attributed to

irreversible alteration of Earth systems (Wright *et al.* 2018; Ceballos *et al.* 2020). The world has experienced unprecedented economic growth and

industrialization over the past two centuries, which can be attributed to widespread technological advancement. Despite the positive aspects of these advancements, we have now seen unsustainable use of resources such as fossil fuels, forests, oceans, and lands resulting in disruption of Earth processes that negatively impact global biodiversity (Wright *et al.* 2018; Norconk *et al.* 2025). Among the most threatened land mammals are the nonhuman primates, which are a species-rich order, only surpassed by the Chiroptera and Rodentia (Estrada *et al.* 2017). The majority of threats facing primates are human driven.

Currently, about 5 billion people reside within 100 km of nonhuman primate habitats, underscoring the need to examine possible consequences of this overlap (Cosby *et al.* 2025). These consequences of human incursions include the escalation of wildlife hunting and trade, with risk of the emergence and spread of infectious diseases such as the Ebola virus (Rouquet *et al.* 2005), the Marburg virus (Bengis *et al.* 2004), and Dengue fever (Kemunto *et al.* 2018). These pose a grave risk to both biodiversity and global public health (Mwangi *et al.* 2016; Akinyi 2021; Estrada & Garber 2022). Additionally, the relationship between humans and monkeys has been deeply embedded in many cultural and mythical narratives for decades, and this relationship is changing with shifts in lifestyle (Alves *et al.* 2010; Fuentes 2012; Rampheri *et al.* 2022; Ikhuluru *et al.* 2023). For instance, some Hindu communities view nonhuman primates as sacred (Karasinski & Erancheri 2026), while in Japan they are often perceived as crafty (Hill & Webber 2010). Conversely, for many farmers around the world, their presence is associated with significant crop depredation and food insecurity (Alves *et al.* 2010; Hill & Webber 2010; Cosby *et al.* 2025).

Kenya holds 21 nonhuman primate species and six subspecies, accounting for 17% of mainland Africa's known nonhuman primate species (De Jong & Butynski 2012; Kivai *et al.* 2025). Five of the 21 species have their geographical range within the biodiversity-rich Mathews Range, a forested mountain chain that crosses the semi-arid plains of Samburu County (De Jong & Butynski 2010). This forested landscape faces severe impacts from climate change (such as prolonged droughts and erratic precipitation) and increased anthropogenic activities, which have impacted the livelihood of many pastoralists (Mwenja 2007). The local community is mainly composed of pastoralists who account for 88% of the total population in the county (Samburu County 2023-2027 Climate Action Plan 2023). Satellite images between 2021

and 2024 have revealed that the Mathews Range Forest lost 193 hectares, with 99% of the loss occurring in natural forest. The impacts of this loss on local primates remain unknown (Global Forest Watch 2025). Mathews Range Forest has been understudied due to its challenging terrain and lack of security. It has not drawn research interest, despite its potential as a key primate hotspot (Kivai & Fundi 2016). Therefore, there is a scarcity of information regarding the community attitudes and perceptions towards the conservation of primates within the Samburu Ecosystem. The most threatened primate species in this landscape is the endangered *Colobus guereza percivali* (Mwenja 2019; IUCN 2026), which is hunted for its pelt and also experiences habitat degradation (Mwenja 2007; Kivai *et al.* 2025). Consequently, the insufficient continuous monitoring of Mt. Uaraguess guereza hampers knowledge of its behavior, population dynamics, anthropogenic activities, and climate change impacts.

Because local community perception of the Mt. Uaraguess guereza and other primates in the area is not well known, this study aimed to document people's perceptions of primate species, the perceived threats to primates and their habitats, the cultural beliefs influencing primate conservation, and community attitudes toward conservation initiatives.

METHODS

Study area

We conducted this study in Mathews Range Forest Reserve (ca. 940 km²) (37-38°E and 0-1°N) in Samburu County, Kenya (Figure 1) from September 2024 to June 2025. This area receives 700–1100 mm of rainfall per year, with temperatures ranging from 14 – 20 °C, with the exception of a prolonged dry season when temperatures may reach 30 °C (Blackett 1994). This area was gazetted in 1956 and declared a forest reserve in 1964. The forest landscape comprises rocky outcrops and steep terrain, with the highest point recorded at 2688 meters above sea level (De Jong & Butynski 2010). The ecosystem supports various primate species such as the Mt. Uaraguess guereza, olive baboons, De Brazza's monkey, northeastern vervet monkeys and nocturnal galagos (De Jong & Butynski 2010; Butynski & De Jong 2025). Also, the habitat is home to over 153 diverse bird species, and other threatened mammals such as the African lion (*Panthera leo*), African elephant

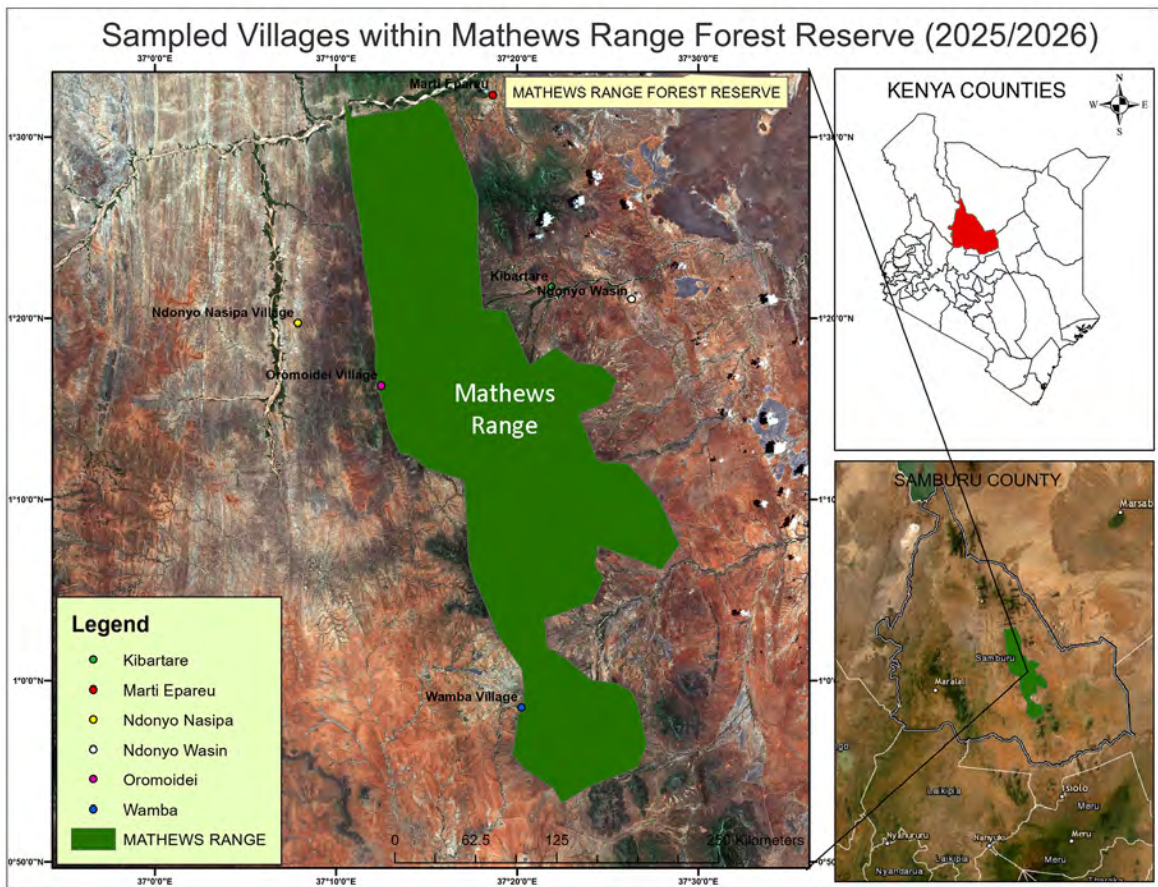


Figure 1. A map showing the Mathews Range Forest Reserve in Samburu County and the distribution of the sampled villages within the study area.

(*Loxodonta africana*), and leopards (*Panthera pardus*) (De Jong & Butynski 2010). Additionally, the ecosystem supports diverse threatened flora, such as the African sandalwood (*Osyris lanceolata*), *Juniperus procera*, *Podocarpus latifolius*, and the Mathews range cycad (*Encephalartos tegulaneus*) (Bronner 1991; Bussmann 2002).

Data Collection and Sampling Strategy

This study was conducted in accordance with the national and institutional ethical guidelines. Formal ethical approval was granted by the Kenya Institute of Primate Research Institutional Scientific and Ethics Review Committee (ISERC/11/2024) and the National Commission for Science, Technology and Innovation (NACOSTI/P/418189). Before data collection, community sensitization meetings were held at Wamba, Ndonyo Nasipa, Oromoidei, Ndonyo Wasin, Kibartare, and Marti Epareu to discuss the study's objectives and potential impacts. Following the community meeting, verbal consent

was obtained from each individual respondent prior to participation. The participants were informed of the voluntary nature of the study, the right to withdraw at any time, and measures to ensure confidentiality of their data. We used the Cochran formula to calculate the ideal sample size of 253 from a total of 4,820 households, with a confidence level of 95% and a margin of error of 6% (Cochran 1977). The total number of households in the study area was 4,820, according to the 2019 Kenya National Population Census (Kenya National Bureau of Statistics 2019). The target villages/areas near the forests were: Wamba, Kibartare, Ndonyo Nasipa, Ndonyo Wasin, Marti Epareu and Oromoidei (Lesorogol & Lesorogol 2024; Oloitipitip *et al.* 2024). The surveyed villages were selected in an evenly distributed pattern to ensure representative coverage of south, central, and northern parts of Mathews Range Forest Reserve.

To ensure data reliability and to minimize bias, data collection involved trained enumerators in identifying features of different primate species,

neutral interviewing, and translating and back-translation of the questions into the local dialect to ensure the intended meaning remained intact. The selection of households was guided by a skipping pattern formula, in which K represented the skipping interval, calculated as the total number of households in the village divided by the number of targeted households (Cochran 1977; Kumar 2013). In each household, only one member was selected for interview using the date rule method (Solati *et al.* 2024). The respondents were interviewed individually to ensure privacy and independent responses. The data collected included human demographic characteristics, socioeconomic profiles, respondents' occupational activities, knowledge of primate species through correct identification and description, the last time they sighted the primate species, perceived ecosystem threats, community perceptions of conservation measures, cultural practices, and taboos. We categorized respondents' observations of primates into four temporal classes:

recent (0-2 months), recent past (3-6 months), intermediate past (6 months to 1 year), and distant past (over 1 year).

Data Analysis

We conducted all statistical analyses using R statistical software (Ver. 2025.05.1+513). A reproducible workflow was maintained using a set seed [set. Seed (123)] and the following packages: dplyr for data manipulation, ggplot2 for visualizations, stats for chi-square and Kruskal-Wallis tests, and Dunn test for post-hoc comparisons. To assess the community knowledge of nonhuman primate species present in the Mathews Range Forest and the patterns of their occurrence, we compared knowledge scores and temporal sightings across villages, gender, education level, and occupation. Descriptive analysis was conducted using frequencies and proportions to assess associations between knowledge or temporal sighting categories

Table 1. Variable classification as either ordinal or nominal, and the code/scale used.

Variable	Type	Coding / Scale
Respondent age	Ordinal	18–30, 31–43, 44–55, 56–68, >69
Gender	Nominal	Male / Female
Education level	Ordinal	None, Primary, Secondary, College
Occupation	Nominal	Pastoralist, Business, Farmer, Government, Private
Village	Nominal	Wamba, Ndonyo Nasipa, Pareu, Oromoidei, Ndonyo Wasin, Kibartare, Marti Epareu
Number of primates known	Ordinal	0–2, 3–4, 5 species
Species sighted	Nominal	Olive baboon, De Brazza's, Mt Uaraguess guereza, Northeastern Vervet, Small-eared greater galago
Last seen	Ordinal	Today, 1 week ago, 1 month ago, 3–6 months, 6–12 months, >1 year
Perceived threats	Nominal	Hunting, Drought, Habitat destruction, Predation, Human activity
Drivers of threats	Nominal	Prolonged drought, Human activities, Natural calamities
Human–primate conflicts	Nominal	Species causing nuisance (e.g., olive baboon, vervet)
Conservation awareness	Nominal	Yes / No
Ecosystem service benefits	Ordinal	Least beneficial / Somewhat beneficial / Beneficial / Most beneficial
Cultural practices and taboos	Ordinal	Less important / Important
Traditional methods to keep primates away	Nominal	Scarecrow, Stones, Fences
Modern methods to keep primates away	Nominal	Electric fence

and socio-demographic factors, using the chi-square test for categorical variables and the Kruskal-Wallis test for ordinal or non-normally distributed data (Chicco *et al.* 2025). The various variables used in the analysis were classified as ordinal or nominal, as shown in Table 1. The dependent variables were knowledge of primate species and time since last sighting, while the independent variables were village, gender, education, and occupation.

To examine the community perceptions of threats facing nonhuman primates and human-primate interactions, we assessed the respondents' reported threats and conflicts across villages and livelihood types. Chi-square tests were used to determine the associations between perceived threats or conflicts and the socio-demographic factors, while Monte Carlo simulations were applied when expected cell counts were low (Li *et al.* 2025). The dependent variables were perceived threats and conflicts (nuisance species, hunting), while the independent variables were village and livelihood type.

To evaluate the community perceptions of conservation activities, ecosystem service benefits, and cultural practices or taboos, we analyzed reported awareness of conservation measures, perceived benefits of ecosystem services, and the importance of taboos or cultural practices across age groups, villages, and gender. Frequencies and cross-tabulations were computed, and chi-square tests were used in determining the associations between beneficiary type, conservation perceptions, and cultural practices (Clark *et al.* 2024). The dependent variables were awareness of conservation, ecosystem service benefits, and importance of taboos/cultural practices, while the independent variables were village, age, gender, and beneficiary type.

RESULTS

Socio-demographic Characteristics of Respondents

Of the 207 respondents, 33% were from Oromoidei, 23% from Ndonyo Wasin and Wamba each, 8% from Ndonyo Nasipa and Marti Epareu, and lastly 4% from Kibartare. The majority of the respondents (53%) were male, while 47% were female. Approximately 66% of the respondents reported having no formal education, while the rest had attained some level of formal education. In terms of age distribution, 33% were in the 18-30 age bracket, another 33% were in the 31-43 age

Table 2. Correct identification of primate species by respondents (number of respondents per species).

Number of Primate Species Identified	Frequency (n)	Percentage (%)
2	5	2.4
3	3	1.4
4	8	3.9
5	191	92.3

bracket, 22% in the 44-55 age bracket, and 10% in the 56-68 age bracket. Only 2% were aged above 69 years. Regarding the respondents' occupations, the majority (73%) were involved in pastoralism, about 15% engaged in business activities, while 6% were involved in farming activities. A smaller proportion were privately employed (3%), worked in the government sector (2%), and only 1% reported being engaged in other forms of employment.

Knowledge and Sightings of Primate Species

Most respondents (92%) correctly identified and described physical features of five primate species, while 1.4% correctly identified three primate species within the study area (Table 2).

The respondents had knowledge of most of the primate species, such as baboons, vervet monkeys, indicating to have seen them during the day, and a few of them (1.60%) had seen the galago during the day (Table 3).

Based on how recently each species was sighted, respondents' observations showed that olive baboons and vervet monkeys were the most frequently seen species, with 96% and 97.6%, respectively, within the past two months. The least sighted primate species was Mt. Uaraguess guereza (16%), followed by De Brazza monkey (23.5%) (Table 4).

Perceived Importance of Matthews Range Forest to Livelihoods

All the respondents (n = 207) recognized that the Mathews Range Forest Reserve ecosystem supports their pastoralism livelihood. Almost all of the respondents (99%) confirmed that livestock grazed within the Reserve. *Crabia laurenti* was the most preferred tree for fodder or pasture (49%),

Table 3. Respondents’ familiarity with diurnal and nocturnal nonhuman primates within the Mathews Range Ecosystem.

Species	No. of respondents	Percentage of respondent who knew the species
Olive baboon (day)	207	100.00
De Brazza’s monkey (day)	188	90.80
Mt Uaraguess guereza	189	91.30
Northeastern vervet monkey (day)	207	100.00
Small eared galago (day)	003	1.60
Small eared galago (night)	184	97.90

followed by *Strychnos henningsii* and the least was the *Euphorbia candelabrum* (Figure 2).

Perceived Threats to Primates

On the community’s knowledge of perceived threats to primates in the area, 98% of the respondents agreed that primates in the Mathews Range ecosystem faced threats, while 2% disagreed. Based on the threats facing primates, lack of food (food resource scarcity) emerged as the most commonly mentioned threat (35.8%) while hunting was reported the least (0.4%) (Figure 3).

Based on the key drivers contributing to the threats, the respondents identified prolonged drought as the major key driver (46.2%), followed by human activities. The respondents identified the destruction of the habitat as the least important driver of threats (0.3%) (Figure 4), while 1.4% of the respondents indicated that they have no knowledge of the key drivers of threats.

Hunting and Cultural Practices

A higher percentage of the respondents indicated that the Mt. Uaraguess guereza had an increased population (57.07%) compared to 42.93% who

reported a decline. Additionally, the respondents indicated that hunting was practiced by locals from outside the area (86.70%), targeting the colobus monkeys (65.40%) for their skin (99.50%) (Table 5).

Community Perceptions of Primate Conservation Measures

Based on responses regarding the costs and benefits of living with primates, 98.5% (n = 195) of the respondents indicated that it was both costly and beneficial to live with primates, while 1.5% (n = 3) felt it was only costly. The comparison of community perceptions of benefits indicated a significant association between beneficiary type and perceived benefit level ($\chi^2 = 1424.5$, $p = 0.0005$). A moderate strength of association was indicated after testing variables (Cramer’s V = 0.98).

The majority of the respondents (99%) indicated that olive baboons were a nuisance, while the rest (1%) identified vervet monkeys as a nuisance. The baboons being a nuisance was attributed to feeding on young goats, especially during the dry seasons, while the vervets invaded their farms. Of the primates found in Mathews range, 95.11% of the respondents indicated that the colobus monkey and De Brazza monkeys were beneficial to them since they attract

Table 4. Temporal classification of primate sightings as per respondents’ responses.

Species	Recent (0–2 months) %	Recent past (3–6 months) %	Intermediate past (6 months–1 year) %	Distant past (>1 year) %
Olive baboon	96.00	–	3.00	1.00
Vervet monkey	97.60	–	3.00	1.00
De Brazza’s monkey	23.50	11.50	29.50	35.50
Mt Uaraguess guereza	16.00	10.00	33.00	41.00
Small-eared galago	91.00	1.00	6.00	2.00

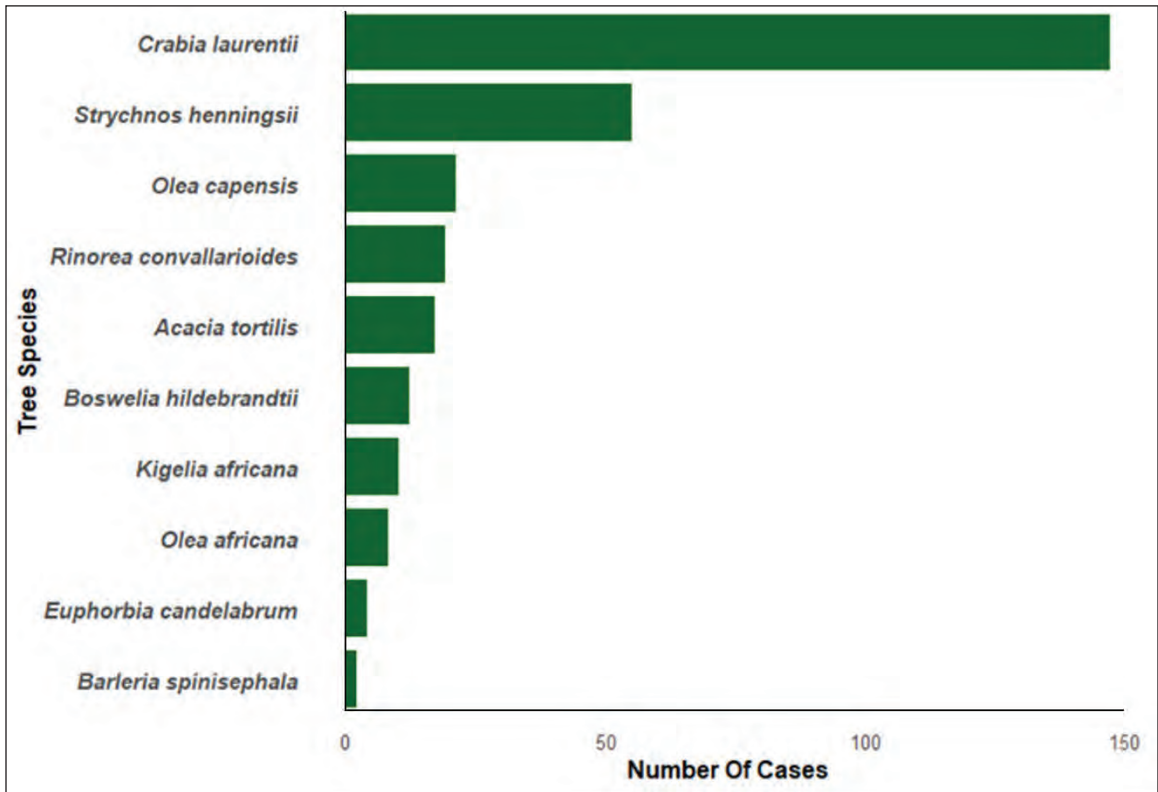


Figure 2. Tree species commonly preferred by community members as livestock fodder sources.

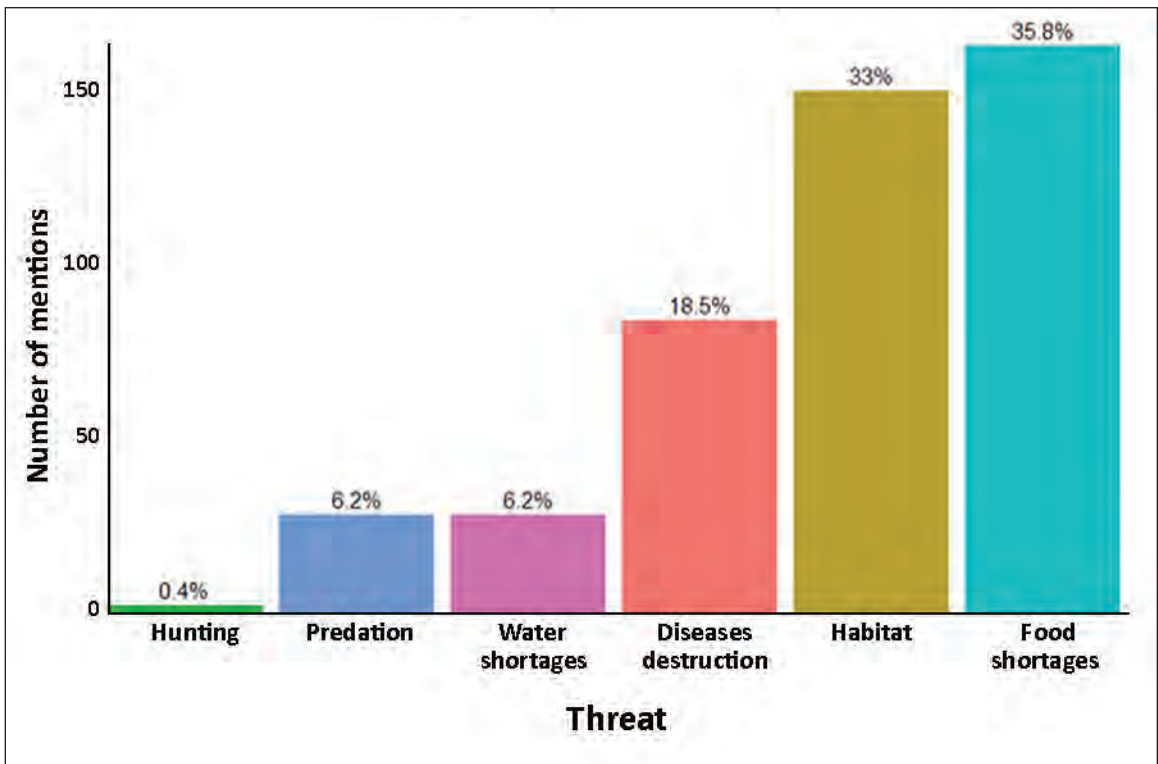


Figure 3. Respondents' responses on the threats to primates within Mathews Ranges.

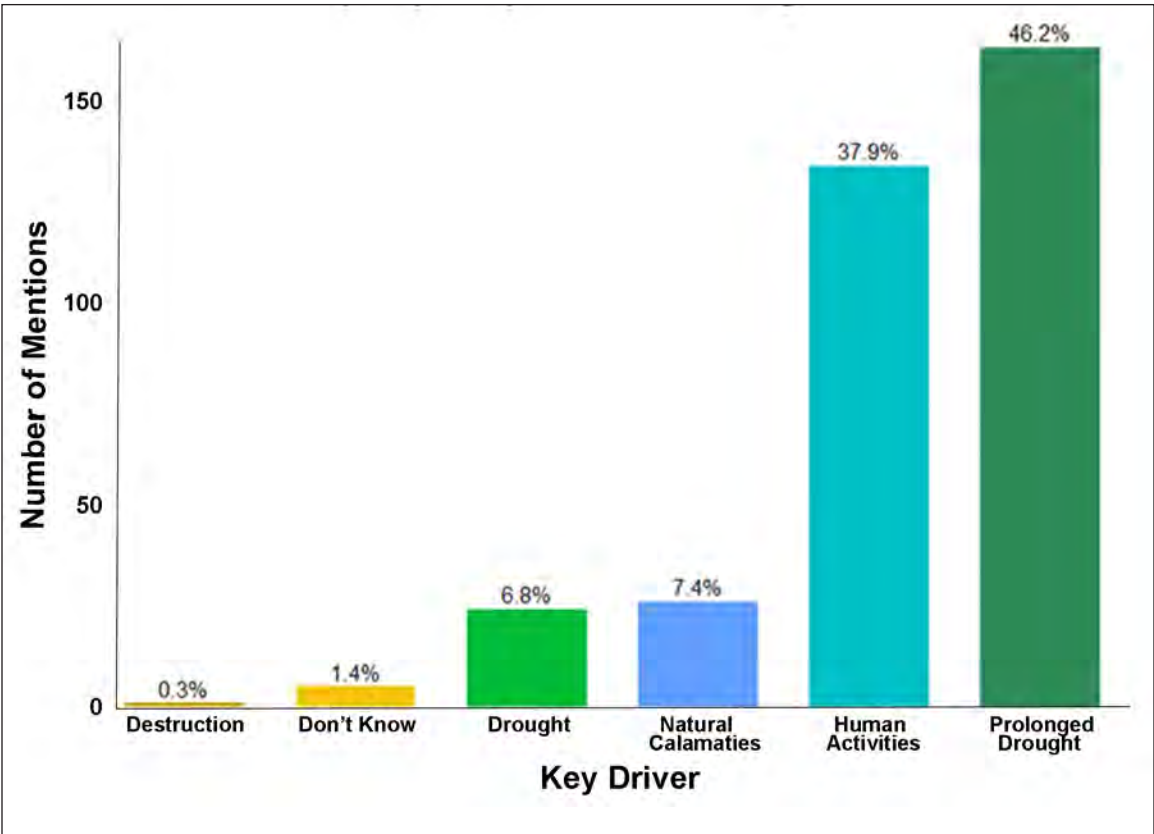


Figure 4. Respondents’ responses on the key drivers of threats to primates within Mathews Ranges.

tourist and researchers. Regarding conservation activities within the Mathews Range ecosystem, less than half (30.58%) of the respondents indicated that they were aware, while the rest (69.42%) were not aware of any conservation activities. When asked about community-driven mitigation efforts towards conservation, 97.54% stated that none existed, only 1% indicated that there were community-driven mitigation exercises, while 1.48% (n = 3) indicated they were unsure. Those who acknowledged the presence of community-driven initiatives cited community-based forest management and tree planting as examples. Conversely, those who stated there were no initiatives provided reasons such as a lack of benefits, limited knowledge, and low interest among community members (Table 6).

Cultural Practices, Taboos, and Beliefs

The majority of the respondents stated that there are taboos and cultural practices that involve primates, particularly the wearing of colobus skin.

Very few of the respondents (0.98%, n = 2) indicated that these beliefs and cultural practices were of importance, while the majority (99.02%, n = 203) rated them as less important in conservation.

A Kruskal-Wallis test was performed on numeric perception scores (scored as 4 = “Benefits most”, 3 = “Somewhat beneficial”, 1 = “Benefits least”) to compare perceptions across all beneficiaries. This test revealed highly significant differences in perception scores among ecosystem services ($\chi^2 = 1379.0$, $df = 6$, $p < 0.001$) confirming that perceptions are not uniform. Post-hoc pairwise comparisons using Dunn’s test with Bonferroni correction indicated that hunting and fruit gathering differed significantly from all other beneficiaries ($p < 0.001$), as did several other pairwise comparisons (e.g., Hunting and fruit gathering vs Pasture and Grazing, Tourism, and Water). In contrast, differences among beneficiaries such as Carbon Credits, Conservation, and Food Production/Farming were not statistically significant after adjustment ($p > 0.05$), suggesting broadly similar perceptions for these services.

Table 5. Respondents' opinions on endangered Mt. Uaraguess Guereza hunting within the study area.

Statement	Response and Frequency	Percentage (%)
Have the population of Mt. Uaraguess guereza increased	Increased (n = 113)	57.07
	Decreased (n = 85)	42.93
Presence of primate hunting of Mt Uaraguess guereza?	Yes (n = 134)	65.4
	No (n = 71)	34.6
Who hunts Mt Uaraguess guereza monkeys	Outside community members (n = 170)	86.7
	Local community members (n = 23)	11.7
	Unknown groups (n = 2)	1.0
	Don't know (n = 1)	0.5
If hunting occurs within the community (n=194 respondents reporting local hunting)	Warriors (young Morans) (n = 194)	94.63
Is the skin sold in the market?	Not sold (n = 205)	99.5
	Don't know (n = 1)	0.5
Is there an alternative way to the use of colobus skin?	Wearing of beads instead of colobus skin (n = 193)	94.15
If no, would you be willing to use it for the same purpose?	Yes (n = 31)	15.5
	No (n = 169)	84.5
Are there any other primates that are hunted?	Yes (n = 4)	2
	No (n = 201)	98

Table 6. Perceived benefits from Mathew Ranges Ecosystem.

Beneficiary	Response	Frequency (n)	Percentage
Carbon credits	Benefits most	203	100
Conservation	Benefits most	203	100
Food production farming	Benefits most	201	99
	Somewhat beneficial	2	0.99
Hunting and fruit gathering	Benefits least	190	93.6
	Benefits most	1	0.49
	Not sure	12	5.91
Pasture and grazing	Benefits most	203	100
Tourism	Benefits most	203	100
Water	Benefits most	203	100

DISCUSSION

This study showed insights into community knowledge, perceptions, and practices regarding primates and conservation in the Mathews Range of Samburu County. The people's knowledge of primates was relatively high. Their awareness of common diurnal primates such as *Papio anubis*, *Chlorocebus pygerythrus arenaria*, and *Colobus guereza percivali*, accuracy in recognizing these species is closely aligned with previous assessments of wildlife richness in the region (Mwenja 2007; De Jong & Butynski 2010; Kivai & Fundi 2016). These species are often found near human settlements and are easily sighted. This explains the community's high awareness of the primates. However, awareness of nocturnal species, such as small-eared galago was relatively low. This was consistent with the findings from Estrada *et al.* (2017), who highlighted that lesser-known primates by locals are often underrepresented in community knowledge. Most of the respondents were permanent residents and pastoralists whose livelihoods depended heavily on the forest ecosystem. The importance of the forest to local community's livelihood and the widespread use of the Reserve for livestock grazing demonstrate the intensity of human dependence on forest resources. This provides a clear framework for observed differences in reported sighting of some species which may indicate decline in primate populations due to habitat degradation, increased competition between livestock and arboreal primates and deforestation.

These close interactions with their landscape shape their awareness of primate species, their understanding of local threats, and their perception of conservation initiatives. Similar findings have been reported in community-based wildlife studies where demographic factors such as age, gender, and livelihood directly influenced levels of ecological knowledge and attitude toward conservation (Fotsing *et al.* 2024).

After assessing the threats that primates face in Mathews Range, it was noted that most of the respondents were aware of the different threats they face. According to Estrada *et al.* (2022), human population increase, agricultural expansion, and climate change are expected to significantly contribute to the loss of additional suitable habitat and a reduction in the viability of local primate populations. Similarly, Mwenja *et al.* (2007) observed that human settlements primarily affect lower-altitude habitats occupied by primates. In

contrast, Kivai and Fundi (2016) reported that selective felling of preferred fodder plant species — especially during periods of severe drought in the mid- and high-altitude areas of the Mathews Range — posed a major threat to both De Brazza's monkey and Percival's guereza.

It was noted that pastoralists posed the greatest threat to the ecosystem. Although, pastoralism can worsen habitat degradation through overgrazing, it is also an essential means of survival for the local communities in Kenya (Mwangi *et al.* 2016). With all the respondents confirming that their animals grazed in Mathews Range Forest, there would be pressure on the resources used in the area. This reflects the growing trend of pressure as seen across Kenya's arid and semi-arid landscapes (Mwangi *et al.* 2016; Samburu County 2023-2027 Climate Change Action Plan 2023). Repeated use of forest zones for dry-season grazing may eventually threaten primate habitats, especially the De Brazza's and colobus monkeys, which depend on closed-canopy environments or riverine ecosystems. Habitat degradation can significantly alter the composition and distribution of gut microbiota while also increasing host's exposure to parasites and pathogens (Amato *et al.* 2013).

While the findings reveal a cultural shift in non-importance of wearing colobus skins that could have been influenced by conservation awareness, the reality is hunting colobus for their skin for traditional practices by pastoral communities remain a major threat in Mathew's range. Recent undocumented reports suggest that the Samburu warriors (morans) potential kill and sell the colobus skin for cultural use either within or outside the community. Thus, with the data contrasting the anecdotal findings, this calls for deeper research and monitoring on the role of culture in shaping primate communities in Mathew's ranges. The findings, however, points to a potential cultural shift, especially influenced by conservation awareness. Globally, primates have historically been used in traditional folk medicine, with the selection of species often tied to folk beliefs, which is supported by our data. Alves *et al.* (2010) as well reported that 101 primate species, representing 38 genera and 10 families, have been used in traditional practices and religious rituals across the world.

On community perceptions on primate conservation local's attitudes were polarized with some recognizing net benefits due to employment opportunities while others focused on specific costs incurred from livestock predation and other

forms of human-nonhuman primate conflict. This divergence suggests that conservation interventions for primates must not only leverage on accrued economic benefits but also directly mitigate conflicts arising from human primates interactions which generate negative conservation attitudes (Kifle 2021; Haile *et al.* 2024; Carter *et al.* 2026).

In addition, it was found that Samburu Morans remain the primary hunters, which reflects the persistence of traditional beliefs that may endanger the primate species. These patterns resemble what Akinyi *et al.* (2021) described as the consequences of human incursions into wildlife habitats due to traditional beliefs. While most of the respondents believed that living with primates was both costly and beneficial, some were unaware of any active conservation activities at Mathew's ecosystem, which included De Brazza and colobus monkeys monitoring, primate ecotourism, girl-child education scholarship and beehive program which aimed at improving the livelihoods of the local people. This variation potentially highlights a major issue in conservation governance, localized conservation initiatives or lack of local inclusion and benefit-sharing, as emphasized by Cosby *et al.* (2025) who argued that conservation should be done holistically and sustainably. Additionally, a good number of the respondents showed a willingness to engage in conservation efforts through awareness creation. The few who wanted to be employed in primate protection, demonstrates a potential for participatory conservation.

On the rating of ecosystem services, respondents identified water, pasture, carbon credits and tourism as the most beneficial. These offer direct benefits to the local people and closely align with global conservation frameworks which advocate for ecosystem services-based management (Wright *et al.* 2018), offering a potential entry for conservation models which support the survival of local communities.

Awareness campaigns, community participation, community conservancy model, and adaptive grazing strategies rooted in the values of local communities may strengthen conservation efforts in Mathews range. Linking the results with global literature it is clear that localized challenges mirror the international conservation concerns. The findings underscore the need for stronger community inclusion in conservation, adaptive grazing strategies and targeted ecological awareness. Together, these measures can enhance protection of endangered primates such as *Colobus guereza percivali* which is a focal species due to its conservation significance,

and role it plays as indicator of ecosystem health thus strengthening sustainability of Mathews Range Forest reserve.

CONCLUSIONS

This study highlights strong community awareness of primates and perceived threats within the Mathews Range ecosystem, particularly regarding habitat degradation and hunting pressures affecting *Colobus guereza percivali* and, to some extent, the *Cercopithecus neglectus*. While respondent perceptions suggest reduced recent sightings of the colobus, these findings should be interpreted cautiously, as they do not substitute for ecological population estimates. Integrating community knowledge with systematic population surveys and wildlife health monitoring will be essential to accurately assess conservation status. Strengthening participatory conservation, adaptive grazing strategies, and culturally informed education programs offers a viable pathway to enhancing primate conservation while sustaining local livelihoods within the Mathews Range Forest Reserve.

Although the sample size was 253 households, the study attained 82% response rate. This minor shortfall constitutes a limitation but does not undermine the statistical validity of the findings. Limitations of analyses include single-level variables (e.g., Water and Carbon Credits), which prevented meaningful calculation of Cramér's V for all pairwise combinations, as well as unequal representation across some beneficiary categories. While univariate and bivariate analyses were the focus of this study, multivariate approaches such as ordinal regression could provide additional insight into how socio-demographic factors jointly influence perceptions and are recommended for future research.

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REFERENCES

- Akinyi, M.Y. 2021. Surveillance of emerging infectious diseases in wild non-human primates in Kenya: successes and challenges. *Research Square* 2021: 1-42. <https://doi.org/10.21203/rs.3.rs-923002/v1>
- Alves, R.R.N., W.M.S. Souto & R.R.D. Barboza. 2010. Primates in traditional folk medicine: a world overview. *Mammal Review* 40(2): 155–180. <https://doi.org/10.1111/j.1365-2907.2010.00158.x>
- Amato, K.R., C.J. Yeoman, A. Kent, N. Righini, F. Carbonero, A. Estrada, H. Rex Gaskins, R.M. Stumpf, S. Yildirim, M. Torralba, M. Gillis, B.A. Wilson, K.E. Nelson, B.A. White & S.R. Leigh. 2013. Habitat degradation impacts black howler monkey (*Alouatta pigra*) gastrointestinal microbiomes. *The ISME Journal* 7(7): 1344–1353. <https://doi.org/10.1038/ismej.2013.16>
- Bengis, R.G., F.A. Leighton, J.R. Fischer, M. Artois, T. Mörner & C.M. Tate. 2004. The role of wildlife in emerging and re-emerging zoonoses. *Revue Scientifique et Technique, Office International des Epizooties* 23(2): 497-512.
- Blackett, H. 1994. Forest inventory report of the Mathews Range Forest Reserve. *KIFCON*, Nairobi 8: 1-14.
- Bronner, G. 1991. Vegetation and land use in the Mathews Range area, Samburu-District, Kenya. *Dissertationes Botanicae* 160: 182 pp.
- Bussmann, R.W. 2002. Islands in the Desert: forest vegetation of Kenya's smaller mountains and highland areas (Nyiru, Ndoto, Kulal, Marsabit, Loroghi, Ndare, Mukogodo, Porrer, Mathews, Gakoe, Imenti, Ngaia, Nyambeni, Loita, Nguruman, Nairobi). *Journal of East African Natural History* 91(1): 27-79. <https://doi.org/10.2982/0012-8317>
- Butynski, T.M. & Y.A. De Jong. 2025. *Chlorocebus pygerythrus* ssp. *arenaria*. *The IUCN Red List of Threatened Species*: e.T253488055A253491049. <https://dx.doi.org/10.2305/IUCN.UK.2025-1.RLTS.T253488055A253491049.en>
- Carter, N.H., E.K. Buchholtz, J.A. Glikman, A.S. Nanni & M. Puri. 2026. Resilience thinking for human–wildlife coexistence: bridging dynamic systems, archetypes, and transformations. *Ambio* 55(5): 1003–1010. <https://doi.org/10.1007/s13280-026-02359-1>
- Ceballos, G., P.R. Ehrlich & P.H. Raven. 2020. Vertebrates on the brink as indicators of biological annihilation and the sixth mass extinction. *Proceedings of the National Academy of Sciences* 117(24): 13596–13602. <https://doi.org/10.1073/pnas.1922686117>
- Chicco, D., A. Sichenze & G. Jurman. 2025. A simple guide to the use of Student's t-test, Mann-Whitney U test, Chi-squared test, and Kruskal-Wallis test in biostatistics. *BioData Mining* 18(1): 56. <https://doi.org/10.1186/s13040-025-00465-6>
- Clark, M., H.M. Hamad, J. Andrews, V. Hillis & M.B. Mulder. 2024. Effects of perceptions of forest change and intergroup competition on community-based conservation behaviors. *Conservation Biology* 38(4): e14259. <https://doi.org/10.1111/cobi.14259>
- Cochran, W.G. 1977. *Sampling Techniques* (3. ed). Wiley.
- Cosby, A.E., B. Andriatsitohaina, R. Archie, C. Jules, K.C. McGoogan, M. Persram, M. Razafitsalama, A. Young, A. & T.S. Steffens. 2025. Primate conservation: a public issue? *American Journal of Primatology* 87(1): e23632. <https://doi.org/10.1002/ajp.23632>
- De Jong Y.A. & T.M. Butynski. 2012. The primates of East Africa: country lists and conservation priorities. *African Primates* 7(2): 135–155.
- De Jong, Y.A. & T.M. Butynski. 2010. Assessment of the primates, large mammals and birds of the Mathews Range Forest Reserve, central Kenya. Unpublished report to The Nature Conservancy, Washington DC.
- Estrada, A. & P.A. Garber. 2022. Principal drivers and conservation solutions to the impending primate extinction crisis: introduction to the special issue. *International Journal of Primatology* 43(1): 1–14. <https://doi.org/10.1007/s10764-022-00283-1>
- Estrada, A., P.A. Garber, A.B. Rylands, C. Roos, E. Fernandez-Duque, A. Di Fiore, K.A.-I. Nekaris, V. Nijman, E.W. Heymann, J.E. Lambert, F. Rovero, C. Barelli, J. Setchell, T.R. Gillespie, R.A. Mittermeier, L.V. Arreaga, M. De Guinea, S. Gouveia, R. Dobrovolski, ... B. Li. 2017. Impending extinction crisis of the world's primates: why primates matter. *Science Advances* 3(1): e1600946. <https://doi.org/10.1126/sciadv.1600946>

- Fotsing, E.D.B., M.M.F. Kamkeng & D. Zinner. 2024. Opinions, attitudes and perceptions of local people towards the conservation of Nigeria-Cameroon chimpanzees in Mpem-Djim National Park, central Cameroon. *People and Nature* 6(2): 865–881. <https://doi.org/10.1002/pan3.10621>
- Fuentes, A. 2012. Ethnoprimatology and the anthropology of the human-primate interface. *Annual Review of Anthropology* 41(1): 101–117. <https://doi.org/10.1146/annurev-anthro-092611-145808>
- Global Forest Watch, F.W. 2025. *Mathews Range Forest Change* 2025. <http://gfw.global/48OSimC>
- Haile, M., T. Gadisa & T.M. Gutema. 2024. Human-De Brazza's monkey conflict in Kafa Biosphere Reserve, Kafa Zone South West, Ethiopia. *BMC Zoology* 9(1): 20. <https://doi.org/10.1186/s40850-024-00210-2>
- Hill, C.M. & A.D. Webber. 2010. Perceptions of nonhuman primates in human-wildlife conflict scenarios. *American Journal of Primatology* 72(10): 919–924. <https://doi.org/10.1002/ajp.20845>
- Ikhuluru, W.E., M.E. Imboma, S.E. Liseche, M.J. Milemele, S.D. Shilabiga & M. Cords. 2023. Local voices: perspectives from the local community on the primates of Kakamega Forest, Western Kenya. *Animals* 13(22): 3483. <https://doi.org/10.3390/ani13223483>
- Karasinski, M. & P. Erancheri. 2026. The blessing of the monkeys, the whisper of enchanted stones: A case study of indigenous ecology in the sacred groves of Kerala (India) and Nagarkot (Nepal). *Religions* 17(2): 224.
- Kemunto, N., E. Mogo, E. Osoro, A. Bitek, M. Kariuki Njenga & S.M. Thumbi. 2018. Zoonotic disease research in East Africa. *BMC Infectious Diseases* 18(1): 545. <https://doi.org/10.1186/s12879-018-3443-8>
- Kenya National Bureau of Statistics. 2019. The 2019 Kenya population and housing census. Volume I: Population by county and sub-county. Kenya National Bureau of Statistics (KNBS).
- Kifle, Z. 2021. Human-olive baboon (*Papio anubis*) conflict in the human-modified landscape, Wollo, Ethiopia. *Global Ecology and Conservation* 31: e01820. <https://doi.org/10.1016/j.gecco.2021.e01820>
- Kivai S.M., P.M. Kabasa, C.M. Kivasu, T.M. Wambua, J.W. Mbugua, B. Lekaaso, R.W. Mburu & P.M. Otolu. 2025. Sustainable Financing and Community Engagement in Primate Conservation: Halting Local Extinction and Building Resilience of a Healthy Planet. 2025 International Primates Day Celebrations (IPD) Report, Kenya Institute of Primate Research, Kenya.
- Kivai S.M. & P.N. Fundi. 2016. Assessment of habitat suitability for De Brazza's Monkey, *Cercopithecus neglectus*, in Mathew's Range Forest Reserve, Kenya: is relocation feasible as the last option? Technical Report, International Foundation for Science, Stockholm, Sweden.
- Kumar, D.R.V. 2013. Respondent selection methods in household surveys. *Jharkhand Journal of Development and Management Studies*. <https://ssrn.com/abstract=2392928>
- Lesorogol, C. & P. Lesorogol. 2024. Community-based wildlife conservation on pastoral lands in Kenya: a new logic of production with implications for the future of pastoralism. *Human Ecology* 52(1): 15–29. <https://doi.org/10.1007/s10745-024-00482-9>
- Li, X., D. Ding, X. Wang, M. Li, Y. Chen, Y. Zhou, S. Deng, W. Xie & L. Kong. 2025. Integration of self-organizing map and Monte Carlo simulation for ecological risk prediction of heavy metal attenuation in groundwater. *Ecotoxicology and Environmental Safety* 302: 118761. <https://doi.org/10.1016/j.ecoenv.2025.118761>
- Mwangi, D.K., M. Akinyi, F. Maloba, M. Ngotho, J. Kagira, D. Ndeereh & S. Kivai. 2016. Socioeconomic and health implications of human-wildlife interactions in Nthongoni, Eastern Kenya. *African Journal of Wildlife Research* 46(2): 87. <https://doi.org/10.3957/056.046.0087>
- Mwenja, I. 2007. A new population of De Brazza's monkey in Kenya. *Primate Conservation* 22(1): 117–122. <https://doi.org/10.1896/052.022.0111>
- Mwenja, I. 2019. *Colobus guereza ssp. percivali*. *The IUCN Red List of Threatened Species* e.T40007A17983118.
- Norconk, M., C.L. Thompson, A. Vreedzaam, S. Atsalis, J.A. Ledogar, C. Landburg & B.W. Wright. 2025. Ecological resilience in a primate community affected by gold mining in suriname. *Biotropica* 57(2): e70007. <https://doi.org/10.1111/btp.70007>
- Oloitipitip, F.R., E. Ndunda & C.M. Gichuki. 2024. Climate variability and livelihood vulnerability of maasai pastoralists in Amboseli ecosystem, Kajiado County, Kenya. *Journal of the Kenya National Commission for UNESCO* 4(2). <https://doi.org/10.62049/jkncu.v4i2.101>
- Rampheri, M.B., T. Dube, C. Shoko, T. Marambanyika & I. Dhau. 2022. Local community attitudes and perceptions towards benefits and challenges

- associated with biodiversity conservation in Blouberg Nature Reserve, South Africa. *African Journal of Ecology* 60(3): 769–779. <https://doi.org/10.1111/aje.12989>
- Rouquet, P., J.-M. Froment, M. Bermejo, A. Kilbourn, W. Karesh, P. Reed, B. Kumulungui, P. Yaba, A. Délicat, P.E. Rollin & E.M. Leroy. 2005. Wild animal mortality monitoring and human ebola outbreaks, Gabon and Republic of Congo, 2001–2003. *Emerging Infectious Diseases* 11(2): 283–290. <https://doi.org/10.3201/eid1102.040533>
- Samburu County, 2023-2027 Climate Change Action Plan. 2023. The Department of Water, Environment, Climate Change, Natural Resources, and Energy; Samburu County.
- Solati, M., F. Boroumand & H. Toutouni. 2024. Applying the last-birthday respondent selection method to an oral health telephone survey in an Iranian population. *Journal of Oral Health and Oral Epidemiology* 13(1): 25–30. <https://doi.org/10.34172/johoe.2309.1594>
- Wright, C., D. Nyberg, L. Rickards & J. Freund. 2018. Organizing in the Anthropocene. *Organization* 25(4): 455–471. <https://doi.org/10.1177/1350508418779649>

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Reproductive Parameters and Group Extinction of Chimpanzees at Bossou, Guinea

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Abstract: Fifty years have passed since we started our field studies of the behavior and ecology of western chimpanzees (*Pan troglodytes verus*) at Bossou, Guinea. Although the group was small, 21 individuals at that time, continuous scientific monitoring and a substantial amount of demographic data were recorded over the years. Here, we calculate the age of first and last birth by females, interbirth interval, reproductive success, number of years alive after the last birth, and longevity. The results show that the average female reproductive success was greater than 2, which should suggest that the population was expanding. However, from 2003, group size began to decline after an apparent epidemic disease killed 5 or 6 individuals. From that point, the population continued to decrease from 19 to only 3 individuals remaining in 2024. These three individuals consisted of two adult males and one old post-reproductive female, leaving no possibility for growth and recovery as a reproductive unit. In addition to the loss of many members to disease, an important reason for the group's decline is that most male and female members born in Bossou after 1976 disappeared around the age of sexual maturation, and only a limited number of chimpanzees temporarily immigrated into the group. Unfortunately, the reproductive fate of the young individuals who disappeared could not be determined. As for the scarcity of immigration into the group, we can only speculate that chimpanzees from the adjacent region of about 6 km were too shy to approach the group, perhaps due to a combination of factors including its proximity to research staff, the noise from the adjacent Bossou village, and the savannah and roads separating them. Our study provides another example of the risk over-habitation poses to the survival of wild chimpanzee populations.

Key words: primiparous age, inter-birth interval, last birth, longevity, emigration, immigration

INTRODUCTION

The chimpanzee is an endangered species, with a decreasing number of wild populations and individuals. A key reason for this decline is the reduction of suitable habitat due to deforestation and forest fragmentation. Another problem for chimpanzees, as well as for most other wildlife species, is the proximity and potential conflict with humans caused by the advancement and invasion of agricultural and industrial development in their native habitat. In such environments, continued study of small populations of chimpanzees in the fragmented habitat is badly needed.

Many studies of wild chimpanzees are limited to the study of intelligence, social behavior, and social organization. However, for conservation efforts biological research is essential, particularly as it relates to reproductive activity.

Calculating reproductive success in terms of the number of female offspring produced by a mother is useful for determining the growth rate and sustainability of a population of animals (Bronikowski *et al.* 2016). If the average number of female offspring that survived to their mother's age equals one, the population size remains stable. If it

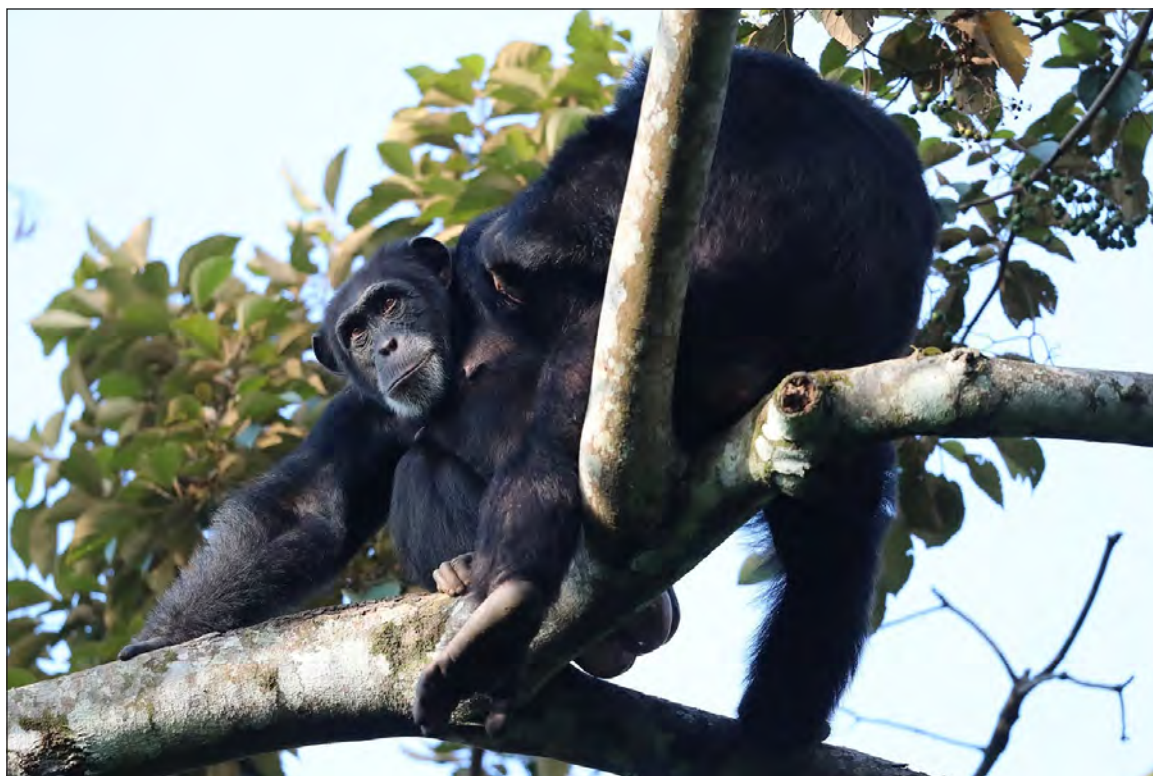


Figure 1. Bossou male, Fanwaa, grooming his mother, Fanle. Photograph by G. Ohashi.

is more than one or less than one, the population is expanding or decreasing, accordingly (Wilson 1975). Thus, calculating reproductive success is important for our ability to predict a population's future.

The long lifespan of chimpanzees requires the inter-generational collaboration of researchers following a single population across multiple generations. However, many female chimpanzees spend most, if not all, of their reproductive lives outside their natal population, making it difficult to accurately measure reproductive success (Goodall 1986; Nishida 2012). Given these constraints, we calculated the reproductive success of individual females where possible and supplement it with additional information relating to population dynamics at Bossou, Guinea.

MATERIALS AND METHODS

Environment

A small group of western chimpanzees (*Pan troglodytes verus*) of Bossou, Lola Prefecture, Republic of Guinea, West Africa, has been studied for their behavior and ecology since 1976 (Figure

1). Bossou village is located at 7°39'N and 8°30'W, about 500 m above sea level. The core area of the chimpanzee group is about 15 km² around five small hills: Gban, measuring 704 m; Guei, 663 m; Bouton, 507 m; Ueyaton, 600 m; and Tonzerou, 560 m asl (Figure 2) (Sugiyama & Koman 1979). The road to the north is connected to the adjacent village Solomeanta and the town Lola surrounded by savanna or cultivated fields. To the west are forest and scattered villages, e.g., Tiaso and Gba, and to the south is grassland and villages (Tuo and Yekepa) and the frontier of Liberia. On the east side are savannah, the villages of Selingbara and Nion, and Mt. Nimba, where there are other wild chimpanzee populations.

Between Nimba and Bossou the land was covered by grasslands which were burned every year during the study period. Villagers did not know whether the fire was natural or artificial. One of our members tried to study these events starting in 2000, however, his personal project (Green Corridor) failed until 2020 when the project was taken over by the government. Until now, the project has not progressed.

This area was primarily tropical rainforest and savanna, but nearly 80% was cultivated fields and/or

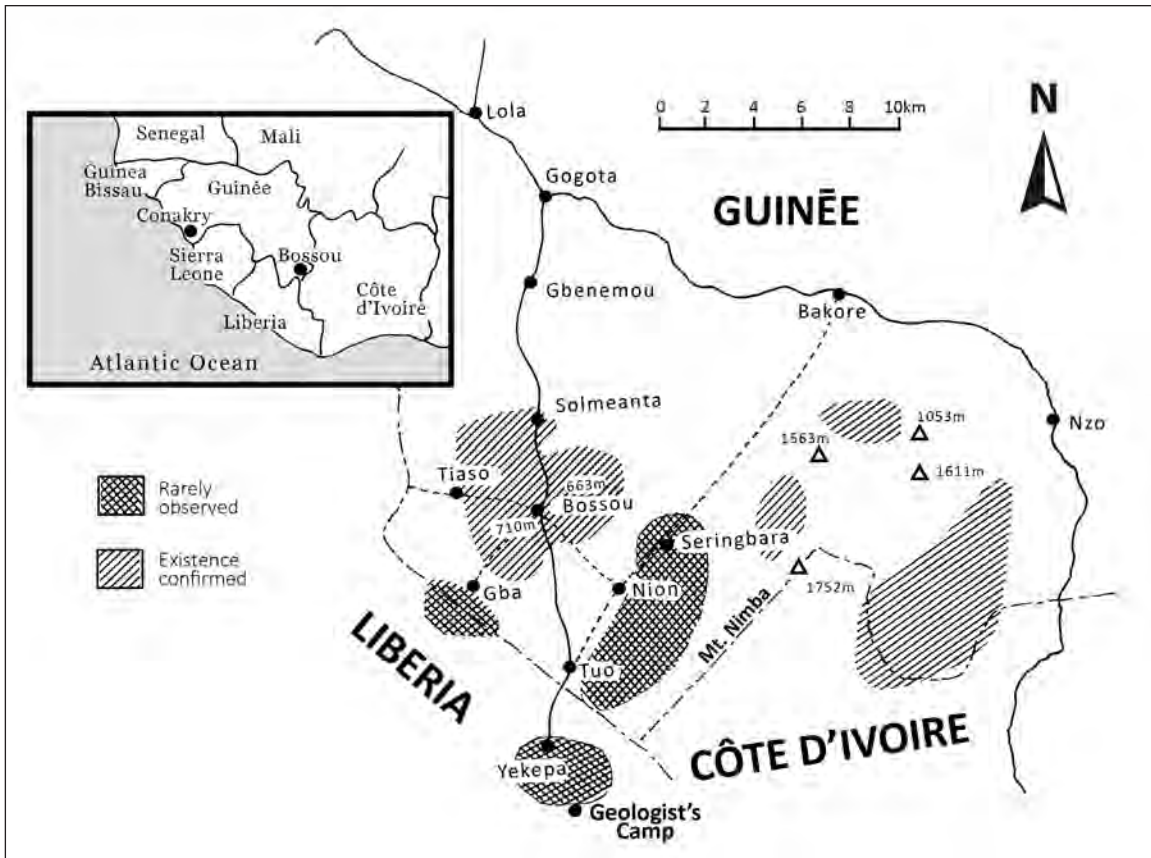


Figure 2. The group often divided into two or three parts and a part sometimes traveled far from the other parts. Then the out-line of the group's range is not clear and obscure. Confirmed area around Bossou village is the core-area and the total area of the home-range can't be shown in this map. Other confirmed areas were observed or heard vocalization by us or our local assistants though the group was not identified.

secondary forests of various stages after abandoned shifting cultivation (slash and burn agriculture). The remaining 20% or more was natural forest on mountain slopes, not suitable for cultivation but easily navigable by wildlife and humans. The forests and fields form a shifting fragmented and mosaic habitat. The forest and village conditions changed little until 1990-2000 because the President of Guinea closed the country to all but those from socialist countries and there were no social, cultural, or economic exchanges with other parts of the world. We rarely encountered villagers in the forest, at least until 2000.

Feeding, Competitors and Other Populations

The main foods of chimpanzees are fruits and young leaves of trees (Sugiyama & Koman 1987). Occasionally the group moved into agricultural fields to feed on bananas, oranges, papayas, young

pineapples, and other crops, though females usually avoid coming out to open ground and wait at the forest edge when adolescent and adult males forage in the fields. The crop feeding occurred more frequently after 2010. There are only a few mango trees in the forest, and chimpanzees regularly feed on these fruits. Occasionally, they also dig out the root of cassava (Sugiyama & Koman 1979, 1987). They take bird eggs from their nests and capture insects and small mammals, such as pangolins (Sugiyama & Koman 1987; Hockings *et al.* 2010). Although there are many wild chimpanzee populations within 100 km around Bossou, none of them were provisioned.

There are no natural predators in and around the core area of the chimpanzees of Bossou. Until recent years, villagers never harmed chimpanzees, though people chased them off from their agricultural fields. Chimpanzees were regarded as sacred animals by villagers who kept their distance from the apes (Yamakoshi 1999). However, since the early 2000s,

habituation of the chimpanzees has progressed. YS, as the director of the research field, informed researchers to maintain a set distance of 7-10m from the chimpanzees. However, some visiting researchers began to observe them closer than this against our direction. An adolescent and young adult male chimpanzee became habituated to researchers and villagers and began visiting cultivated fields in the forest and village gardens to take papaya fruits (Hockings 2011). After 2015, male chimpanzees were reported to attack and hurt village children who were carrying bananas to the village from their cultivated fields. These behaviors were rarely seen before the years 2000-2010.

The only feeding competitors of chimpanzees are one hornbill species (*Ceratogymna atrata*) and other birds and squirrels. Occasionally, two monkey species, the green monkey (*Chlorocebus sabaeus*) and spot-nosed monkey (*Cercopithecus petaurista*), were observed in the range of chimpanzees, but their densities are low.

In the Nimba mountains, more than 6 km east of Bossou, the presence of other groups of chimpanzees has been confirmed (Humble 2011a; Koops 2011). In the Liberian territory, south and southeast of Bossou, chimpanzee groups also exist within several kilometers (Sugiyama 1989; Ohashi 2011). From 1976, when the long-term study was started until 2002, the group size of Bossou chimpanzees remained at approximately 20 (range: 16-23; average: 20.5 individuals) but decreased due to fatalities from the spread of a flu-like infectious disease (Humble 2011b). From November 2003 to March 2004, six individuals disappeared: two old females, two 2-3 year old infants, and two 13 year old females. We were able to confirm that the first 4 individuals died, but we are not certain if the last two young adult females died or emigrated. The population continued to decrease (Sugiyama & Fujita 2011) until only three individuals remained in 2024.

The human population has grown, and the village borders slightly expanded since 1990-91, but the size of the forest and cultivated area remained stable (Y. Sugiyama, pers. obs.). The main reason for the population increase is the inland war that started at the end of 1989 when an anti-government rebellious troop rose in Cote d'Ivoire and invaded Liberia. Refugees, mostly merchants or mining laborers, came to Bossou to escape the conflict (Sugiyama 2008). The market expanded and became noisier, but the cultivated fields saw only modest changes (Y. Sugiyama, pers. obs.).

Data Collection

An expedient way of collecting data on individuals at different ages is to combine and calculate the mean values of same age class members. The main caveat of doing this for our study is that, at Bossou, most female and male chimpanzees disappeared when they were adolescent or young adults. This made it difficult, if not impossible, to determine whether their exit from the group was due to death or emigration. Under these constraints, we attempted to calculate reproductive parameters in each age class whenever possible.

Demographic records of Bossou chimpanzees have been collected every year since 1976, until 2011, except for 1978, 1981, 1984. After 2012, data collection was carried out by our trained local assistants. The age of individuals in the group in 1976, when the study started, was estimated. Age estimation of chimpanzees was made based on experience of YS at Budongo, Uganda, and on published data from captive subjects at Primate Research Institute, Inuyama, and Arnhem Zoo, Netherlands. The number of offspring and their body size were important for age estimation of females as well as notation of their behavior and physical features.

Approximate age was also determined based on the following indicators: a mother always carries her new infant near her breasts until it reaches a year old or more. When travelling, she carries it ventrally, often supporting with a hand for as much as two years. As an infant develops it begins to ride on the mother's back grasping the hairs of her neck and flank (Sugiyama 2008). Until five years of age, a chimpanzee infant spends most of the time near its mother. Even when they can walk independently of the mother, they rarely move more than several meters away. Up to about five years of age, these young chimpanzees are classified as infants. After about five years of age, they are classified as juveniles, and (males in particular) will begin to travel apart from their mothers at least occasionally. The ages of all other individuals are known.

RESULTS

First and Last birth, Longevity, and Interbirth Interval

The average age at first birth was 10.2 yrs (range = 8-13 yrs, N = 5). A nulliparous female who disappeared at 14 years of age is not included in this calculation.

The average age of last birth for seven females was 35.7 yrs (range = 26-51 yrs, $N = 7$). Six of these were already full-grown adults with one or two young offspring when the research started, taking into consideration possible errors in estimating age. The average estimated age of the six females at death was 55.8 yrs (range = 49-66 yrs, $N = 6$). One female of 67 yrs (estimated) was still alive in 2025; the average longevity of the above seven females is therefore more than 57.6 yrs.

The average interbirth interval was 4.56 yrs (range = 2-11 yrs, $N = 25$). If the four cases where the offspring died before 5 years of age are excluded, which is the standard acceptable method of calculating interbirth interval, the average IBI increases to 5.04 years (range = 3-11 yrs, $N = 21$). The latter IBI will be used in the following sections.

Infant birth and death

During the 50 years between 1976 and 2025, 40 chimpanzees – 23 females (57%) and 17 males (42%) – were born. Infant deaths at less than 5 years of age were 6 females (26.1%) and 4 males (23.5%). In this calculation, infants present in Bossou when the study started were not included. There was no statistically significant difference in sex (Fisher's exact test, two-tailed, $p = 1$). One four-year-old female who disappeared with her mother was assumed to have emigrated and was not included in this calculation.

Disappearance of Juveniles, Adolescents, and Young Adults

Out of 54 juveniles, adolescents, and young adults (5-15 years old), 29 disappeared (females = 16 of 31, 51.6%; males = 13 of 23, 56.5%). There was no statistically significant sex difference (Fisher's exact test, two-tailed, $p = 0.77$; Figure 3). Many of these disappearances occurred suddenly. In all cases the individuals were never sighted again, so it was not possible to determine whether they emigrated or died.

At the start of the study there were 7 adult females in the group: 6 were fully mature with infants and one was close to achieving maturity. All females born subsequently, except for two, disappeared before turning 16 years old.

Among 22 male infants present at the start of, and throughout, the study period, 5 (22.7%) disappeared before reaching the age of 5. They were presumed dead since all the mothers were still living in the group. Excluding these five infant deaths, 13 of 17 (76.5%) disappeared before reaching the age of 17 yrs. Only one male was known to have survived for more than 30 years in the group. Two-thirds of the males who reached 5 years of age disappeared before reaching full-grown adulthood. YS observed two such cases, one, an 11-year-old male who sustained a minor injury to his calf disappeared in November 1991, and another, a 12-year-old who was last seen

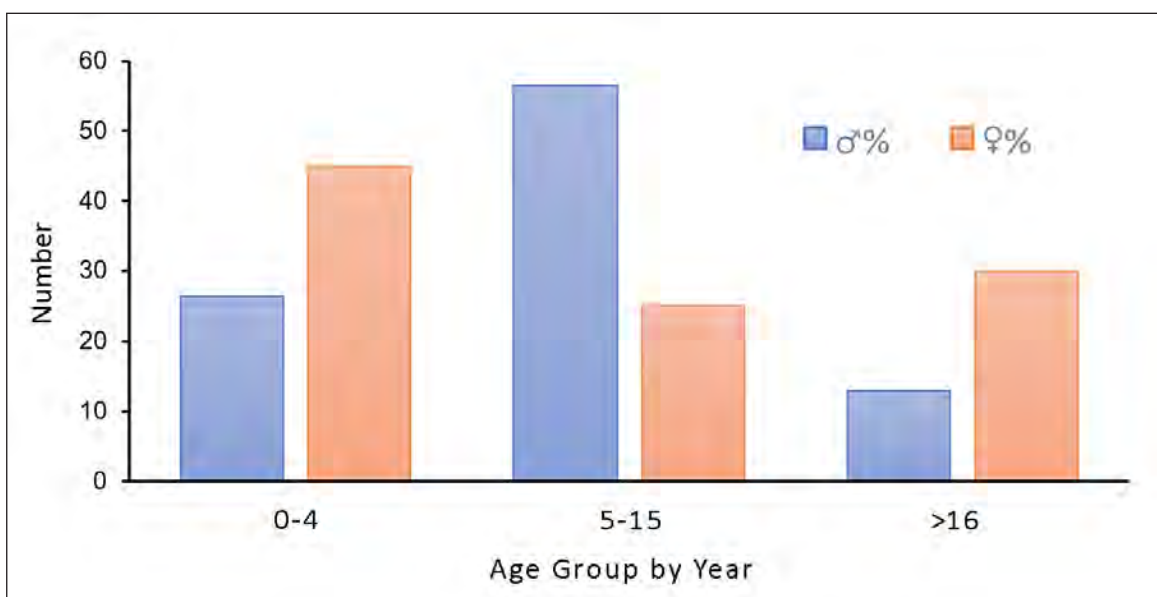


Figure 3. Age class (in years) of individuals that disappeared from the Bossou chimpanzee group.

in August 1999. They were probably not dead, at least, immediately after they disappeared (Sugiyama 2008). Mortal remains of chimpanzees of more than 5 years of age were rarely found in the core area.

Between November and December 2003 when a flu-like disease was spread among many chimpanzees, two old females, two 2-3 year infants, and a 13-year-old female disappeared. The old females and the infants were likely deceased, but it remains unclear if the younger female emigrated or died. In March 2004, another 13-year-old female disappeared but we do not know if her disappearance was related to the flu-like disease.

Immigration

Throughout the 50-year study, only two strange males, one older than 30 years and another less than 20, joined the group in the early stages of the study. The older male established friendly relations with the group males, but females kept a distance of more than 10 m. He stayed for only 20 days, then disappeared again. The younger male stayed about one year, formed typical social bonds with other members, then disappeared (Sugiyama & Koman 1979). It was not known if they were born in Bossou or another forest. No other immigration by males has been observed. No immigrant females were observed throughout our entire study period.

Only seven males 15 years of age or older have lived in the group, except for the above mentioned two males who temporarily joined in the early years. Five males of known age disappeared, ranging in age from 15 to 56 yrs (average = 27.8 yrs, $N = 5$). Two full-grown males were still alive in Bossou as of 2025.

Longevity

Six out of seven adult and sub-adult females from the study population were dead or presumably dead at an average of 55.8 years of age (range = 49-66 yrs, $N = 6$). This number may increase as the last remaining female was still alive as of 2026 and is estimated to be 67 years old. Thus, the longevity of matured females can be stated as more than 57.6 yrs. As the last birth was on average at 35.9 years of age, Bossou females can be said to continue to live for a further 21.7 years until death.

Reproductive Success

On average, female chimpanzees of Bossou became sexually mature at around nine years of age,

gave birth to their first offspring at 10.2 years, and continue to give birth thereafter every 5.23 years until the age of 35.7 years on average. Throughout their lives they sired 4.88 offspring with 2.66 (54.5%) being females.

These data are from a limited number of individuals, however, as most natal females emigrated from Bossou or died between the age of 5 and 15, and there have been no new immigrant females join the group.

Changes of Demographic Parameters Over Time

Reproductive parameters are compared from recent data to previous reports published 17 and 32 years after the start of the study (Sugiyama 1994, Sugiyama & Fujita 2011; Table 1). The primiparous age of young active females born in the Bossou group has decreased since the last report, but that did not significantly change the group's reproductive parameters, perhaps because nutritional capacity in the environment changed little while the population began to decline.

DISCUSSION

Social Organization and Reproductive Success

Field primatology after World War II began with research on Japanese macaques (*Macaca fuscata*) in early 1950s, focusing on social organization and social behavior (Itani 1953, 1985). Chimpanzee studies began in early 1960s focusing mainly on social and cultural behaviors (Goodall 1963). Thereafter, many studies on nonhuman primates focused more on special characteristics of primates. For example, adaptation to the environment leads to healthier (and more) offspring and the species' social and cultural behaviors are parts of this process. To better predict the success of a species, the study of reproductive success is important for the individual and the preservation of individual populations.

In many primate species, group members of one or both sexes transfer from their natal group as adolescents or young adults. As such, studies of the long-term reproductive success of great apes are few (Bronikowski *et al.* 2016). Ours is one of the few studies to calculate the long-term reproductive success of a group of chimpanzees from the perspective of both males and females; most previous studies of reproductive parameters have focused only on females (Wallis 1997).

The most serious problem for Bossou chimpanzees is their imminent extinction, despite

Table 1. The main reproductive parameters of chimpanzees at Bossou.

Year/time since the beginning of data collection	Age at first birth (range)	Interbirth interval (range) *	Individual lifetime reproductive output (average no. of infants)	References
1993/ 17yrs	13 (12-14)	5.1 (3-11)	6.5	Sugiyama, 1994
2003/ 28 yrs	10.6 (9.5-13)	5.2		Sugiyama & Fujita 2011
2025/ 50 yrs	11.4 (8-14)	5.5 (3-11)	5.23	This study

* omitted infant death less than 5 years old

the high reproductive success of individual females over the last 50 years. Some of the females who disappeared may be living outside of Bossou and continue to reproduce, but we have no way to verify this. Thus, while the population was showing healthy levels of reproductive success the actual population size decreased. It seems to be only a matter of time before the Bossou population goes extinct

Reproductive Opportunity of Emigrant Females and the Absence of Female Immigration at Bossou

According to all previous studies on wild chimpanzees, all or most females emigrate from their natal groups and immigrate to adjacent groups as adolescents or young adults (e.g., Goodall 1986; Nishida 2012; Nakamura *et al.* 2016; this study). Recruitment of reproductive females from outside and outbreeding by natal females is necessary for

the long survival of chimpanzee populations. This begs the question as to why no female immigration occurred in Bossou.

Males that Disappeared, and Their Reproductive Opportunity

While most published reports focus on female chimpanzee reproductive opportunity, no one has discussed the reproductive future of young males who may have emigrated, because male disappearances are often automatically considered to be due to the death of the individual (Nakamura 2016; Sugiyama 2022).

In all chimpanzee groups ever studied in their natural environment, there were more adult females than adult males. Though some males remain in their natal group, others have disappeared (e.g., Muller & Wrangham 2014), for no apparent reason or signs of illness. At Bossou, a few males remained

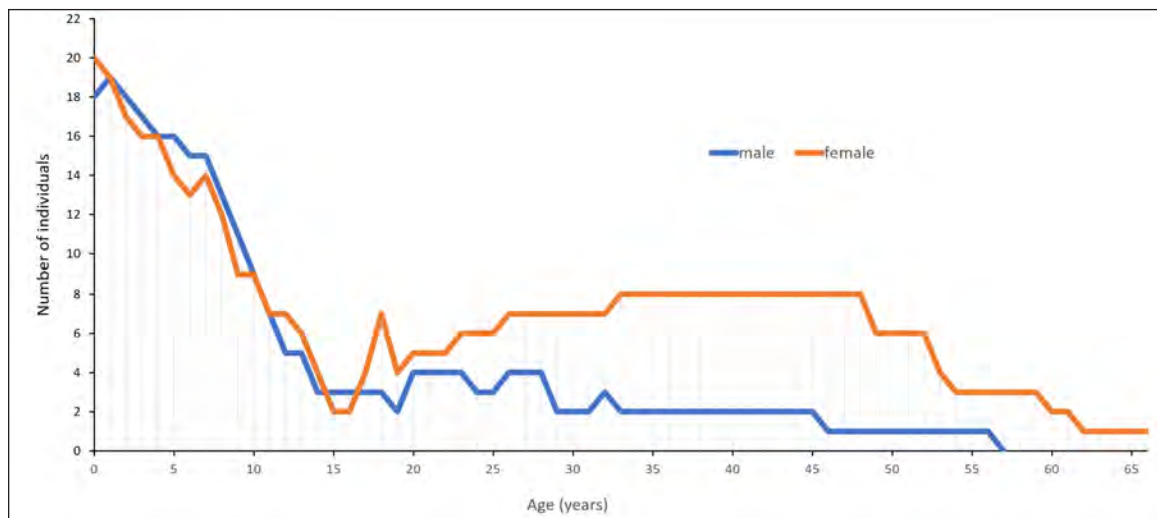


Figure 4. Number of individuals of each age/sex in the Bossou chimpanzee group through 50 years, 1976-2025. The increase of females of 18 or more years depends on adults who were in the group since the beginning of the study. The figure shows most of the males and females disappeared before reaching 16-17 years of age. After 18 years of age, members were almost stable until their deaths because there was no immigration into the group.

in their natal group, but many more disappeared. There was no sex difference in the disappearing rate of 5-15-year-olds, the species' most active and adventurous age groups (Muller & Wrangham 2014; Bronikowski *et al.* 2016). At least some of these males might have emigrated voluntarily to search for more resources, avoid mating with relatives, or find greater mating access opportunities (Figure 4).

At present, a better understanding of the fate of males that disappear must be given higher priority in chimpanzee studies. We need to know if they had any opportunity to sire offspring in their natal group and/or in another group they may have joined later. At least in Bossou we have DNA evidence of one infant that did not match the genetic profile of any of the resident males and, therefore, must have been sired by an extra-group male (Sugiyama *et al.* 1993; McCarthy *et al.* 2018). Bossou females sometimes travel separately from their group and may be mating with such extra-group males though we have no direct observation of such matings.

Many primate species have one-male and multi-female groups, e.g., Hanuman langurs (*Presbytis entellus*) (Sugiyama 1963). In these examples many males stay alone or form all-male parties outside of the reproductive group. They try to mate with group females, sometimes by taking over a group of females and other times approaching the periphery of a group. Some of these males may succeed to sire infants at least once in their long lifetime (Sugiyama 1984).

But what about chimpanzees? Although it is hard to document, male reproductive opportunity is important for understanding chimpanzee social structure. To the best of our knowledge, there are no detailed observations of males after they have left their natal group.

Over-habituation

As this study suggests, the population size of the Bossou chimpanzee group remained stable, at approximately 20 individuals, between 1976 (perhaps from as early as the 1960s, Kortlandt 1962) until 2002. Therefore, we predict that carrying capacity of the forest of Bossou is around 20 chimpanzees, with no dramatic changes in forest size and composition until 2002 according to our observations. Data suggests that the forest temporarily expanded between the 1960s to 1970s (Yamakoshi & Leblan 2013). The lack of female immigration must be one of the main reasons the population size decreased. The human population increased from 1990-2000s with

the influx of refugees from neighboring countries may have played a role (see Figure 4) (Sugiyama 2008). From our observation and villagers' accounts, human inhabitants and cultivated fields slightly increased but the main part of the chimpanzee range and villagers' attitude to chimpanzees did not change until about the early 2000s. Change occurred in the attitude of some visiting researchers, as well. Despite existing rules regarding maintaining a safe distance, they approached close to the chimpanzees for better observation. The researchers became more comfortable being close to chimpanzees and the chimpanzees habituated to having humans – both researchers and villagers – in proximity. This led to over-habituation.

A remarkable change of the Bossou chimpanzees' behavior after 2000-2010 can be seen as follows. Chimpanzees, mostly males, came into the village gardens and climbed up papaya trees to take fruits, a behavior that we had never seen before 2010. Chimpanzees sometimes approached researchers within 5m when they were looking the other way, even while on the ground. This was a behavior that was rarely seen before. Males accepted researchers within 7-10 m on the ground which was rarely seen before 2010 too. Sometimes males, adults and adolescents, attacked women and children when they were carrying bananas or other fruits from the fields to the village. This was also never seen before 2010. We were now aware of a troubling change in the villager-chimpanzee relationship possibly caused by the researchers' behavior.

Extinction of a Local Population

Why have no females immigrated to the Bossou population? We speculate there are three possible hypotheses.

The first hypothesis could be that the group's over-habituation to humans makes it difficult for unhabituated, more human-shy, females from other groups to approach the Bossou group. Out-group female chimpanzees may be avoiding the Bossou group because of the proximity maintained between chimpanzees and humans, mainly researchers, spending long hours with them in the forest.

The second hypothesis is that although adjacent groups are only 6 km away, they are separated by savanna, cultivated fields, villages, and roads. The home range of chimpanzees is fragmented into several parts by a road and lanes which have gradually broadened since about 2000. Risk-averse chimpanzees, particularly lone females or those with

young offspring, avoid traversing such areas. Even Bossou females avoid going into cultivation fields and crossing roads alone.

The third hypothesis is the loud music and vocalization uttered by villagers, especially on the days of market, festivals, and other meetings – as well as increasing traffic noise. Market and traffic noise have increased greatly since around 2000. However, if such noises were the reason for strangers' avoidance, it may be that all seven adult female chimpanzees who were in Bossou since the start of the research were not immigrants. We had no information on the general environment before we began the study to know whether these circumstances were similar then or not. Were all these females born in Bossou? It is difficult to expect so considering immigration trends reported by other researchers (Goodall 1986; Nakamura 2016).

The first mentioned hypothesis for lack of immigrants is supported as there were two (male) immigrants in the very early stages of the study, but not later. Over-habituation caused by researchers, not by villagers, may have kept shy chimpanzees from adjacent populations away. The weak point of this hypothesis is that in the other research sites chimpanzee transfers are common even when they are more habituated than at Bossou (Goodall 1963). The second hypothesis is supported by our observation that Bossou females were very shy to come out to open field. The weak point of this hypothesis is that the original seven females assumed to be immigrated from other sites. The third hypothesis may have worked as a barrier against shy females too, at least in more recent years.

In the end, no one thing can be confirmed as the sole cause of the lack of immigration to Bossou during the study period; all described factors likely played a role over time.

This study presented the reproductive parameters and discussed the unique situation of the Bossou chimpanzee populations. Comparative discussion, including data on chimpanzees at other sites and related species, will be done in a future article as that is a more complex subject.

Finally, our research team must stop the daily tracking of chimpanzees in Bossou which has been discontinued since 1976. While our research activities have terminated, we are periodically sending a few individuals to Bossou for short periods to monitor any changes of the situation. We will see if chimpanzees eventually come from other habitats to join the remaining group. We do not expect chimpanzees will be artificially introduced from other wild populations or captive ones as

these actions would disturb the natural ecosystem. Chimpanzee research and conservation at Bossou and Nimba continues under local research authority.

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REFERENCES

- Bronikowski, A.M., M. Cords, S.C. Alberts, J. Altmann, D.K. Brockman, L.M. Fedigan, A. Pusey, T. Stoinski, K.B. Strier & W.F. Morris. 2016. Female and male life tables for seven wild primate species. *Scientific Data* DOI:10.1038/sdata.2016.6.
- Goodall, J. 1963. My life among wild chimpanzees. *National Geographic* 124(2): 172–308.
- Goodall, J. 1986. *The Chimpanzees of Gombe: Patterns of Behaviour*. Belknap Press of the Harvard University Press, Harvard.
- Hockings, K.J. 2011. The crop raiders of the sacred hill. In *The Chimpanzees of Bossou and Nimba*. T. Matsuzawa, T. Humle & Y. Sugiyama, eds. Springer, Tokyo. Pp. 211–220.
- Hockings, K.J., J.R. Anderson, T. Matsuzawa. 2010. Flexible feeding on cultivated underground storage organs by forest dwelling chimpanzees at Bossou, West Africa. *Journal of Human Evolution* 58: 227–233.
- Humle, T. 2011a. The chimpanzees of Yeale, Nimba. In *The Chimpanzees of Bossou and Nimba*. T. Matsuzawa, T. Humle & Y. Sugiyama, eds. Springer, Tokyo. Pp. 267–275.
- Humle, T. 2011b. The 2003 epidemic flu-like respiratory disease at Bossou. In *The Chimpanzees of Bossou and Nimba*. T. Matsuzawa, T. Humle & Y. Sugiyama, eds. Springer, Tokyo. Pp. 325–333.
- Itani, J. 1953. Monkeys of Takasakyama. Kobunsha,

- Tokyo. (in Japanese)
- Itani, J. 1985. Japanese primatology in retrospect and in prospect. *Primate Research* 1: 5-14. (In Japanese)
- Koops, K. 2011. Chimpanzees in the Seringbara region of the Nimba mountains. In *The Chimpanzees of Bossou and Nimba*. T. Matsuzawa, T. Humle & Y. Sugiyama, eds. Springer, Tokyo. Pp. 277-287.
- Kortlandt, A. 1962. Chimpanzees in the wild. *Scientific American* 206(5): 128-138.
- McCarthy, M.S., J.D. Lester, K.E. Langergraber, C.B. Stanford & L. Vigilant. 2018. Genetic analysis suggests dispersal among chimpanzees in a fragmented forest landscape in Uganda. *American Journal of Primatology* e22902. <https://doi.org/10.1002/ajp.22902>
- Muller, M.N. & R.W. Wrangham. 2014. Mortality rates among Kanyawara chimpanzees. *Journal of Human Evolution* 66: 107-114.
- Nakamura, M. 2016. Demography of the M Group. In *Mahale Chimpanzees: 50 Years of Research*. M. Nakamura, K. Hosaka, N. Itoh & K. Zamma, eds. Cambridge University Press, Cambridge. Pp. 82-93.
- Nakamura, M., K. Hosaka, N. Itoh & K. Zamma (eds.). 2016. *Mahale Chimpanzees: 50 Years of Research*. Cambridge Univ. Press, Cambridge.
- Nishida, T. 2012. *Chimpanzees of the Lakeshore: Natural History and Culture of Mahale*. Cambridge Univ. Press, Cambridge.
- Ohashi, G. 2011. From Bossou to the forest of Liberia. In *The Chimpanzees of Bossou and Nimba*. T. Matsuzawa, T. Humle & Y. Sugiyama, eds. Springer, Tokyo. Pp.313-321.
- Sugiyama, Y. 1963. On the social change of Hanuman langurs (*Presbytis entellus*) in their natural condition. *Primates* 6: 382-418.
- Sugiyama, Y. 1984. Some aspects on infanticide and inter-male competition among langurs, *Presbytis entellus*, at Dharwar, India. *Primates* 25: 423-432.
- Sugiyama, Y. 1989. Population dynamics of chimpanzees at Bossou, Guinea. In *Understanding Chimpanzees*. P.G. Heltne, L.A. Marquardt, eds. Harvard University Press, Cambridge, MA. Pp.134-145.
- Sugiyama, Y. 1994. Age-specific birth rate and lifetime reproductive success of chimpanzees at Bossou, Guinea. *American Journal of Primatology* 32: 311-318.
- Sugiyama, Y. 2008. *Emergence of Culture*. Kyoto University Academic Press, Kyoto. (in Japanese)
- Sugiyama, Y. 2022. My primate studies. *Primates* 63: 9-24.
- Sugiyama, Y. & S. Fujita. 2011. The demography and reproductive parameters of Bossou chimpanzees. In *The Chimpanzees of Bossou and Nimba*. T. Matsuzawa, T. Humle & Y. Sugiyama, eds. Springer, Tokyo. Pp. 23-34.
- Sugiyama, Y., S. Kawamoto, O. Takenaka, K. Kumazaki & N. Miwa. 1993. Paternity discrimination and inter-group relationships of chimpanzees at Bossou. *Primates* 34: 554-552.
- Sugiyama, Y. & J. Koman. 1979. Social structure and dynamics of wild chimpanzees at Bossou, Guinea. *Primates* 20: 323-339.
- Sugiyama, Y. & J. Koman. 1987. A preliminary list of chimpanzees' alimentation at Bossou, Guinea. *Primates* 28: 133-147.
- Wallis, J. 1997. A survey of reproductive parameters in the free-ranging chimpanzees of Gombe National Park. *Reproduction and Fertility* 109: 297-307.
- Wilson, E.O. 1975. *Sociobiology: The New Synthesis*. Belknap Press of Harvard University Press, Cambridge.
- Yamakoshi, G. 1999. Chimpanzees of a sacred forest: co-existence with humans at Bossou, Guinea. *Ecosophia* 3: 106-117. (in Japanese)
- Yamakoshi, G. & V. Leblan. 2013. Conflicts between indigenous and scientific concepts of landscape management for wildlife conservation: human-chimpanzee politics of coexistence at Bossou, Guinea. *Revue de Primatologie* (online), 5: document 6, DOI 10.4000/primatologie.1762.

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Evaluating Key Factors Affecting Drone-Based Detection of Ursine Colobus (*Colobus vellerosus*)

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Abstract: Monitoring arboreal primates in dense tropical forests is challenging due to limited visibility and accessibility. This study examines the effectiveness of RGB drone imaging in detecting *Colobus vellerosus* in the Kikélé Sacred Forest in Benin. We conducted 36 flights using a DJI Mini 3 drone during the dry and wet seasons to test various flight parameters (altitude, speed, angle), environmental factors (season, land cover, contrast), and observer-related factors (observer time and observer identity). The visual data were analyzed using a negative binomial generalized linear mixed model (GLMM), incorporating observer effort and temporal variables. The probability of detection decreased significantly with altitude. However, morning flights and rainy season conditions improved detectability. The time taken for observer analysis had a positive influence on detection results. Behavioral responses varied among the three groups, with active flight and disappearance recorded in the group located deeper within the forest. Our results suggest that *C. vellerosus* was more readily detected from drone imagery at lower flight altitudes under the conditions tested. These results support the integration of drone-based protocols into primate monitoring, including for cryptic arboreal species inhabiting dense forest environments. While limitations remain in terms of visibility and observer subjectivity, this approach offers a promising, non-invasive tool for conservation studies that will likely be further enhanced by the future integration of AI-based detection systems.

Key words: white-thighed colobus, sacred forest of Kikélé, drone, wildlife conservation, remote sensing

INTRODUCTION

Tropical forests, although home to some of the richest biodiversity on the planet, remain among the most difficult environments to inventory due to their dense vegetation, vertical structural complexity, and poor accessibility (Bibby *et al.* 2000; Rovero & Spitale 2016). In sub-Saharan Africa, anthropogenic pressure, particularly linked to agricultural expansion and extensive livestock farming, is leading to rapid deforestation (Gibbs *et al.* 2010; Laurance *et al.* 2014), exacerbating the fragmentation of forest habitats. This fragmentation compromises ecological connectivity, particularly affecting arboreal species whose survival depends on canopy continuity (Junker *et al.* 2012; Betts *et al.* 2017).

These threats highlight the need for reliable information on the distribution and population status of arboreal primates, which is essential for assessing population trends and informing conservation planning (Matsuda Goodwin *et al.* 2020). For *Colobus vellerosus*, population estimates and their reliability are particularly important because the species has experienced substantial population declines and occurs in increasingly fragmented habitats (Wong & Sicotte 2006; Wikberg *et al.* 2024).

Detecting wildlife in forested environments, particularly nocturnal, cryptic or canopy-dwelling species, represents a major challenge for ecologists and biodiversity managers (Burton *et al.* 2015).

Although conventional approaches such as line transects, photographic trapping, and acoustic monitoring have led to notable advances (Effiom *et al.* 2013; Wearn & Glover-Kapfer 2019), they have significant limitations in terms of spatial coverage, temporal resolution and logistical cost, particularly in tropical environments.

Primates are among the most threatened mammalian groups globally, with a large proportion of species facing elevated extinction risk, with habitat loss, hunting, and agricultural expansion among the major drivers of population decline (Chapman *et al.* 2010; Campbell *et al.* 2011; Estrada *et al.* 2022; Basabose *et al.* 2024). Primate populations are undergoing widespread declines across their geographic ranges, driven primarily by habitat loss and fragmentation, hunting, and other forms of anthropogenic pressure (Estrada *et al.* 2022; Garber *et al.* 2024). The white-thighed colobus (*C. vellerosus*), also known as the ‘magistrate colobus’ or ‘Ursine colobus’, exemplifies this conservation concern. The species is currently classified as Critically Endangered on the IUCN Red List, with an inferred population decline of more than 80% over the past three generations, driven primarily by habitat destruction, habitat degradation, and hunting (Matsuda Goodwin *et al.* 2020; Wikberg *et al.* 2024).

Despite this critical status, information on the species’ distribution, population density and population dynamics remains spatially limited (Wong & Sicotte 2006; Wikberg *et al.* 2024).

In light of these constraints, the emergence of remote sensing technologies, particularly unmanned aerial vehicles (UAVs or drones), offers innovative prospects. Equipped with red-green-blue (RGB), thermal infrared or multispectral cameras, drones can rapidly survey large areas and acquire high-resolution imagery, including in difficult-to-access environments (Hodgson *et al.* 2018; Rahman *et al.* 2022). Research has demonstrated their effectiveness in detecting various animal species, including deer, seals, koalas, monkeys, rhinos, and birds (Koh & Wich 2012; Koski *et al.* 2014; Mulero-Pázmány *et al.* 2014; Flores *et al.* 2021; Nago *et al.* 2021; Kpatchia *et al.* 2025). Applications of drones in primate research have expanded beyond the detection of great-ape nests to include direct detection, counting, and behavioral monitoring of arboreal primates using RGB and thermal sensors. Recent studies have investigated drone-based detection of spider monkeys, chimpanzees, baboons, and orangutans, while systematic assessments have also evaluated the potential of thermal drones for monitoring a broad

range of primate species (Wich *et al.* 2023; Gazagne *et al.* 2024; Pinel-Ramos *et al.* 2024; Duporge *et al.* 2025).

Direct detection of wild colobus monkeys from RGB drone imagery remains poorly documented, particularly for *C. vellerosus* in dense West African forest canopies. At the regional scale, this study is part of emerging research in West Africa. In other tropical regions, drone-based primate research has included studies of orangutans in Southeast Asia and arboreal mammals, including primates, in Neotropical rainforest canopies using thermal infrared sensors (Koh & Wich 2012; Kays *et al.* 2019).

The present study, therefore, aimed to evaluate the potential of drone-based RGB imagery for detecting *C. vellerosus* and to identify flight, environmental, and observer-related factors influencing its detectability in the Sacred Forest of Kikélé, Benin.

MATERIAL AND METHODS

Study area

The study was conducted in the sacred forest of Kikélé (9°10'N, 2°28'E), a semi-deciduous forest formation in south-central Benin, characterized by a closed, dense canopy reaching heights of between 20 and 30 m. This forest is home to a residual population of black-and-white colobus monkeys, specifically white-thighed colobus (*C. vellerosus*), a priority species for conservation, endemic to the forests of West Africa. Figure 1 shows the Sacred Forest of Kikélé, Benin, where drone-based surveys of the white-thighed colobus (*Colobus vellerosus*) were conducted.

Data collection

Data were acquired using a DJI Mini 3 (<http://www.dji.com>) drone, a lightweight quadcopter weighing less than 250 g and equipped with a 4K RGB camera. The drone was controlled using the DJI Fly app, which allowed manual adjustment of flight altitude, speed, and flight plan.

Data were collected during two contrasting climatic seasons: the rainy season (July–August) and the dry season (February–March), with nine days of observation per season, to incorporate seasonal variations in primate behavior (Ekaye & Ogoanah 2022).

Before the drone surveys, the entire Sacred Forest of Kikélé was systematically explored on the ground to locate *C. vellerosus* groups and identify their

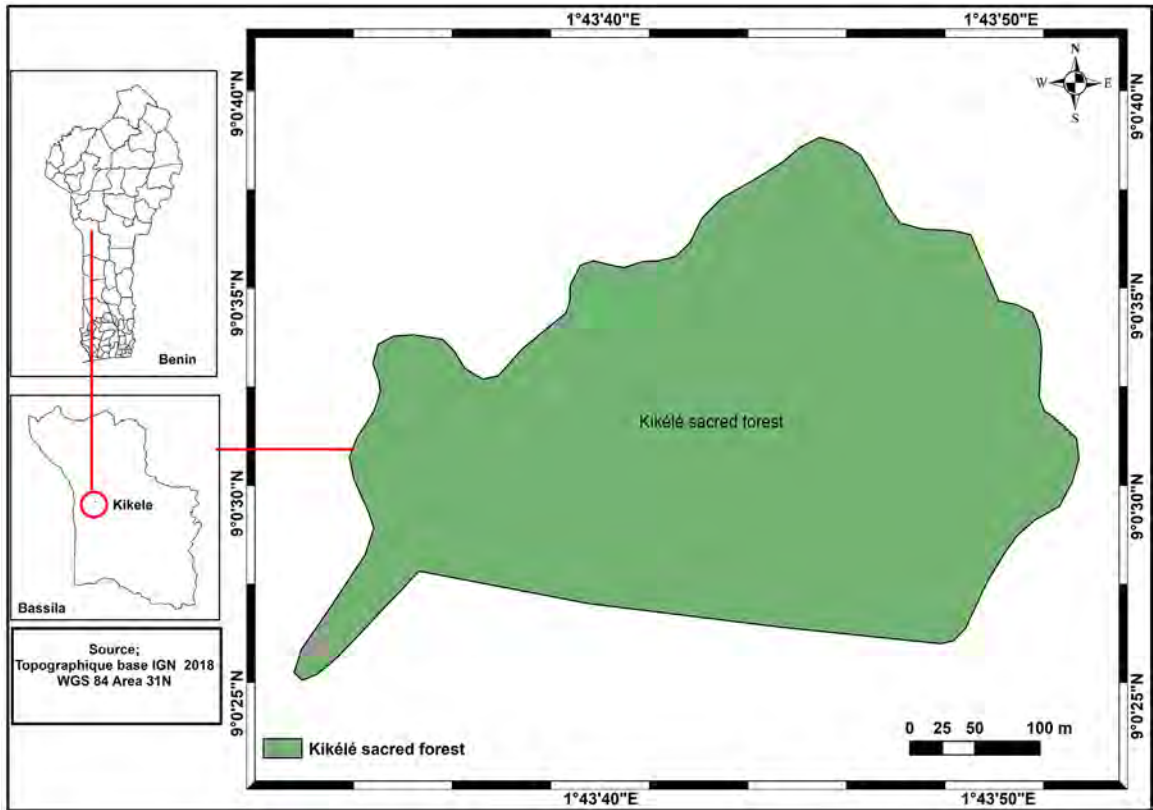


Figure 1. Geographical location of the Kikélé Sacred Forest in Benin.

resting and foraging areas. This survey identified three groups that were subsequently selected for the drone experiments. Locating the animals before the experimental flights ensured that the target species was present in the surveyed areas and provided a consistent field setting for evaluating the effects of different flight configurations on detectability. A similar approach has been used in recent drone-based primate research, in which flights were conducted over known sleeping sites of spider monkey groups to facilitate the evaluation of flight speed, height, and camera angle (Pinel-Ramos *et al.* 2024). The objective of the present study was not to estimate total population size of *C. vellerosus* in the forest.

The key parameters tested directly in the field were altitude (UA), flight speed, and approach angle of the drone, all factors that may influence animal detection and behavioral responses (Ditmer *et al.* 2015; López & Mulero-Pázmány 2019).

We tested five classes of altitude: 10 m, 20 m, 30 m, 40 m, and 50 m above the canopy. Altitude was calculated for each flight using the equation:

$$UA = AD - HC$$

where AD represents the altitude of the drone relative to the ground, and HC represents the local canopy height, estimated using a laser rangefinder, a method used in similar contexts (Van Andel *et al.* 2015; Christie *et al.* 2016). The protocol always began at the highest altitude, with a gradual descent, to minimise initial disturbances.

Two speeds were tested: hovering (0 m/s) and slow flight at 2 m/s, simulating standard prospecting (Koh & Wich 2012). Two approach angles were applied: a vertical angle (90°) perpendicular to the canopy and an oblique lateral angle (~45°), in order to assess lateral visibility and behavioral responses under different flight profiles (Koh & Wich 2012; Van Andel *et al.* 2015).

For each combination of parameters (altitude, speed, angle), a one-minute video and ten photographs were taken using the on-board camera. Recordings were conducted during two predefined daily observation periods (06:30–09:00 and 16:00–18:00), chosen to represent morning and late-afternoon conditions and to encompass periods when *C. vellerosus* could be observed in the canopy. Previous observations indicated that ursine colobus use sleeping trees during the morning and may

subsequently move to lower canopy strata or the ground as the day progresses (Teichroeb *et al.* 2012).

Each group of colobus monkeys was exposed to several flight configurations, spaced at least 30 minutes apart to limit behavioral bias (Ditmer *et al.* 2015). The flyover sites were identified in advance during ground surveys focused on roosts and foraging areas.

Contrast between *C. vellerosus* and the surrounding canopy was assessed visually from the drone imagery during laboratory annotation. It was categorized into three ordinal levels: 0 = low contrast, when the animal was difficult to distinguish from the surrounding vegetation; 1 = medium contrast, when the animal was distinguishable but partially blended with the background; and 2 = high contrast, when the animal was clearly distinguishable from the surrounding vegetation.

In this study, the variable 'Land cover' refers specifically to the degree of canopy obstruction within the drone imagery, rather than to land cover at the landscape scale. It was assessed visually from the images used for observer analysis and represented the proportion of the viewed canopy area occupied by vegetation that could obstruct the visibility of colobus individuals. Four ordinal categories were used: 1 = 0–25%, 2 = 25–50%, 3 = 50–75%, and 4 = 75–100% canopy obstruction. This index was used to characterize the degree of visual obstruction potentially affecting the detection of colobus individuals in the imagery.

Four observers with experience in visual wildlife identification independently reviewed the drone-acquired images and video sequences. Before the annotation process, all four observers participated in a standardized calibration session using images showing different postures and viewing conditions of *C. vellerosus*. The purpose of the calibration was to harmonize species-identification criteria and reduce observer-related variation during subsequent independent annotations. Each observer then independently examined the same image and video sequences using Timelapse Image Analysis software, without access to the classifications made by the other observers. Additionally, for each image or video sequence, the time of day was categorized as morning or afternoon. Observer time was recorded separately for each observer as the time spent reviewing each image or video sequence, from the beginning of the assessment until the observer completed the review.

To assess the behavioral responses of *C. vellerosus* to drone approaches, responses were recorded during the experimental flights across different flight altitudes. Responses were classified

using a simplified ethogram adapted from Rahman *et al.* (2022) and van Andel *et al.* (2015). Five categories were considered: (1) no reaction, (2) attention directed toward the drone, (3) passive flight (slow movement without vocalization), (4) active flight (rapid movement with agitation), and (5) disappearance (visual loss of individuals). The occurrence of each response was recorded under the different flight altitudes to describe variation in behavioral responses.

To limit biases related to observer subjectivity, a standardized procedure inspired by established protocols, notably those used at the Nazinga hunting ranch by Vermeulen *et al.* (2013) and on avian fauna by Kpatchia *et al.* (2025), was adopted.

Data analysis

We evaluated the influence of Altitude, Contrast, Land cover, Observer time, Time of day, and Season on animal detection, while observer identity was accounted for as a random effect. Table 1 summarises the variables considered in the detection models.

All statistical analyses were conducted in R software (R Core Team 2023).

Multicollinearity among the candidate explanatory variables was assessed using variance inflation factors (VIFs), following Fox & Weisberg (2019). Because Land cover and Contrast were strongly associated with Altitude, these two variables were excluded from the final detection model, while Altitude was retained because it represented the primary flight parameter experimentally manipulated in the study.

A negative binomial generalized linear mixed model (GLMM) was then fitted using the glmmTMB package (Brooks *et al.* 2017) to account for overdispersion in the detection data. Observer identity was included as a random effect to account for between-observer heterogeneity and the repeated assessment of the same imagery by the four observers. Altitude, Observer time, Time of day, and Season were included as fixed effects.

Associations among categorical variables were assessed using Pearson's chi-square tests of independence. These analyses were used to examine associations among the categorical variables recorded during image assessment, including Contrast, Land cover, Season, and Time of day. These tests were conducted separately from the detection model and were used to describe relationships among the recorded environmental and temporal variables.

Potential two-way interactions were considered only when there was an *a priori* ecological or methodological rationale for their inclusion. Given

Table 1. Summary of Predictor Variables for Generalized Linear Mixed Models (GLMM).

Variable	Nature	Levels/Units	Type	Characteristics
Altitude	Continuous	Meter (m)	Independent	Flight parameters
Observer	Categorical	Observer1 - Observer4	Random effect	Observer bias
Observer time	Continuous	Second (s)	Independent	Operational
Times of day	Categorical	Morning and Afternoon	Independent	Temporal
Season	Categorical	Wet, Dry	Independent	Environmental
Contrast	Categorical	High, Low, Middle	Independent	Environmental
Land cover	Categorical	Percentage %	Independent	Environmental
Animal detection	Count	Number of Detection	Dependent	Ecological

the available sample size, models containing a larger number of interaction terms resulted in convergence problems and unstable parameter estimates. The candidate model set was therefore restricted to a limited number of biologically justified two-way interactions, which were subsequently evaluated within the model-selection framework.

Candidate models were compared using an information-theoretic approach based on Akaike's Information Criterion corrected for small sample size (AICc) (Burnham & Anderson 2004; Johnson & Omland 2004). The dredge() function from the MuMIn package (Bartoń 2012) was used to compare the candidate model combinations. Models with $\Delta\text{AICc} < 2$ were considered to have comparable support and were retained for model averaging. To account for model-selection uncertainty, parameter estimates were averaged across these supported models using the model.avg() function from MuMIn, with conditional averaging.

In addition to detection probability, we assessed the behavioral responses of *C. vellerosus* to drone approaches using the predefined ethogram.

Behavioral responses were examined descriptively in relation to flight altitude, speed, and approach angle. Flight speed and approach angle were not included as predictors in the final GLMM; their potential influence on behavioral responses was explored descriptively by summarising the observed responses under the different flight configurations.

RESULTS

Assessment of detection probability as a function of flight and environmental variables

Model comparison based on Akaike's Information Criterion corrected for small sample size (AICc) identified the most parsimonious models explaining variation in detection probability (Table 2). The effects of the retained predictors are presented below. More specifically, observer time had a significant positive effect on detection probability ($\beta = 0.182$, $p < 0.001$), indicating that longer assessment times were associated with a higher probability of detection.

Table 2. Model selection results based on AICc values for the GLMMs evaluating the effects of observer time, altitude, time of day, and season on detection probability of *Colobus vellerosus*.

	Estimate	Std. Error	Adjusted SE	z value	Pr(> z)	
Intercept	2.33633	0.08299	0.08324	28.066	< 2e-16	***
Observer time	0.18214	0.04072	0.04083	4.461	8.16e-06	***
Altitude20	-0.16654	0.09157	0.09185	1.813	0.06981	.
Altitude30	-0.44715	0.09566	0.09596	4.660	3.16e-06	***
Altitude40	-1.00351	0.10221	0.10253	9.788	< 2e-16	***
Altitude50	-1.48234	0.11020	0.11053	13.411	< 2e-16	***
Times of day Morning	0.45469	0.06283	0.06303	7.214	< 2e-16	***
Season Rainy	0.20154	0.07657	0.07681	2.624	0.00869	**

In contrast, altitude had a significant negative effect on detection probability ($\beta = -0.447$, $p < 0.001$). This effect was most pronounced at 40 m (Estimate = -1.003 , $p < 0.001$) and 50 m (Estimate = -1.482 , $p < 0.001$), indicating that higher altitudes reduce the detectability of black-and-white colobus. Regarding time of day, observations conducted in the morning were associated with a significantly higher probability of detection ($\beta = 0.455$, $p < 0.001$). Detection probability was also significantly higher during the rainy season ($\beta = 0.202$, $p = 0.0087$) (Figure 2).

In addition to the regression analyses, Pearson's chi-square tests of independence were used to examine associations among the categorical variables. First, a strong dependence was recorded between contrast and land cover ($\chi^2 = 71.53$, $df = 6$, $p < 0.001$). This significant association indicates that the observer-assessed contrast between the colobus and the surrounding canopy was related to the degree of canopy obstruction recorded in the drone imagery. In addition, a significant association was found between contrast and season ($\chi^2 = 21.33$, $df = 2$, $p < 0.001$), indicating that contrasts vary according to the season. Another marked dependence was detected between land cover and season ($\chi^2 = 59.2$, $df = 3$, $p < 0.001$). Finally, no significant association was found between the time of day and contrast ($\chi^2 = 0.997$, $df = 2$, $p = 0.608$).

Behavioral reactions of colobus to drone flight configurations

A total of 36 drone flights were conducted over three groups of *C. vellerosus* in the sacred forest of Kikélé, including 21 vertical flights and 15 horizontal flights. Five types of behavioral responses were considered *a priori*: no reaction, attention directed toward the drone, passive flight (slow movement without vocalization), active flight (rapid movement with agitation), and disappearance (loss of visual contact with individuals). No reaction was recorded among the 31 individuals assessed during the experimental flights (0%).

Among the 31 individuals assessed, 15 (48.4%) directed their attention toward the drone, characterized by a cessation of activity and visual orientation toward the drone. This behavior was observed at altitudes ranging from 25 to 35 m, at a flight speed of 2 m/s and an approach angle of 90°, with recorded response times ranging from 3 to 5 s.

Passive flight was observed in 8 individuals (25.8%), who moved slowly or changed position without apparent agitation. This response was

observed at an altitude of 18 m, a flight speed of 2 m/s and an approach angle of 45°, with recorded response times of 2–3 s.

Active flight was observed in 5 individuals (16.1%). These responses occurred at altitudes below 20 m and at a flight speed of 2 m/s under both approach angles, with a recorded response time of approximately 2 s.

Disappearance from the camera field of view was recorded for 3 individuals (9.7%). These responses occurred at altitudes below 20 m, at a flight speed of 2 m/s and under both approach angles.

DISCUSSION

Our study aimed to explore the combined effects of several drone flight, environmental and operational parameters, including altitude, speed, approach angle, contrast, land cover, time of day, season and observer effects on the visual detection and behavioral responses of the black-and-white colobus monkey (*C. vellerosus*) in the sacred forest of Kikélé, Benin. By combining visual observations from experimental flights with standardized behavioral analysis, we identified flight and observational conditions associated with variation in detection probability and described behavioral responses to drone approaches. This study is part of a broader trend in developing non-invasive tools for primate conservation, where drones offer a promising compromise between accessibility, accuracy, and ecological impact.

We found that altitude was inversely correlated with the probability of visual detection of individuals. This finding is consistent with the general relationship between increasing sensor-target distance and reduced detection performance reported in drone-based wildlife surveys (Hodgson *et al.* 2018). At an altitude of 10 to 20 m above the canopy, the contrasting morphology of colobus monkeys (black-and-white coat) remains relatively visible. At higher altitudes, the smaller apparent size of individuals and increasing visual obstruction may reduce their detectability in the imagery.

The seasonal effect, although more subtle, was also significant: detection probability was higher during the rainy season. Food-resource distribution and its implications for feeding behavior have been studied specifically in *C. vellerosus* (Saj & Sicotte 2007). Seasonal changes in food availability or canopy use may have contributed to the higher detection probability observed during the rainy season in our study. Differences in illumination between seasons may also have affected the visual

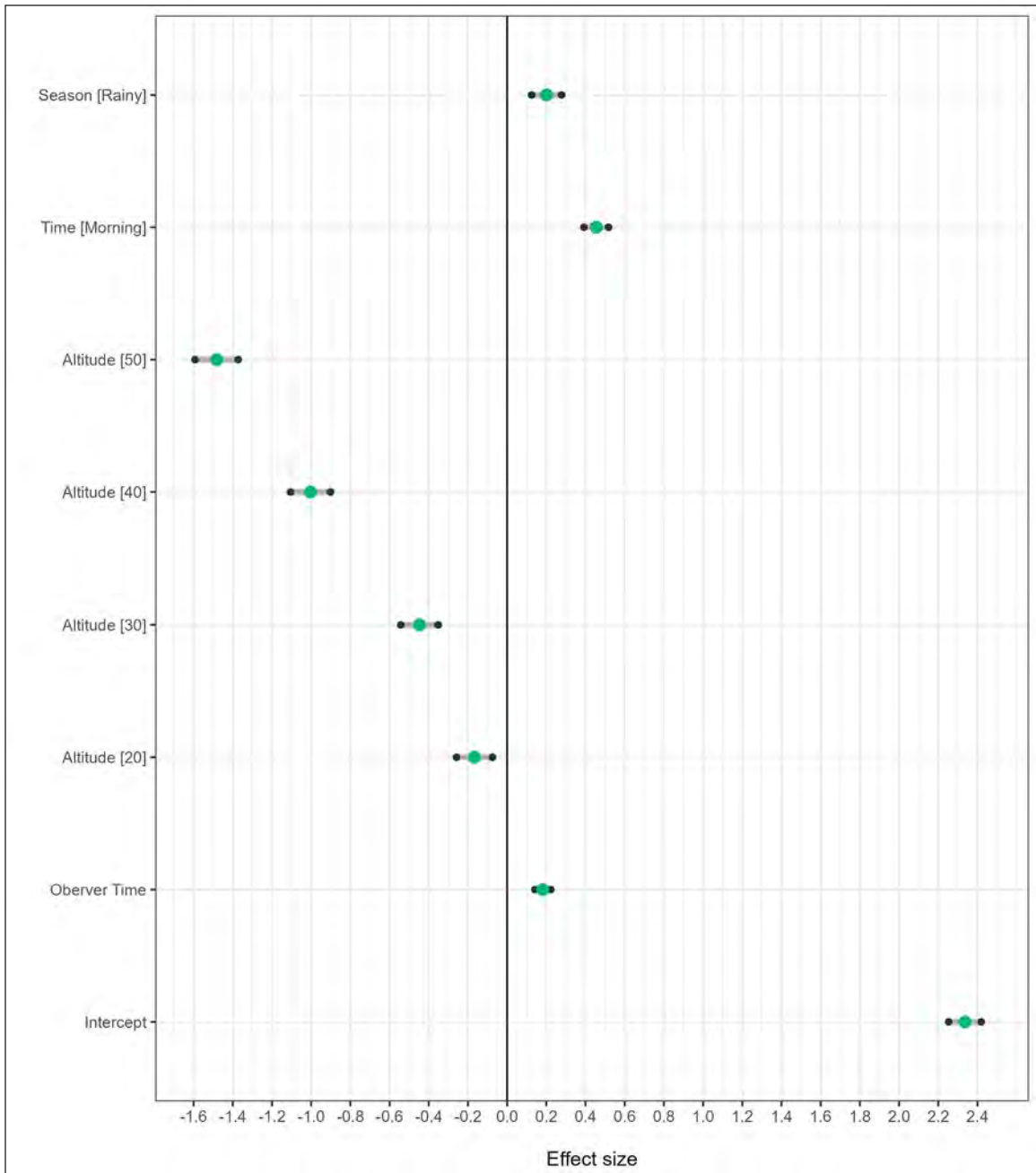


Figure 2. Estimated effect sizes of the predictors influencing the detection probability of *Colobus vellerosus*, as obtained from the GLMM.

contrast between individuals and the surrounding canopy. However, because food availability, canopy use, and illumination were not measured directly, these explanations remain tentative.

The behavioral observations also indicated variation in responses under the different approach angles. Because approach angle was not included as a predictor in the final detection GLMM, these observations should be interpreted descriptively rather than as evidence of a statistically tested effect

on detection probability. Oblique shots ($\sim 45^\circ$) may provide complementary views of individuals in areas with irregular canopy structure, although this potential advantage was not tested statistically in the present study.

With regard to flight speed, behavioral observations were recorded under hovering and slow-flight conditions. Because flight speed was not included as a predictor in the final detection GLMM, its potential influence on detection cannot

be inferred statistically from the present analysis. The observed behavioral responses under the tested flight configuration nevertheless provide descriptive information that can inform future experiments designed specifically to test the effects of flight speed. This is consistent with observations reported by Rahman *et al.* (2022), showing that slow movement speeds could be used effectively, relative to still shots, without significant loss of information, while reducing the flight time needed to cover large areas.

Time of day was also associated with detection probability. Observations made between 06:30 and 09:00 had a significantly higher probability of detection than those made at the end of the day. This higher detectability may be related to the daily activity and ranging pattern of *C. vellerosus*. Teichroeb *et al.* (2012) reported that groups generally remained in their sleeping trees for a period after sunrise before moving toward feeding areas. Individuals remaining in the upper canopy during the early morning may therefore be easier to detect from drone imagery than later in the day, when groups may become more dispersed or move into denser vegetation.

From a behavioral point of view, the responses of the colobus to drone approaches varied among individuals and flight conditions. Attention toward the drone and passive flight were the most frequently recorded responses, accounting for 15 (48.4%) and 8 (25.8%) of the 31 individuals assessed, respectively. These responses indicate that attention and movement responses were more frequently recorded than disappearance from the camera field of view. Similar variation in primate responses to drone approaches has been reported by Rahman *et al.* (2022), highlighting the importance of flight conditions and species-specific behavioral responses when assessing potential disturbance. However, because behavioral responses in the present study were assessed descriptively, these patterns should be interpreted cautiously.

Behavioral responses also differed among the three groups. The two groups located near the forest edge and human dwellings showed predominantly attention and passive-flight responses, whereas active flight and disappearance were recorded in the group located deeper within the forest. These differences may reflect variation among groups in their previous exposure to human activity, habitat context, group-specific behavior, or other unmeasured factors. However, because previous exposure to humans was not quantified in this study, we cannot attribute the observed differences specifically to habituation.

Recent advances in drone-based image analysis also offer promising opportunities for improving

the scalability of primate monitoring. Duporge *et al.* (2025) for example, developed the BaboonLand dataset to support automated detection and behavioral recognition of baboons from drone videos. Similarly, Delplanque *et al.* (2022) demonstrated the potential of convolutional neural networks for detecting and identifying African mammals in aerial imagery. These developments suggest that the image and video datasets generated through drone surveys could eventually support semi-automated or automated detection of arboreal primates. However, in structurally complex forest canopies, human interpretation remains important for validating detections and dealing with partially obscured individuals.

For future RGB-drone surveys of arboreal primates, our findings highlight the importance of standardizing flight altitude, survey timing, observer procedures, and image interpretation. Under the conditions tested in the present study, lower flight altitudes were associated with higher detection probability, while morning surveys were associated with higher detection probability. Flight speed and approach angle should also be considered when designing future behavioral studies, although their effects on detection probability were not evaluated in the final GLMM in the present study. Behavioral responses should be monitored during drone operations so that flight protocols can be adapted when strong responses occur. Recent work on RGB-camera drones for monitoring arboreal mammals in tropical forests similarly highlights the importance of canopy structure and flight design for detection success (Pinel-Ramos *et al.* 2025).

More broadly, RGB drones may be most useful when integrated with complementary approaches, such as thermal sensors or automated image analysis, to improve the monitoring of threatened arboreal mammals in structurally complex forests.

CONCLUSION

Our study demonstrates the potential of drone-based surveys for detecting *C. vellerosus* in dense tropical forest under the conditions tested. Flight altitude was an important predictor of detection probability, with detection decreasing at higher altitudes. Detection probability was also higher during morning observations and during the rainy season, although these effects should be interpreted in relation to the environmental and behavioral conditions of the study site. Behavioral responses to drone approaches varied among individuals and flight conditions, with attention and passive flight

being the most frequently recorded responses, while active flight and disappearance were observed at lower altitudes.

These findings highlight the importance of carefully selecting flight altitude and timing when designing drone-based surveys of arboreal primates. Although our results were obtained from *C. vellerosus* in a single forest, they provide a methodological basis for further studies of this species and may inform future surveys of other black-and-white colobus species. Further studies across species, habitats, and seasons are needed to determine how generalisable these relationships are and to refine flight protocols for primate monitoring.

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REFERENCES

- Basabose, A. K., E. M. Mihingano, M. B. Myakabeji, M. K. Bibentyo, S. M. Bazibuhe & M. B. Mambo. 2024. Confirmed presence of a small, isolated population of *Cercopithecus mitis* on Idjwi Island, Democratic Republic of Congo. *African Primates* 18: 9–18.
- Bartoń, K. 2012. *MuMIn: Multi-Model Inference*. R package version 1.7.7.
- Betts, M. G., C. Wolf, W. J. Ripple, B. Phalan, K. A. Millers, A. Duarte, S. H. M. Butchart and T. Levi. 2017. Global forest loss disproportionately erodes biodiversity in intact landscapes. *Nature* 547: 441–444.
- Bibby, C. J., M. Jones & S. Marsden. 2000. *Expedition Field Techniques: Bird Surveys*. BirdLife International.
- Brooks, M. E., K. Kristensen, K. van Benthem, A. Magnusson, C. W. Berg, A. Nielsen, H. J. Skaug, M. Mächler & B. M. Bolker. 2017. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. *R Journal* 9: 378–400.
- Burnham, K. P. & D. R. Anderson. 2004. Multimodel inference. *Sociological Methods & Research* 33: 261–304.
- Burton, A. C., E. Neilson, D. Moreira, A. Ladle, R. Steenweg, J. T. Fisher, E. Bayne & S. Boutin. 2015. Wildlife camera trapping: a review and recommendations for linking surveys to ecological processes. *Journal of Applied Ecology* 52: 675–685.
- Campbell, G., H. Kuehl, A. Diarrassouba, P. K. Ngoran & C. Boesch. 2011. Long-term research sites as refugia for threatened and over-harvested species. *Biology Letters* 7: 723–726.
- Chapman, C. A., T. T. Struhsaker, J. P. Skorupa, T. V. Snaith & J. M. Rothman. 2010. Understanding long-term primate community dynamics: implications of forest change. *Ecological Applications* 20: 179–191.
- Christie, K. S., S. L. Gilbert, C. L. Brown, M. Hatfield & L. Hanson. 2016. Unmanned aircraft systems in wildlife research: current and future applications of a transformative technology. *Frontiers in Ecology and the Environment* 14: 241–251.
- Delplanque, A., S. Foucher, P. Lejeune, J. Linchant & J. Théau. 2022. Multispecies detection and identification of African mammals in aerial imagery using convolutional neural networks. *Remote Sensing in Ecology and Conservation* 8: 166–179.
- Ditmer, M. A., J. B. Vincent, L. K. Werden, J. C. Tanner, T. G. Laske, P. A. Iaizzo, D. L. Garshelis & J. R. Fieberg. 2015. Bears show a physiological but limited behavioral response to unmanned aerial vehicles. *Current Biology* 25: 2278–2283.
- Duporge, I. et al. 2025. BaboonLand dataset: tracking primates in the wild and automating behaviour recognition from drone videos. *International Journal of Computer Vision* 1: 1–8.
- Effiom, E. O., G. Nuñez-Iturri, H. G. Smith, U. Ottosson & O. Olsson. 2013. Bushmeat hunting changes regeneration of African rainforests. *Proceedings of the Royal Society B: Biological Sciences* 280: 1–8.
- Ekiye, S. A. & S. O. Ogoanah. 2022. Seasonal variation, diversity and population dynamics of four species of monkey in Okomu National Park. *Journal of Research in Forestry* 14: 1–10.
- Estrada, A. et al. 2022. Global importance of Indigenous Peoples, their lands, and knowledge systems for saving the world's primates from extinction. *Science Advances* 8:1–19.
- Flores, D., I. González-Hernández, R. Lozano, J. M. Vazquez-Nicolas & J. L. H. Toral. 2021. Automated agave detection and counting using a convolutional neural network and unmanned aerial systems. *Drones* 5: 1–17.
- Fox, J. & S. Weisberg. 2019. *An R Companion to Applied Regression*. 3rd ed. Sage Publications, Davis.
- Garber, P. A. et al. 2024. Global wildlife trade and trafficking contribute to the world's nonhuman primate conservation crisis. *Frontiers in Conservation Science* 5: 1–17.
- Gazagne, E., R. J. Gray, S. Wich, A. Hambuckers & F. Brotcorne. 2024. Development of a global thermal

- detection index to prioritize primate research with thermal drones. *Scientific Reports* 14: 1–12.
- Gibbs, H. K., A. S. Ruesch, F. Achard, M. K. Clayton, P. Holmgren, N. Ramankutty & J. A. Foley. 2010. Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. *Proceedings of the National Academy of Sciences of the United States of America* 107: 16732–16737.
- Hodgson, J. C. *et al.* 2018. Drones count wildlife more accurately and precisely than humans. *Methods in Ecology and Evolution* 9: 1160–1167.
- Johnson, J. B. & K. S. Omland. 2004. Model selection in ecology and evolution. *Trends in Ecology & Evolution* 19: 101–108.
- Junker, J. *et al.* 2012. Recent decline in suitable environmental conditions for African great apes. *Diversity and Distributions* 18: 1077–1091.
- Kays, R., J. Sheppard, K. Mclean, C. Welch, C. Paunescu, V. Wang, G. Kravitz & M. Crofoot. 2019. Hot monkey, cold reality: surveying rainforest canopy mammals using drone-mounted thermal infrared sensors. *International Journal of Remote Sensing* 40: 407–419.
- Koh, L. P. & S. A. Wich. 2012. Dawn of drone ecology: low-cost autonomous aerial vehicles for conservation. *Tropical Conservation Science* 5: 121–132.
- Koski, W. R., T. A. Thomas, D. W. Funk & A. M. Macrander. 2014. Marine mammal sightings by analysts of digital imagery versus aerial surveyors: a preliminary comparison. *Journal of Unmanned Vehicle Systems* 1: 25–40.
- Kpatchia, E. J., S. G. A. Nago, O. A. H. Gado, F. Bahleman & H. Oebel. 2025. Potential of drones for avian ecological monitoring in West African mangrove ecosystems. *Open Journal of Ecology* 15: 359–373.
- Laurance, W. F. *et al.* 2014. A global strategy for road building. *Nature* 513: 229–232.
- López, J. J. & M. Mulero-Pázmány. 2019. Drones for conservation in protected areas: present and future. *Drones* 3: 1–23.
- Matsuda Goodwin, R., S. Gonedelé Bi, G. Nobimè, I. Koné, D. Osei, G. Segniagbeto & J. F. Oates. 2020. *Colobus vellerosus*. *The IUCN Red List of Threatened Species* 2020: e.T5146A169472127. <https://doi.org/10.2305/IUCN.UK.2020-2.RLTS.T5146A169472127.en>
- Mulero-Pázmány, M., R. Stolper, L. D. Van Essen, J. J. Negro & T. Sassen. 2014. Remotely piloted aircraft systems as a rhinoceros anti-poaching tool in Africa. *PLoS ONE* 9: 1–10.
- Nago, S. G. A. *et al.* 2021. Utilisation de drone pour le suivi écologique de la faune dans un ranch au Nord Bénin. *International Journal of Innovation and Applied Studies* 32: 291–302.
- Pinel-Ramos, E. J., F. Aureli, S. Wich, S. Longmore & D. Spaan. 2024. Evaluating thermal infrared drone flight parameters on spider monkey detection in tropical forests. *Sensors* 24: 1–19.
- Pinel-Ramos, E. J., F. Aureli, S. Wich, F. Rodrigues de Melo, C. Rezende, F. Brandão, F. C. S. Alves de Melo & D. Spaan. 2025. An assessment of the effectiveness of RGB-camera drones to monitor arboreal mammals in tropical forests. *Drones* 9: 1–23.
- R Core Team. 2023. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria.
- Rahman, D. A., A. B. Y. Sitorus & A. A. Condro. 2022. From coastal to montane forest ecosystems, using drones for multi-species research in the tropics. *Drones* 6: 1–31.
- Rovero, F. & D. Spitalé. 2016. Camera trapping for biodiversity assessment in tropical forests: A review of field methods and results. *Biodiversity Monitoring and Conservation* 6: 100–128.
- Saj, T.L. & P. Sicotte. 2027. Predicting the competitive regime of female *Colobus vellerosus* from the distribution of food resources. *International Journal of Primatology* 28: 315–336. <https://doi.org/10.1007/s10764-007-9124-x>
- Teichroeb, J. A., T. D. Holmes & P. Sicotte. 2012. Use of sleeping trees by ursine colobus monkeys (*Colobus vellerosus*) demonstrates the importance of nearby food. *Primates* 53: 287–296.
- van Andel, A. C., S. A. Wich, C. Boesch, L. P. Koh, M. M. Robbins, J. Kelly & H. S. Kuehl. 2015. Locating chimpanzee nests and identifying fruiting trees with an unmanned aerial vehicle. *American Journal of Primatology* 77: 1122–1134.
- Vermeulen, C., P. Lejeune, J. Lisein, P. Sawadogo & P. Bouché. 2013. Unmanned aerial survey of elephants. *PLoS ONE* 8: 1–7.
- Wearn, O. R. & P. Glover-Kapfer. 2019. Snap happy: camera traps are an effective sampling tool when compared with alternative methods. *Royal Society Open Science* 6: 1–13.
- Wich, S. A., N. Bonnin, A. Hutschenreiter, A. K. Piel, A. Chitayat, F. A. Stewart, L. Pintea & J. T. Kerby. 2023. Using drones to determine chimpanzee absences at the edge of their distribution in Western Tanzania. *Remote Sensing* 15: 1–11.
- Wikberg, E. C., E. Glotfelty, B. Adu Yeboah, R. Koranteng, C. Kodom, B. Owusu Antwi & A. Boahen. 2024. Predictors of population estimates of the Critically Endangered white-thighed black-and-white colobus *Colobus vellerosus*. *Primate Conservation* 38: 83–94.
- Wong, S. N. P. & P. Sicotte. 2006. Population size and density of *Colobus vellerosus* at the Boabeng-Fiema Monkey Sanctuary and surrounding forest fragments in Ghana. *American Journal of Primatology* 68: 465–476.

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Brief Communication:

Taxonomy of the Eastern Patas Monkey: Review of the Authority Name, Year, and Epithets 'pyrronotus' and 'pyrrhonotus'

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INTRODUCTION

Patas monkeys *Erythrocebus* Trouessart, 1897, are semi-terrestrial primates endemic to tropical Africa. They are characterized by their large size (up to 18 kg), slender bodies, and orange, white, and black pelage (Figures 1 & 2). The taxonomy of the species and subspecies within *Erythrocebus* is complex and far from resolved. We are currently undertaking a review of the taxonomic arrangement within *Erythrocebus*.

During our review of the literature, we found considerable variation in the spelling of the epithet for the eastern patas monkey---'pyrronotus' vs 'pyrrhonotus.' Also, the names of the authority and year of publication of these two epithets vary considerably in the literature. Table 1 presents examples of this variation.

The confusion over 'pyrronotus' vs 'pyrrhonotus' goes back to the protologue of *Cercopithecus pyrronotus* Hemprich & Ehrenberg, 1829. These authors first published the description and specific name of this monkey in *Verhandlungen der Gesellschaft Naturforschender Freunde zu Berlin* (1829, p. 407; Figure 3). The epithet 'pyrronotus' is presented twice in this work.

Hemprich & Ehrenberg (1833) subsequently published additional supporting text and an illustration with a caption (Plate 10) in *Symbolae Physicae* ('1832' appears in this publication but it was not printed and made available until 1833). Here they introduced the name 'pyrrhonotus' (Figure 4) while the caption to the drawing applied the name 'pyrronotus' (Figure 5).

Hemprich & Ehrenberg (1833) used 'pyrrhonotus' in the title and listed 'pyrrhonotus' as a synonym (i.e., *Cercopithecus pyrrhonotus* Ehrenberg *Verhandl. d. Gesellschaft naturf. Fr. zu Berlin I.* 1927). They mentioned 'pyrrhonotus' twice in the description, while 'pyrronotus' was only presented in the caption to Plate 10. It is unlikely, therefore, that the spelling 'pyrrhonotus' is a lapsus. Note that *pyrrhos* originates from the Greek word *pyr* (fire), meaning 'flame-colored', 'fiery', or 'red-haired', *notus* means 'back'. As such, 'pyrrhonotus' is morphologically consistent and semantically appropriate for *Erythrocebus*.

From the time of its introduction in 1829 until 1981, 'pyrronotus' was frequently used (Table 1), probably mostly by those who had read both Hemprich & Ehrenberg (1829) and Hemprich & Ehrenberg (1833). Geoffroy Saint-Hilaire & Cuvier (1842) used 'pyrronotus.' Apart from Hemprich & Ehrenberg (1833), Geoffroy Saint-Hilaire (1855) appears to have been the first author to apply 'pyrrhonotus.' Sclater (1872, 1893), Schlegel (1876), Forbes (1897), Trouessart (1897), and Anderson & de Winton (1902) followed Geoffroy Saint-Hilaire (1855) by citing 'pyrrhonotus.'

In 1905, Matschie brought 'pyrronotus' back into the literature. This usage was subsequently applied in some works (e.g., Allen 1925; Schwarz 1927; Hill 1966; Kock 1969; Yalden *et al.* 1977; Napier 1981), while 'pyrrhonotus' was retained in others (e.g., Pocock 1907; Elliot 1909, 1913; Hollister 1924; Allen 1939; Setzer 1956; Butler 1966; Dandelot 1974; Groves 1993, 2001, 2005; Grubb *et al.* 2003; Wallis



Figure 1. Eastern patas monkeys *Erythrocebus patas pyrrhonotus*, Borana Conservancy, Laikipia Plateau, central Kenya. Photograph by Y. de Jong & T. Butynski.



Figure 2. Adult male eastern patas monkey *Erythrocebus patas pyrrhonotus*, Kidepo Valley National Park, northeastern Uganda. Photograph by Y. de Jong & T. Butynski.

Table 1. Variation in the spelling of ‘pyrronotus’ vs ‘pyrrhonotus’ as the epithet for the eastern patas monkey.

Reference	Name	Authority and year cited
Geoffroy Saint-Hilaire & Cuvier (1842)	<i>pyrronotus</i>	No authority or year provided
Geoffroy Saint-Hilaire (1855)	<i>pyrrhonotus</i>	Ehrenberg (1829) Hemprich & Ehrenberg (1830)
Sclater (1872, 1893); Trouessart (1897); Butler (1966)	<i>pyrrhonotus</i>	Hemprich & Ehrenberg (no year provided)
Schlegel (1876)	<i>pyrrhonotus</i>	Ehrenberg (no year provided)
Forbes (1897); Elliot (1913); Hollister (1924)	<i>pyrrhonotus</i>	Hemprich & Ehrenberg (1838)
Anderson & de Winton (1902); Pocock (1907); Dandelot (1974); Groves (1993, 2001, 2005); Grubb <i>et al.</i> (2003); Wallis (2013); Gippoliti (2017); De Jong <i>et al.</i> (2025); GBIF (2026); IUCN (2026); PSG (2026)	<i>pyrrhonotus</i>	Hemprich & Ehrenberg (1829)
Matschie (1905); Allen (1925); Hill (1966); Kock (1969); Yalden <i>et al.</i> (1977); Napier (1981)	<i>pyrronotus</i>	Hemprich & Ehrenberg (1829)
Elliot (1909)	<i>pyrrhonotus</i>	No authority or year provided
Schwarz (1927)	<i>pyrronotus</i>	Hemprich & Ehrenberg (no year provided)
Allen (1939), Setzer (1956)	<i>pyrrhonotus</i>	Hemprich & Ehrenberg (1832)
MDD (2026)	<i>pyrronotus</i>	Ehrenberg (1929)

2013; Gippoliti 2017; De Jong *et al.* 2025; Table 1).

The Global Biodiversity Information Facility (GBIF 2026), the IUCN Red List of Threatened Species (IUCN 2026), and the IUCN/SSC Primate Specialist Group (PSG 2026) use ‘*pyrrhonotus*.’ The American Society of Mammalogist’s Mammal Diversity Database (MDD 2026), however, uses ‘*pyrronotus*.’

Below, in italics, are parts of Article 32 (Original Spellings) and Article 33 (Subsequent Spellings) in the International Code of Zoological Nomenclature (ICZN 1999). Here, we have inserted comments relevant to the usage of ‘*pyrronotus*’ and ‘*pyrrhonotus*’, and our conclusions. Our insertions are preceded by ‘***’.

Article 32. Original spellings

32.1. Definition

The “original spelling” of a name is the spelling used in the work in which the name was established.

*** The “original spelling” in Hemprich & Ehrenberg (1829) is ‘*pyrronotus*.’

32.2. Correct original spelling

The original spelling of a name is the “correct original spelling”, unless it is demonstrably incorrect as provided in Article 32.5.

*** The “correct original spelling” is ‘*pyrronotus*.’ It is not “demonstrably incorrect.”

32.3. Preservation of correct original spelling

The correct original spelling of a name is to be preserved unaltered, except where it is mandatory to change the suffix or the gender ending under Article 34 (for treatment of emendations and incorrect subsequent spellings see Articles 32.5, 33.2, 33.3, 33.4).

*** The “correct original spelling” is ‘*pyrronotus*.’

32.5. Spellings that must be corrected (incorrect original spellings)

32.5.1. *If there is in the original publication itself, without recourse to any external source of information, clear evidence of an inadvertent error, such as a lapsus*

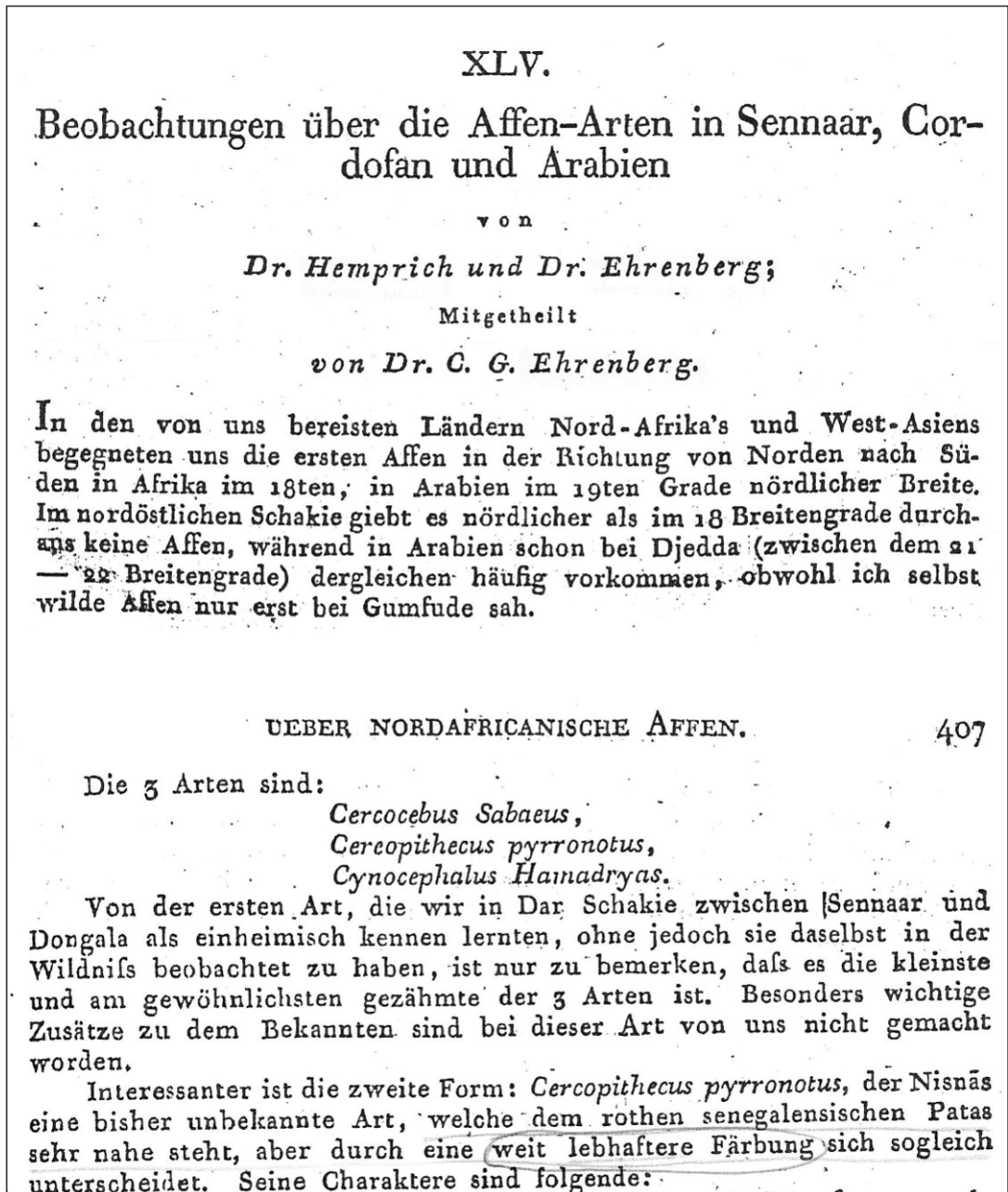


Figure 3. Title of the *Cercopithecus pyrrhonotus* prologue by Hemprich & Ehrenberg (1829) in *Verhandlungen der Gesellschaft Naturforschender Freunde zu Berlin* (1829) (6): 406–408.

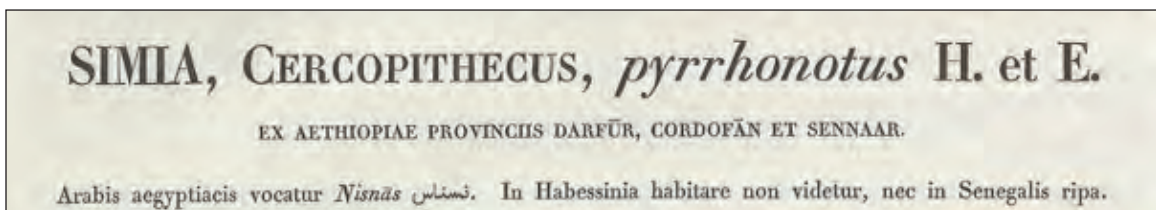


Figure 4. Title of the *Cercopithecus pyrrhonotus* protologue by Hemprich & Ehrenberg (1833) in *Symbolae Physicae, seu Icons et Descriptions Mammalium* (Zoologica II, Mammalium, Part I). Berlin.



Figure 5. *Cercopithecus pyrrhonotus* in Plate 10 in Hemprich & Ehrenberg (1833). Note the spelling ‘pyrrhonotus’ in the caption.

calami or a copyist’s or printer’s error, it must be corrected. Incorrect transliteration or latinization, or use of an inappropriate connecting vowel, are not to be considered inadvertent errors.

*** The name ‘pyrrhonotus’ is not a lapsus, but rather an incorrect latinization. It seems likely that Hemprich & Ehrenberg (1833), purposefully, introduced ‘pyrrhonotus’ (= red back) in order to provide a name that corrected the latinization of ‘pyrronotus.’ The name ‘pyrronotus’ (i.e., without the ‘h’) is not a stand-alone word in classical Greek or Latin but rather is a misspelling of ‘pyrrhonotus.’ Nonetheless, ‘pyrronotus’ is the “correct original spelling” for this epithet.

33.2.3. Any other emendation is an “unjustified emendation.”

Article 33. Subsequent spellings

33.1. Kinds of subsequent spellings

A subsequent spelling of a name, if different from the original spelling [Art. 32.1], is either an emendation [Art. 33.2], or an incorrect subsequent spelling [Art. 33.3], or a mandatory change [Art. 34].

*** The “original spelling” is ‘pyrronotus.’ The “subsequent spelling” is ‘pyrrhonotus.’ The spelling ‘pyrrhonotus’ is not a lapsus as it is not “demonstrably incorrect.”

33.2. Emendations

Any demonstrably intentional change in the original spelling of a name other than a mandatory change is an “emendation”, except as provided in Article 33.4.

33.2.1. A change in the original spelling of a name is only to be interpreted as “demonstrably intentional” when in the work itself, or in an author’s (or publisher’s) corrigenda, there is an explicit statement of intention, or when both the original and the changed spelling are cited and the latter is adopted in place of the former, or when two or more names in the same work are treated in a similar way.

*** Hemprich & Ehrenberg (1833) do not provide an “explicit statement of intention” that this work serves as an emendation for the spelling of ‘pyrrhonotus’, nor do they provide a justification or explanation as to why they introduced the name ‘pyrrhonotus.’ Nonetheless, this work serves as an emendation for ‘pyrrhonotus’ as this change is “demonstrably

intentional”, since “both the original spelling and the changed spelling are cited and the latter is adopted in place of the former”, and because the two names “are treated in a similar way.” Furthermore, intent is demonstrated by the fact that the addition of the letter ‘h’ correctly latinizes ‘pyrronotus’. This is not a lapsus. Although this is an intentional emendation it is, nonetheless, an “unjustified emendation.”

33.2.2. *The correction of an incorrect original spelling in accordance with Article 32.5 is a “justified emendation”, and the name thus corrected retains the authorship and date of the original spelling [Art. 19.2].*

*** The name ‘pyrronotus’ is not an “incorrect original spelling.”

33.2.3. *Any other emendation is an “unjustified emendation”; the name thus emended is available and it has its own author and date and is a junior objective synonym of the name in its original spelling; it enters into homonymy and can be used as a substitute name, but*

33.2.3.1. *when an unjustified emendation is in prevailing usage and is attributed to the original author and date it is deemed to be a justified emendation.*

*** Based on the above, ‘pyrrhonotus’ is an “unjustified emendation.” However, since ‘pyrrhonotus’ has been in common usage in major taxonomic works since 1855, and in “prevailing usage” since about 1974 (Table 1), ‘pyrrhonotus’ is now deemed a “justified emendation.”

33.3. Incorrect subsequent spellings

Any subsequent spelling of a name different from the correct original spelling, other than a mandatory change or an emendation, is an “incorrect subsequent spelling”; it is not an available name and, like an incorrect original spelling [Art. 32.4], it does not enter into homonymy and cannot be used as a substitute name, but

33.3.1. *when an incorrect subsequent spelling is in prevailing usage and is attributed to the publication of the original spelling, the subsequent spelling and attribution are to be preserved and the spelling is deemed to be a correct original spelling.*

*** The emendation presented in Hemprich & Ehrenberg (1833) for ‘pyrrhonotus’ is an “unjustified emendation.” As such, ‘pyrrhonotus’ is an “incorrect subsequent spelling.” Since, however, ‘pyrrhonotus’ has been in “prevailing usage” for over 50 years, this name must now be preserved and taken to be the “correct original spelling.”

As far as we are aware, the correct name for the eastern patas monkey has not been of much concern---until now. The considerable disparities among the names and years used for the authorship of the names ‘pyrronotus’ and ‘pyrrhonotus’ strongly suggest that few authors studied the two publications in which these names first appeared. This lack of attention to the prologues seems to be the reason that ‘pyrrhonotus’ has been able to increasingly gain usage over the past 120 years or so.

We conclude:

1. That ‘pyrronotus’ in Hemprich & Ehrenberg (1829) precedes ‘pyrrhonotus’ in Hemprich & Ehrenberg (1833), that ‘pyrronotus’ was the “correct original spelling”, and that these are the correct authority names and years of publication for these names.
2. That ‘pyrrhonotus’ in Hemprich & Ehrenberg (1833) was an “unjustified emendation” and, therefore, represented an “incorrect subsequent spelling.” The reason for this is that ‘pyrronotus’ was the “correct original spelling.”
3. That the “incorrect subsequent spelling” of ‘pyrrhonotus’ should now be taken as a “correct original spelling” and “current valid spelling” on the basis that ‘pyrrhonotus’ has been in “prevailing usage” for about the last 50 years.
4. That ‘pyrronotus’ in Hemprich & Ehrenberg (1829) is now the “historic original spelling” and “invalid.”
5. That, applying the current taxonomic arrangement, the name, authority, and year of publication for the eastern patas monkey is ‘*Erythrocebus patas pyrrhonotus* (Hemprich & Ehrenberg, 1829).’

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REFERENCES

- Allen, G.M. 1939. A checklist of African mammals. *Bulletin of the Museum of Comparative Zoölogy at Harvard College* 83: 1–763.
- Allen, J.A. 1925. Primates collected by the American Museum Congo Expedition. *Bulletin of the American Museum of Natural History* 47: 283–499.
- Anderson, J. & W.E. de Winton. 1902. *Zoology of Egypt: Mammalia*. Revised and completed by W.E. de Winton. Hugh Rees Limited, London.
- Butler, H. 1966. Some notes on the distribution of primates in the Sudan. *Folia Primatologica* 4: 416–423.
- Dandelot, P. 1974. Order Primates. Part III. In *The Mammals of Africa: An Identification Manual*. J. Meester & H.W. Setzer, eds. Smithsonian Institution Press, Washington, DC. Pp. 1–45.
- De Jong, Y.A., T.M. Butynski & A.B. Rylands. 2025. *Erythrocebus patas*. *The IUCN Red List of Threatened Species* 2025. Gland, Switzerland. e.T174391079A205893855. Website: <<https://www.iucnredlist.org>>.
- Elliot, D.G. 1909. Descriptions of apparently new species and subspecies of monkeys of the genera *Callicebus*, *Lagothrix*, *Papio*, *Pithecius*, *Cercopithecus*, *Erythrocebus*, and *Presbytis*. *Annals and Magazine of Natural History* (8) 4: 244–274.
- Elliot, D.G. 1913. *A Review of the Primates. Volume III: Anthropeoidea* (Miopithecus to Pan). Monograph Series, American Museum of Natural History, New York.
- Forbes, H.O. 1897. *A Hand-Book to the Primates*. Volume 2. W.H. Allen, London.
- GBIF. 2026. Global Biodiversity Information Facility (GBIF). 2026. Website: <<https://www.gbif.org/>>.
- Geoffroy Saint-Hilaire, I. 1855. *Voyage Autour du Monde sur la Frégate la Vénus*. Zoologie: Mammifères. Gide & J. Baudry, Paris.
- Geoffroy Saint-Hilaire, M. & M.F. Cuvier. 1842. *Histoire Naturelle des Mammifères*. Muséum d'Histoire Naturelle, Paris.
- Gippoliti, S. 2017. On the taxonomy of *Erythrocebus* with a re-evaluation of *Erythrocebus poliophaeus* (Reichenbach, 1862) from the Blue Nile Region of Sudan and Ethiopia. *Primate Conservation* (31): 53–59.
- Groves, C.P. 1993. Speciation in living hominoid primates. In *Species, Species Concepts and Primate Evolution*. W.H. Kimbel & L.B. Martin, eds. Plenum Press, New York. Pp. 325–339.
- Groves, C.P. 2001. *Primate Taxonomy*. Smithsonian Institution Press, Washington, DC.
- Groves, C.P. 2005. Order Primates. In *Mammal Species of the World: A Taxonomic and Geographic Reference* (3rd edition). D.E. Wilson & D.M. Reeder, eds. Johns Hopkins University Press, Baltimore, MD. Pp.111–184.
- Grubb, P., T.M. Butynski, J.F. Oates, S.K. Bearder, T.R. Disotell, C.P. Groves & T.T. Struhsaker. 2003. Assessment of the diversity of African primates. *International Journal of Primatology* 24: 1301–1357.
- Hemprich, F.G. & C.G. Ehrenberg. 1829. Beobachtungen über die Affen-Arten in Sennar, Cordofan und Arabien. *Verhandlungen der Gesellschaft Naturforschender Freunde zu Berlin* (1829) (6): 406–408. Website: <<https://www.biodiversitylibrary.org/page/48509218>>.
- Hemprich, F.G. & C.G. Ehrenberg. 1833. *Simia, Cercopithecus, pyrrhonotus* H. et E. *Symbolae Physicae, seu Icons et Descriptions Mammalium* (Zoologica II, Mammalium, Part I). Berlin. ('1832' appears in this publication but it was not published and made available until 1833). Website: <<https://www.biodiversitylibrary.org/page/48509218#page/81/mode/1up>>.
- Hill, W.C.O. 1966. *Primates: Comparative Anatomy and Taxonomy, Volume 6: Catarrhini, Cercopithecoidea, Cercopithecinae*. Edinburgh University Press, Edinburgh.
- Hollister, N. 1924. East African mammals in the United States National Museum. Part III. Primates, Artiodactyla, Proboscidea, and Hyracoidea. *Bulletin of the United States National Museum* 99: 1–164.
- ICZN. 1999. *International Code of Zoological Nomenclature*, 4th edition. Website: <<https://code.iczn.org/>>.
- IUCN. 2026. *IUCN Red List of Threatened Species* 2026. Website: <<https://www.iucnredlist.org/>>.
- Kock, D. 1969. Die verbreitung der primaten im Sudan. *Zeitschrift für Säugetierkunde* 33: 193–216.
- Matschie, P. 1905. Einige anscheinend neue meerkatzen. *Sitzungsberichte der Gesellschaft Naturforschender Freunde zu Berlin* 1905: 262–279.
- MDD. 2026 Mammal Diversity Database. 2026. Website: <<https://www.mammaldiversity.org/taxon>>.
- Napier, P.H. 1981. *Catalogue of Primates in the British Museum (Natural History) and Elsewhere in the British Isles. Part II: Family Cercopithecidae, Subfamily Cercopithecinae*. British Museum (Natural History), London.

- Pocock, R.I. 1907. A revision of monkeys of the genus *Cercopithecus*. *Proceedings of the Zoological Society of London* 77: 447–1121.
- PSG. 2026. IUCN/SSC Primate Specialist Group. 2026. Website: <<http://www.primates-sg.org>>.
- Schlegel, H. 1876. *Les singes: Simiae*. Monographie 40. *Muséum d'Histoire Naturelle des Pays-Bas* (Leiden) 7: 1–356.
- Schwarz, E. 1927. Die formen der gattung *Erythrocebus*. *Sitzungs-berichte der Gesellschaft Naturforschender Freunde zu Berlin* 1926: 24–31.
- Sclater, P.L. 1872. *Revised List of the Vertebrate Animals Now or Lately Living in the Gardens of the Zoological Society of London*. Longmans, Green, Reader & Dyer, London.
- Sclater, P.L. 1893. On a new African monkey of the genus *Cercopithecus*, with a list of known species. *Proceedings of the Zoological Society of London* 1893: 243–258.
- Setzer, H.W. 1956. Mammals of the Anglo-Egyptian Sudan. *Proceedings of the United States National Museum* 106: 447–587.
- Trouessart, E.-L. 1897. *Catalogus Mammalium tam Viventium quam Fossilium*. R. Friedlander & Sohn, Berlin.
- Wallis, J. 2013. Genus *Erythrocebus*. In *Handbook of the Mammals of the World. Volume 3. Primates*. R.A. Mittermeier, A.B. Rylands & D.E. Wilson, eds. Lynx Edicions, Barcelona. Pp. 671–672.
- Yalden, D.W., M.J. Lagen & D. Kock. 1977. Catalogue of the mammals of Ethiopia. 3. Primates. *Monitore Zoologico Italiano, Supplemento* 9(1): 1–52.

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Brief Communication:

From Camera Traps to Conservation Action: A Field-ready Workflow for Offline AI-assisted Wildlife Monitoring in Kibale National Park, Uganda

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INTRODUCTION

African tropical forests are vital carbon and biodiversity reserves, yet they are being altered at unprecedented rates by deforestation, degradation, hunting, infrastructure and agricultural expansion (Malhi *et al.* 2013; Worden *et al.* 2026). Global assessments highlight the scale of the biodiversity crisis: around one million species are estimated to be threatened with extinction unless the drivers of change are reduced (IPBES 2019), and global deforestation in 2015–2025 remained around 10.9 million hectares per year (FAO 2025). Tropical forests alone harbour an estimated 62% of the world's terrestrial vertebrate species, and a large proportion of endemic taxa (Pillay *et al.* 2022).

Habitat alteration and fragmentation, crop-foraging, and expanding transport infrastructure concentrate interactions between people and primates along forest edges, crop-forest mosaics and road networks (Naughton-Treves *et al.* 1998; Chapman *et al.* 2000; McLennan *et al.* 2020, 2021; Thompson *et al.* 2020; Edwards *et al.* 2023; Praill *et al.* 2023; Deneke *et al.* 2024). They also complicate the monitoring of threatened and cryptic taxa in dense vegetation where direct observations are often limited (Kühl *et al.* 2008; Zwerts *et al.* 2021; Piel *et al.* 2022).

In this context, camera traps (CT) - typically ground-based in systematic or stratified arrays

and, where canopy-specific questions require it, complemented by arboreal deployments - can help document understorey and canopy use (Moore *et al.* 2020, 2021). Camera traps limit observer proximity and disturbance, thus potentially lowering zoonotic transmission risks associated with close human–nonhuman primate contact (Gilardi *et al.* 2015). However, camera-trap projects routinely generate very large volumes of images and videos, and manual screening is a persistent bottleneck (Le Borgne & Bouget 2023; Mulero-Pázmány *et al.* 2025). Automated species identification using deep learning algorithms can reduce this burden, but classification alone does not constitute an operational monitoring system. Field programmes also require procedures for study design, deployment, secure data transfer and backup, quality control of automated predictions, and translation of detections into ecological analyses or conservation responses.

DeepForestVision (DFV) was developed to address the automated-processing component of this workflow for African tropical forests (Magaldi *et al.* 2025, 2026a). It is an offline AI tool designed to process both camera-trap photographs and videos, with a prediction space of 64 classes comprising 61 animal classes, as well as human, vehicle, and blank records. Its development relied on a large and heterogeneous collaborative corpus, including

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2,775,671 photographs and 221,982 videos collected from camera traps at more than 63 research sites across 11 African countries. These data originated from a diversity of research and conservation projects, each designed for its own objectives and therefore using different camera-trap models, field protocols, recording modes, and sampling strategies. This pooling of datasets collected for various ecological and conservation objectives and used for model development under data-sharing agreements, allowed DeepForestVision to be trained and tested on the diversity of species, environments, and field conditions encountered across African tropical-forest monitoring programmes.

The purpose of our contribution is broader than automated labelling of camera-trap media. We present the end-to-end, field-ready workflow used by the Sebitoli Chimpanzee Project (SCP) in Kibale National Park, Uganda, linking the formulation of monitoring questions and co-designed camera deployment with data stewardship, offline AI-assisted triage, human quality control, ecological analysis, and conservation feedback. The added value of this approach is to convert large volumes of raw camera-trap media into standardized and quality-controlled information that can support both rapid operational responses - for example to injured animals, illegal activities or wildlife incursions - and longer-term analyses of species occurrence, activity and spatial or seasonal patterns, with AI used to prioritise and structure human review rather than replace local ecological expertise. Recent work from the SCP illustrates this downstream use of automated classifications: DeepForestVision outputs from a standardized camera-trap network were combined with passive acoustic monitoring and local ecological knowledge to assess vertebrate biodiversity, demonstrating how automated classifications can contribute to broader, multi-method ecological assessment rather than constituting an endpoint in themselves (Magaldi *et al.* 2026b). Our aim here is to facilitate the adoption and adaptation of this workflow by other tropical-forest field programmes while highlighting the practical choices required to make camera trapping and AI useful complements to local expertise and long-term research and conservation programmes. Detailed procedures, templates, and checklists are provided in *Camera Trap Project Manual: Wildlife Monitoring in African Tropical Forests with DeepForestVision* (Magaldi *et al.* 2026c), available from *African Primates'* website (here). This workflow was developed within the One Forest Vision initiative (OFVi), a scientific cooperation and

capacity-building programme supporting countries in tropical basins to monitor forest degradation, carbon stocks, and tropical biodiversity, and to co-build sustainable solutions with local communities (OneForestVision 2024).

FROM LABELS TO CONSERVATION ACTION: THE SEBITOLI CHIMPANZEE PROJECT

The Sebitoli Chimpanzee Project is a long-term field programme established in 2008 in the Sebitoli area of Kibale National Park, Uganda, by the Muséum National d'Histoire Naturelle and the NGO Great Ape Conservation project, with the aim to understand and reduce human-wildlife pressure on biodiversity. Its Ugandan field staff support integrated research and conservation missions, including daily chimpanzee follows, maintenance of the forest trail network, anti-poaching activities, and environmental education. These efforts respond to multiple, well-documented pressures in and around Kibale, including illegal harvesting and the socio-economic drivers of wild-meat consumption, as well as infrastructure impacts associated with the Sebitoli road within the park (Krief *et al.* 2020a; Bortolamiol *et al.* 2023). SCP also coordinates the “Chimps Guardians” programme, involving 20 villagers from six neighbouring communities in crop-guarding at the forest edge (Sebitoli Chimpanzee Project 2025). The camera-trap programme, conducted since 2013 by a specific SCP team, is a component designed to capture information that is difficult to obtain through direct observation alone, such as rare or cryptic taxa, health issues such as injuries or deformities, nocturnal activity and specific behaviours of interest (Krief *et al.* 2014; Lacroux *et al.* 2019, 2022).

Kibale's forest-agriculture mosaic and road infrastructure create a dynamic human-primate interface. Camera-trap data provide a parallel line of evidence to direct observation via focal follows or patrol effort, supporting the study of activities and interactions (e.g., chimpanzee tool use, geophagy or crop feeding), rapid alerts (e.g., snared or injured animals, human presence in sensitive zones or crop-feeding by chimpanzees and baboons) and longer-term ecological analyses (e.g., elephant phenotype and hybridization (Bonnald *et al.* 2023), seasonal edge use, activity timing and chimpanzee community composition).

Since 2013, SCP has deployed camera traps across more than 200 distinct sampling locations (“stations”) within the Sebitoli study area and its forest-agriculture boundary, generating 193,370

videos. These stations represent successive deployment locations rather than cameras operating simultaneously; the programme currently runs 41 camera-traps with protocols addressing complementary goals such as: (i) monitoring chimpanzee health and behaviour inside the forest; (ii) recording other primate activity at community borders and resource hotspots; (iii) assessing terrestrial mammal community inventory; (iv) monitoring crop feeding intrusions at the edge of Kibale NP (Figure 1); (v) conducting short-term targeted deployments to investigate specific questions or periods (Krief *et al.* 2020b).

Importantly, SCP treats CT and AI as complementary tools embedded in human expertise. Local knowledge guides where the cameras are placed, how detections are interpreted in context (seasonality, crop cycles, patrol history), and which results are action-relevant. Our team is currently evaluating how best to combine CT outputs with other remote sensing methods and local knowledge to improve biodiversity and threat monitoring across scales (ongoing research).

Below, we summarise the operational SCP camera-trap workflow (Figure 2) that is detailed in *Camera Trap Project Manual: Wildlife Monitoring in African Tropical Forests with DeepForestVision*. Several camera-trap initiatives have already provided valuable protocols and resources for biodiversity assessment in African forests, including work associated with long-term great ape research

sites (e.g., Morgan *et al.* 2024 and the associated *Visual Guide to Identifying Birds and Mammals with Camera Traps in Intact Forests* available at <https://wustl.app.box.com/s/14nqkpymh8tqwrqd7czw0c9czk6ogiow>). The workflow presented here is intended to complement these resources by linking field deployment with standardized data stewardship, offline AI-assisted classification, documented quality control and an explicit feedback pathway from camera-trap detections to research and conservation action.

A FIELD-READY WORKFLOW: FROM DESIGN TO CONSERVATION ACTION

The SCP CT workflow comprises eight linked steps spanning three broad phases: (1) co-design and deployment; (2) field operations and data stewardship; and (3) offline AI-assisted labelling with documented quality control, analysis and conservation feedback (Figure 2). Standardization reduces data loss and improves comparability across seasons and with other research sites, while flexibility allows protocols to address specific research and conservation questions.

1. **Co-design with local knowledge.** In SCP, CT protocols are defined jointly by researchers and field staff around concrete questions (e.g., community composition, spatial overlap with human activity, seasonal use of edges, and



Figure 1. Chimpanzees crop-feeding at the edge of Kibale National Park. Image extracted from CT (©SCP).

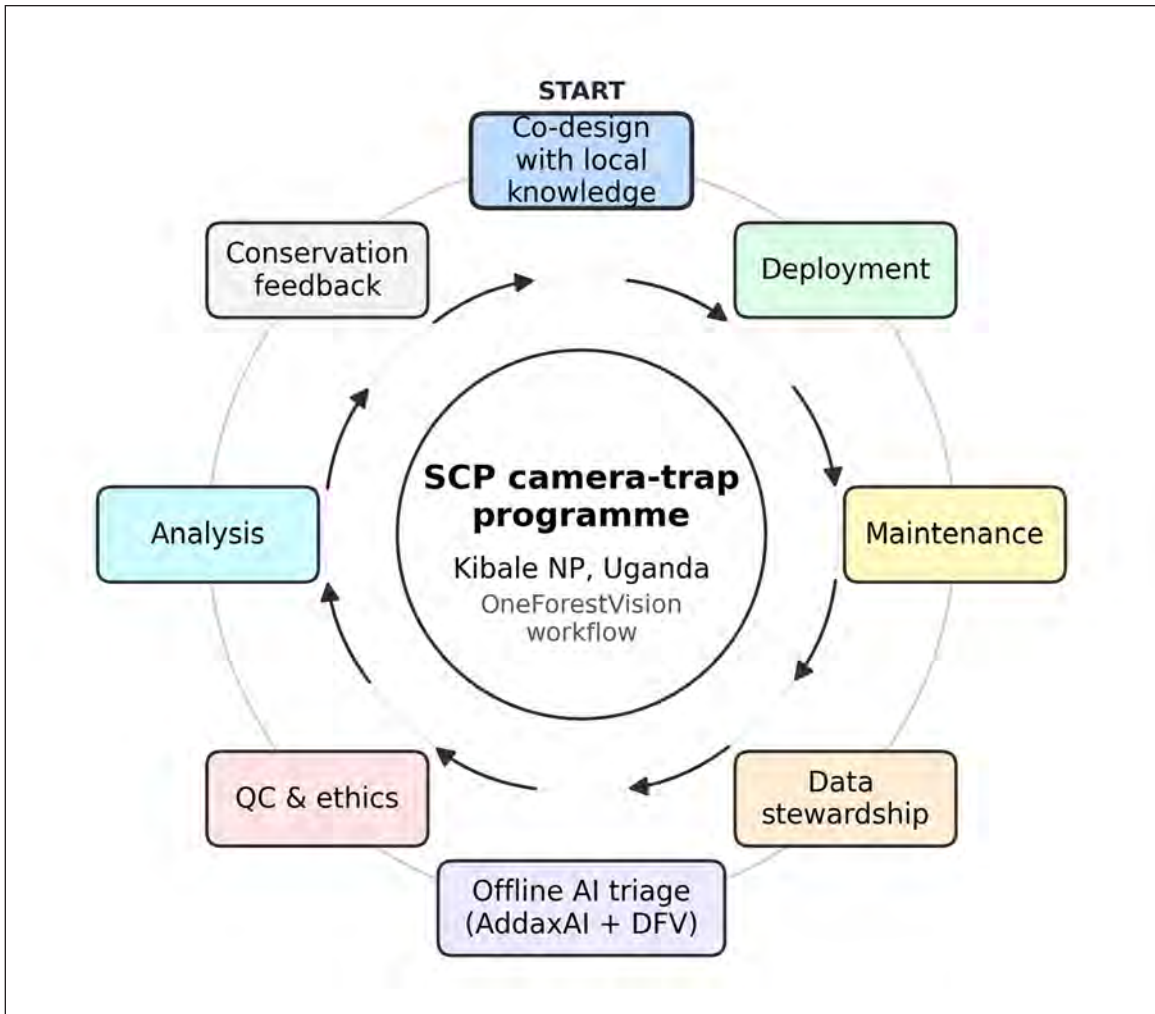


Figure 2. Workflow used by the SCP camera-trap programme, from co-designed field deployment to offline AI triage with DeepForestVision (DFV), quality control (QC), and conservation feedback.

detection of rare or cryptic taxa). Local ecological knowledge is central at this step: trackers and assistants interpret signs, trail networks, and seasonal resource distributions that cannot be inferred from maps alone. This framing helps ensure that CT and AI outputs support decisions and hypotheses relevant to the site, rather than generating unprioritized data accumulation.

2. **Deployment.** Cameras are placed on trails, resource hotspots, and (optionally) vertical stratification. At SCP, cameras are currently deployed at ground level, prioritising locations selected with local ecological knowledge (e.g., established wildlife trails and resource hotspots such as water points, geophagy sites and mineral lick sites) (Figure 3). This station placement strategy increases encounter rates and can also record some typically arboreal primates when they descend to the ground or move through

the understorey near hotspots. Arboreal camera-trapping remains a promising complementary option for reducing detection bias against arboreal taxa and documenting canopy use (Moore *et al.* 2020, 2021). Where safe access and permits allow, we recommend piloting a limited set of elevated units alongside the ground network and documenting height, orientation, and canopy context for each station.

3. **Maintenance.** In humid forest conditions, routine checks are the main safeguard against silent failures. In the current standardized SCP biodiversity-monitoring protocol, camera traps are visited weekly to retrieve data, replace batteries as required, verify camera alignment and functioning, and clear vegetation or other obstacles from the detection zone. Visit frequency can be adapted for other deployments according to battery autonomy, storage capacity, trigger



Figure 3. Camera-trap installation by Robert Asimwe. Photograph by Hugo Magaldi, ©SCP.

rate, accessibility, damage and theft risk, and the urgency of the monitoring objective. Small changes, e.g., new leaf growth, fallen branches, or near-field obstacles, can trigger constant “blank” recordings or cause infrared reflections that make night footage unusable, so teams do minimal vegetation trimming and basic cleaning of lenses and sensors. Clip counts and blank rates are reviewed to detect malfunctioning units early, and any unit showing repeated issues is repositioned or retrieved for inspection.

4. **Data stewardship.** Because most irreversible data loss occurs during copying or accidental overwriting, SCP uses a strict SD-card rotation and a simple, repeatable backup pipeline. SD cards are physically separated into “ready” versus “to copy,” and collected cards are locked and never reused until backups are verified. At

camp, files are copied into a consistent folder structure, transfer is checked (counts and spot-check viewing), then a second copy is created on a separate drive. Equipment and consumables (cameras, SDs, batteries, locks) are tracked with basic inventories so that each field batch remains traceable.

5. **Offline AI-assisted triage and labelling.** SCP uses AddaxAI (van Lunteren 2023) to run DeepForestVision (Magaldi *et al.* 2025, 2026a) offline, allowing teams to pre-sort blanks, prioritise clips for manual review and generate an initial label table with confidence scores. For videos, post-processing can summarise predictions across frames to produce one prediction per file.
6. **Quality control and ethics.** Deep learning outputs are hypotheses, not final identifications. SCP applies targeted QC focusing on low-confidence predictions, taxa of high conservation concern, and night imagery where glare and partial bodies can increase error. Where species-level identification is uncertain, higher-rank labels are used to avoid false precision. In landscapes like Kibale, where chimpanzees range near croplands and a road bisects habitat, CT stations may record people unintentionally. “Human bycatch” has ethical implications for privacy and trust, and requires explicit governance, restricted access and clear policies on storage, use and sharing (Sandbrook *et al.* 2021). Within SCP, human detections are handled with a precautionary approach: access is limited to authorised staff, and the corresponding data are kept private and are not used for research purposes.
7. **Analysis and reporting.** SCP uses camera-trap outputs at two time scales: rapid triage for operational decisions and longer-term analyses for research and conservation reporting. AI-assisted outputs help remove blanks, prioritise clips for manual review, and generate a standard label table that supports presence/absence summaries, activity patterns, and seasonal comparisons. In parallel, the team maintains a curated set of “special clips” for rapid internal reporting: rare or cryptic taxa, notable behaviours, and events relevant to threats or management.
8. **Conservation feedback.** Camera-trap monitoring is designed to feed back into conservation action and improved monitoring. Potentially urgent detections (e.g., illegal activities, injured animals, or sensitive events near the forest–farm interface) are flagged

rapidly and shared through the appropriate SCP and protected-area channels. Monitoring metrics (failure rates, blank rates, repeated misfires) are used to adjust placement, settings, visit frequency, and security measures, reducing avoidable data loss. Finally, identified weaknesses, such as recurring misclassifications or missing taxa, are logged and used to refine protocols and improve future AI-assisted workflows.

LIMITS AND PERSPECTIVES

Despite their value, camera-trap programmes have practical and ethical limits. In forest landscapes, cameras may be stolen, vandalised or destroyed, leading to gaps in sampling and replacement costs (Meek *et al.* 2019). CT placement and data handling also create information-security risks: location metadata and detections can be misused to target threatened fauna, and “human bycatch” raises privacy and trust concerns—both of which call for explicit governance, restricted access, and clear policies on storage and sharing (Sharma *et al.* 2020; Sandbrook *et al.* 2021). Logistically, CT networks require sustained supplies of batteries and, when rechargeable systems are used, reliable electricity for charging, and these constraints influence visit frequency and sampling design.

Rapid technical progress offers clear perspectives. Newer systems increasingly support wireless transmission and solar charging, improving autonomy and reducing battery dependence (Barros *et al.* 2024). In parallel, field-ready workflows are moving toward near real-time AI triage and alerting, which can shorten the time between detection and response (Whytock *et al.* 2023). Integrating CT with complementary sensors, particularly passive acoustic monitoring, can strengthen inference in dense vegetation by covering taxa and signals that cameras miss (Buxton *et al.* 2018). Finally, recent advances in animal re-identification (ReID) frameworks provide a route toward more robust individual identification for some species, opening possibilities for non-invasive demography and movement analyses, when combined with rigorous validation and local expertise (Wahlthine & Wahlthine 2024).

AVAILABILITY OF SUPPLEMENTARY MATERIAL

The Camera Trap Project Manual: Wildlife Monitoring in African Tropical Forests with DeepForestVision technical guide is available from the *African Primates* website (here).

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REFERENCES

- Barros, A.L., S. Alcobia, P. Gonçalves, D.I. MacKenzie & M. Santos-Reis. 2024. Assessment of technological developments for camera-traps: a wireless transmission system and solar panels. *Wildlife Society Bulletin* 48(1): e1506. <https://doi.org/10.1002/wsb.1506>
- Bonnald, J., R. Cornette, M. Pichard, E. Asalu & S. Krief. 2023. Phenotypical characterization of African savannah and forest elephants, with special emphasis on hybrids: the case of Kibale National Park, Uganda. *Oryx* 57(2): 188–195. <https://doi.org/10.1017/S0030605321001605>
- Bortolamiol, S., T. Feuillet, W. Kagoro, R. Namirembe, E. Asalu & S. Krief. 2023. Illegal harvesting within a protected area: spatial distribution of activities, social drivers of wild meat consumption, and wildlife conservation. *Animals* 13(5): 771. <https://doi.org/10.3390/ani13050771>
- Buxton, R.T., P.E. Lendrum, K.R. Crooks & G. Wittemyer. 2018. Pairing camera traps and acoustic recorders to monitor the ecological impact of human disturbance. *Global Ecology and Conservation* 16: e00493. <https://doi.org/10.1016/j.gecco.2018.e00493>
- Chapman, C.A., S.R. Balcomb, T.R. Gillespie, J.P. Skorupa & T.T. Struhsaker. 2000. Long-term effects of logging on African primate communities: a 28-year comparison from Kibale National Park, Uganda. *Conservation Biology* 14(1): 207–217. <https://doi.org/10.1046/j.1523-1739.2000.98592.x>
- Deneke, Y., A. Megaze, W. Tekalign, T. Dobamo & H. Leirs. 2024. Patterns of primates crop foraging and the impacts on incomes of smallholders across the mosaic agricultural landscape of Wolaita zone, southern Ethiopia. *PLOS ONE* 19(11): e0313831. <https://doi.org/10.1371/journal.pone.0313831>
- Edwards, W.I., V.D. Popescu, N. Guma, H. Agaba,

- G. Balyesiima, L. Nakami & N.J. Stevens. 2023. Living at the edge: home range patterns of the Buraiga Chimpanzee Community, Kibale National Park, Uganda. *Frontiers in Ecology and Evolution* 11: 1267688. <https://doi.org/10.3389/fevo.2023.1267688>
- FAO. 2025. Global Forest Resources Assessment 2025. Food and Agriculture Organization of the United Nations, Rome.
- Gilardi, K.V., T.R. Gillespie, F.H. Leendertz, E.J. Macfie, D.A. Travis, C.A. Whittier & E.A. Williamson. 2015. Best Practice Guidelines for Health Monitoring and Disease Control in Great Ape Populations. Occasional Paper of the IUCN Species Survival Commission No. 56. IUCN SSC Primate Specialist Group, Gland, Switzerland. <https://portals.iucn.org/library/sites/library/files/documents/ssc-op-056.pdf>
- IPBES. 2019. Global Assessment Report on Biodiversity and Ecosystem Services: Summary for Policymakers. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn.
- Kühl, H., F. Maisels, M. Ancrenaz & E.A. Williamson. 2008. Best Practice Guidelines for Surveys and Monitoring of Great Ape Populations. Occasional Paper of the IUCN Species Survival Commission No. 36. IUCN SSC Primate Specialist Group (PSG), Gland, Switzerland. 32 Pp.
- Krief, S., M. Cibot, S. Bortolamiol, A. Seguya, J.-M. Krief & S. Masi. 2014. Wild chimpanzees on the edge: nocturnal activities in croplands. *PLOS ONE* 9(10): e109925. <https://doi.org/10.1371/journal.pone.0109925>
- Krief, S., A. Iglesias-González, B.M.R. Appenzeller, J.P. Okimat, J.B. Fini, B. Demeneix, et al. 2020a. Road impact in a protected area with rich biodiversity: the case of the Sebitoli road in Kibale National Park, Uganda. *Environmental Science and Pollution Research* 27(22): 27914–27925. <https://doi.org/10.1007/s11356-020-09081-8>
- Krief, S., C. Couturier, J. Bonnald, J.P. Okimat, E. Asalu & J.-M. Krief. 2020b. COVID-19 and chimpanzees from a field perspective: mitigation measures, ecological and economical situation after four months in Sebitoli, Kibale National Park, Uganda. *Pan African News* 27(2): 16–20
- Lacroux, C., N. Guma & S. Krief. 2019. Facial dysplasia in wild forest olive baboons (*Papio anubis*) in Sebitoli, Kibale National Park, Uganda: use of camera traps to detect health defects. *Journal of Medical Primatology* 48(3): 143–153. <https://doi.org/10.1111/jmp.12399>
- Lacroux, C., B. Robira, N. Kane-Maguire, N. Guma & S. Krief. 2022. Between forest and croplands: nocturnal behavior in wild chimpanzees of Sebitoli, Kibale National Park, Uganda. *PLOS ONE* 17(5): e0268132. <https://doi.org/10.1371/journal.pone.0268132>
- Le Borgne, H. & C. Bouget. 2023. Suivis de biodiversité par la reconnaissance automatique des espèces sur photographies: perspectives et défis. *Naturae* 2023(6): 75–96. <https://doi.org/10.5852/naturae2023a6>
- Magaldi, H., R. Cornette, J.J. Tibesigwa, R. Katumba, H. Rugonge, B. Amarasekaran, N. Anderson, N. Cappelle, A.W. Cardoso, D. Cornélis, T. Deschner, D. Fonteyn, R.M. Garriga, P. van Lunteren, X. Rufay, H. Vanthomme, J.A. Zwerts & S. Krief. 2025. DeepForestVision: Automated wildlife identification for camera traps of African tropical forests. *Ecological Solutions and Evidence* 6(4): e70167. <https://doi.org/10.1002/2688-8319.70167>
- Magaldi, H., T. d'Audiffret, E.F. Akomo-Okoue, B. Amarasekaran, N. Anderson, C. Auger, N. Cappelle, D. Cornelis, R. Cornette, T. Deschner, G. Dubus, D. Fonteyn, R.M. Garriga, J. Hatlauf, I. Kasekendi, R. Katumba, A. Kazandjian, A. Ngomanda, S. Ntie, S. Pika, X. Rufay, H. Rugonge, J.J. Tibesigwa, P. van Lunteren, H. Vanthomme, J.A. Zwerts & S. Krief. 2026a. DeepForestVisionV2: Ecology-driven taxonomy expansion for camera-trap monitoring in African tropical forests. arXiv. <https://doi.org/10.48550/arXiv.2606.20223>
- Magaldi, H., G. Dubus, R. Katumba, H. Rugonge, I. Kasekendi, M. Allasonnière-Tang & S. Krief. 2026b. Bridging local ecological knowledge and remote sensing for wildlife assessment and conservation: insights from Sebitoli, Kibale National Park, Uganda. *Environments* 13(9): 496. <https://doi.org/10.3390/environments13090496>
- Magaldi, H., I. Kasekendi, R. Katumba, H. Rugonge, J.J. Tibesigwa & S. Krief. 2026c. Camera Trap Project Manual: Wildlife Monitoring in African Tropical Forests with DeepForestVision (Version v2). Zenodo. <https://doi.org/10.5281/zenodo.22709132>
- Malhi, Y., S. Adu-Bredu, R.A. Asare, S.L. Lewis & P. Mayaux. 2013. African rainforests: past, present and future. *Philosophical Transactions of the Royal Society B* 368(1625): 20120312. <https://doi.org/10.1098/rstb.2012.0312>
- McLennan, M.R., G.A. Lorenti, T. Sabiiti & M. Bardi. 2020. Forest fragments become farmland: dietary response of wild chimpanzees (*Pan troglodytes*) to fast-changing anthropogenic landscapes. *American Journal of Primatology* 82(4): e23090. <https://doi.org/10.1002/ajp.23090>
- McLennan, M.R., B. Hintz, V. Kiiza, J. Rohen, G.A. Lorenti & K.J. Hockings. 2021. Surviving at the extreme: chimpanzee ranging is not restricted in a deforested human-dominated landscape in Uganda. *African Journal of Ecology* 59(1): 17–28. <https://doi.org/10.1111/aje.12803>
- Meek, P.D., G. Ballard, J. Sparkes, M. Robinson, B. Nesbitt, P.J.S. Fleming, et al. 2019. Camera

- trap theft and vandalism: occurrence, cost, prevention and implications for wildlife research and management. *Remote Sensing in Ecology and Conservation* 5(2): 160–168. <https://doi.org/10.1002/rse2.96>
- Moore, J.F., W.E. Pine, F. Mulindahabi, P. Niyigaba, G. Gatorano, M.K. Masozera & L. Beaudrot. 2020. Comparison of species richness and detection between line transects, ground camera traps, and arboreal camera traps. *Animal Conservation* 23(5): 561–572. <https://doi.org/10.1111/acv.12569>
- Moore, J.F., K. Soanes, D. Balbuena, C. Beirne, M. Bowler, F. Carrasco-Rueda, et al. 2021. The potential and practice of arboreal camera trapping. *Methods in Ecology and Evolution* 12(10): 1768–1779. <https://doi.org/10.1111/2041-210X.13666>
- Morgan, D., S. Strindberg, P. McElmurray, A. Zambarda, I. Singono, S. Huskisson, S. Musgrave, C.E. Ayina, J. Funkhouser, H. Hellmuth, P. Joshi, R. Cassidy & C. Sanz. 2024. Extending the conservation impact of great ape research: flagship species sites facilitate biodiversity assessments and land preservation. *Primates* 65(6): 571–591. <https://doi.org/10.1007/s10329-023-01080-x>
- Mulero-Pázmány, M., S. Hurtado, C. Barba-González, M.L. Antequera-Gómez, F. Díaz-Ruiz, R. Real, et al. 2025. Addressing significant challenges for animal detection in camera trap images: a novel deep learning-based approach. *Scientific Reports* 15: 16191. <https://doi.org/10.1038/s41598-025-90249-z>
- Naughton-Treves, L., A. Treves, C. Chapman & R. Wrangham. 1998. Temporal patterns of crop-raiding by primates: linking food availability in croplands and adjacent forest. *Journal of Applied Ecology* 35(4): 596–606. <https://doi.org/10.1046/j.1365-2664.1998.3540596.x>
- OneForestVision. 2024. OneForestVision Initiative. <https://www.oneforestvision.org/eng>. Accessed on 26 February 2026
- Piel, A.K., A. Cruncheon, I.E. Knot, C. Chalmers, P. Fergus, M. Mulero-Pázmány, et al. 2022. Noninvasive technologies for primate conservation in the 21st century. *International Journal of Primatology* 43: 133–167. <https://doi.org/10.1007/s10764-021-00245-z>
- Pillay, R., M. Venter, J. Aragon-Osejo, P. González-del-Pliego, A.J. Hansen, J.E.M. Watson & O. Venter. 2022. Tropical forests are home to over half of the world's vertebrate species. *Frontiers in Ecology and the Environment* 20(1): 10–15. <https://doi.org/10.1002/fee.2420>
- Praill, L.C., T.M. Eppley, S. Shanee, et al. 2023. Road infrastructure and primate conservation: introducing the Global Primate Roadkill Database. *Animals* (Basel) 13(10): 1692. <https://doi.org/10.3390/ani13101692>
- Sandbrook, C., D. Clark, T. Toivonen, T. Simlai, S. O'Donnell, J. Cobbe & W.M. Adams. 2021. Principles for the socially responsible use of conservation monitoring technology and data. *Conservation Science and Practice* 3(5): e374. <https://doi.org/10.1111/csp2.374>
- Sebitoli Chimpanzee Project. 2025. Equipes de terrain. <https://sebitolichimpanzeeproject.com/le-projet/equipes-de-terrain/>. Accessed on 26 February 2026.
- Sharma, K., M. Fiechter, T. George, J. Young, J.S. Alexander, A. Bijoor, K. Suryawanshi & C. Mishra. 2020. Conservation and people: towards an ethical code of conduct for the use of camera traps in wildlife research. *Ecological Solutions and Evidence* 1(2): e12033. <https://doi.org/10.1002/2688-8319.12033>
- Thompson, M.E., M.N. Muller, Z.P. Machanda, E. Otali & R.W. Wrangham. 2020. The Kibale Chimpanzee Project: over thirty years of research, conservation, and change. *Biological Conservation* 252: 108857. <https://doi.org/10.1016/j.biocon.2020.108857>
- van Lunteren, P. 2023. AddaxAI: A no-code platform to train and deploy custom YOLOv5 object detection models. *Journal of Open Source Software* 8(88): 5581. <https://doi.org/10.21105/joss.05581>
- Wahlteine, O. & S.J. Wahlteine. 2024. An open-source general purpose machine learning framework for individual animal re-identification using few-shot learning. *Methods in Ecology and Evolution* 15(2): 373–387. <https://doi.org/10.1111/2041-210X.14278>
- Whytock, R.C., T. Suijten, T. van Deursen, J. Świeżewski, H. Mermiaghe, N. Madamba, N. Mouckoumou, J.A. Zwerts, A.F.K. Pambo, L. Bahaa-el-din, S. Brittain, D. Lehmann, C. Orbell, L.J.T. White & K.A. Abernethy. 2023. Real-time alerts from AI-enabled camera traps using the Iridium satellite network: a case-study in Gabon, Central Africa. *Methods in Ecology and Evolution* 14(3): 867–874. <https://doi.org/10.1111/2041-210X.14036>
- Worden, S., R. Fu, A.A. Bloom, et al. 2026. Congo Basin carbon cycle responses to global change. *Global Change Biology* 32(1): e70688. <https://doi.org/10.1111/gcb.70688>
- Zwerts, J.A., P.J. Stephenson, F. Maisels, M. Rowcliffe, C. Astaras, P.A. Jansen, J. van der Waarde, L.E.H.M. Sterck, P.A. Verweij, T. Bruce, S. Brittain & M. van Kuijk. 2021. Methods for wildlife monitoring in tropical forests: comparing human observations, camera traps, and passive acoustic sensors. *Conservation Science and Practice* 3: e568. <https://doi.org/10.1111/csp2.568>

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Obituary:

Jean-Pierre Gautier (1939 - 2024)

Un Hommage à Un Primatologue Français Pionnier

David Brugière

La primatologie française et mondiale a perdu un de ses plus éminents représentants avec la disparition le 23 septembre 2024 de Jean-Pierre Gautier, directeur de recherche au Centre National de la Recherche Scientifique (CNRS), France.

Né en 1939 à Fougères, en Bretagne, Jean-Pierre fait des études de biologie à l'Université de Rennes (France). En janvier 1965, il rejoint la Mission Biologique du Gabon (MBG) fondée l'année précédente à Makokou par le professeur Pierre-Paul Grassé. Son épouse, Dr. Annie Gautier-Hion était arrivé six mois plus tôt pour travailler sur le comportement de jeunes gorilles captifs, orphelins de la chasse. Quelque mois plus tard, cette colonie sera décimée par une épidémie de Yersinose, ce qui conduira Annie et Jean-Pierre à travailler sur les primates sauvages présents dans les forêts entourant la MBG. Leur première étude conjointe se focalise sur le plus petit primate diurne d'Afrique centrale, le talapoin (*Miopithecus talapoin*). Tandis qu'Annie étudie l'écologie de cette espèce (Gautier-Hion 1968, 1970), Jean-Pierre étudie ses vocalisations (Gautier 1974). Il étendit ensuite ces travaux sur la communication acoustique aux autres espèces de cercopithèques (Gautier 1969, 1971, 1973), un sujet totalement inédit à l'époque et qui constituera l'objet de sa thèse de doctorat soutenue à l'Université de Rennes (Gautier 1975).

Au fil du temps, de nombreux jeunes cercopithèques orphelins de la chasse sont recueillis à la MBG. C'est ainsi qu'une colonie captive de plusieurs espèces de cercopithèques se met progressivement en place. En 1960, le Gabon acquiert son indépendance et la MBG est placée sous la tutelle du Ministère gabonais en



Jean-Pierre Gautier

charge de la Recherche Scientifique. Elle devient l'Institut de Recherche en Ecologie Tropicale (IRET). En 1969, la colonie de Cercopithèques est transférée en France, à la Station Biologique de Paimpont (SBP), une annexe de l'Université de Rennes. Cette colonie, qui abritera jusqu'à 10 espèces de cercopithèques différentes, fera l'objet d'études comportementales par plusieurs générations d'étudiants français et étrangers.

Jean-Pierre continuera à travailler sur les vocalisations de cercopithèques sauvages et captifs en alternant les périodes de terrain à la MBG et de laboratoire à la SBP. Ces travaux donneront lieu à de nombreuses publications (Gautier 1978, 1983, 1985; Gautier & Gautier-Hion 1982, 1983, 1988). En 1985, il co-organise avec Annie Gautier-Hion à la SBP le premier colloque international sur les cercopithèques africains réunissant plus de 30 spécialistes internationaux de différentes disciplines (biogéographie, biologie évolutive, biologie moléculaire, éthologie, etc.). Un ouvrage de référence regroupant les contributions du colloque et incluant les illustrations de J. Kingdon sera publié en 1988 (Gautier-Hion *et al.* 1988).

En 1990, dans le cadre du Programme de Conservation des Forêts d'Afrique Centrale financé par l'Union Européenne, Jean-Pierre et Annie démarrent un programme de recherche dans le Parc National de la Salonga en République Démocratique du Congo. La situation politique les oblige à quitter le pays et à se réinstaller au Gabon. En 1986, une nouvelle espèce de cercopithèque forestier, le singe soleil (*Cercopithecus solatus*) est découverte dans la forêt des Abeilles (Harrison 1988), une zone très isolée

du centre Gabon et dont la faune et la flore n'ont jamais été étudiés. La forêt des Abeilles est alors entièrement incluse dans des concessions forestières. Annie et Jean-Pierre vont alors négocier avec une compagnie forestière la création du site de recherche dédiée à l'étude de la faune et de la flore ainsi qu'à l'étude de l'impact de l'exploitation forestière sur la biodiversité forestière: ce sera la Station de la Recherche de la Makandé (SRM) (Brugière & Gautier 1995). Montée en partenariat avec l'IRET et deux universités belges et financée en partie par l'Union Européenne, cette station accueillera pendant ses six années de fonctionnement (1991-



Dr. J-P. Gautier tracking radio-collared *Cercopithecus solatus* in the Forêt des Abeilles, Gabon, 1995.

1997) de nombreux étudiants et chercheurs gabonais et internationaux. Jean-Pierre assurera la direction de la Station. C'est à cette occasion, en 1993, que je fis la connaissance de Jean-Pierre et Annie, lorsqu'ils décidèrent de me confier une étude sur l'évaluation des densités de cercopithèques de la SRM. Cette collaboration, qui ne devrait durer que quelques mois, couvrira finalement sept années. Pendant cette période, Jean-Pierre travaillera à la SRM sur le singe soleil dont plusieurs spécimens furent capturés et équipés de collier émetteurs dont il assurera lui-même la fabrication (Gautier 1988; Gautier *et al.* 1992; Fleury & Gautier 1998; Brugière & Gautier 1999). Il équipera également plusieurs individus de colobe satan (*Colobus satanas*), une espèce mal connue à l'époque et qui fera l'objet d'une thèse de doctorat (Fleury 1998) et de plusieurs publications (Fleury & Gautier-Hion 1997, 1999)

La collaboration entre le CNRS et la compagnie forestière pour la gestion de la SRM se terminera début 1997. Jean-Pierre continuera à travailler ensuite sur l'exploitation des données de terrain acquises sur le singe soleil et sur les nombreux enregistrements sonores de vocalisation de cercopithèques. Il contribuera ainsi en 1999 à l'édition avec Annie

Gautier-Hion d'un ouvrage de référence sur les primates d'Afrique centrale dont il écrira le chapitre dédié aux vocalisations (Gautier-Hion *et al.* 1999). Cet ouvrage, magnifiquement illustré, inclura un CD permettant d'écouter les principales vocalisations de 20 espèces de primates du bassin du Congo.

Jean-Pierre prendra sa retraite du CNRS en 2000. Il continuera à travailler et échanger avec la communauté scientifiques sur son sujet de prédilection, la communication sonore des cercopithèques (Gautier *et al.* 2002). Sa dernière mission de terrain aura lieu au Gabon en 2010 où il fera partie d'une mission de recherche destinée à

retracer le parcours au XIX siècle de l'explorateur franco-américain Pau du Chaillu. Dans l'ouvrage qui présentera les résultats de cette mission, il écrira un article remarquable sur l'histoire de la découverte du gorille de plaine en Afrique centrale (Gautier 2007).

J'ai eu la chance de travailler avec Jean-pierre de 1993 à 2000, au Gabon à la SRM puis à la Station Biologie de Paimpont. Avec Annie il co-dirigea ma thèse sur les déterminants des densités de Cercopithèque en forêt tropicale présentée en 1998 à l'Université de Rennes. J'ai toujours été admirateur de l'immense culture scientifique et littéraire de Jean-pierre, son dynamisme, son humanisme et de son inaltérable sens de l'humour. Jean-Pierre faisait parti de ces chercheurs qui aiment partager leurs connaissances avec un sens unique de la narration et de la vulgarisation. Ses études pionnières sur la communication vocale des cercopithèques en milieu sauvage restent encore aujourd'hui un travail de référence dans le domaine de la bioacoustique.

J'espère que le vrombissement de la forêt tropicale et les vocalisations des primates d'Afrique qu'il a tant étudiées l'accompagnent là où il repose aujourd'hui.

La mémoire de Jean-Pierre Gautier se perpétue au travers de sa fille Nacha et sa petite-fille Axel.



French and global primatology lost one of its most eminent representatives with the passing on September 23, 2024, of Dr. Jean-Pierre Gautier, research director at the French National Center for Scientific Research (CNRS).

Born in 1939 in Fougères, Brittany, Jean-Pierre studied biology at the University of Rennes (France). In January 1965, he joined the Gabon Biological Mission (GBM), founded the previous year in Makokou by

Professor Pierre-Paul Grassé. His wife, Dr. Annie Gautier-Hion, had arrived six months earlier to work on the behavior of young captive gorillas orphaned by hunting. A few months later, this colony was decimated by an epizootic outbreak of Yersiniosis, which led Annie and Jean-Pierre to work on the wild primates present in the forests surrounding the GBM. Their first joint study focused on the smallest diurnal primate in Central Africa, the talapoin (*Miopithecus*

talapoin). While Annie studied the ecology of this species (Gautier-Hion 1968, 1970), Jean-Pierre studied its vocalizations (Gautier 1974). He then extended this work on acoustic communication to other species of Cercopithecine monkeys (Gautier 1969, 1971), a subject that was completely new at the time and which would form the subject of his doctoral thesis presented at the University of Rennes a few years later (Gautier 1975).

Over time, many young guenons orphaned by hunting were taken in by the GBM. This led to the gradual establishment of a captive colony of several species of Cercopithecines. In 1960, Gabon gained independence and the GBM was placed under the supervision of the Gabonese Ministry of Scientific Research. It became the Institute for Research in Tropical Ecology (IRET). In 1969, the primate colony was transferred to France, to the Paimpont Biological Station (PBS), an annex of the University of Rennes.

This colony, which would be home to up to 10 different species of guenons, would be the subject of behavioral studies by several generations of French and foreign students. Jean-Pierre continued to work on the vocalizations of wild and captive guenons, alternating between fieldwork at the GBM and laboratory work at the PBS. This work would result in numerous publications (Gautier, 1978, 1983, 1985; Gautier & Gautier-Hion 1982, 1983, 1988). In 1985, he co-organized with Annie Gautier-Hion at the SBP the first international symposium on African guenons, bringing together more than 30 international specialists from different disciplines (biogeography, evolutionary biology, molecular biology, ethology, etc.). A reference book, compiling the contributions of the symposium and including illustrations by Jonhatan Kingdon was published in 1988 (Gautier-Hion *et al.* 1988).

In 1990, as part of the Central African Forest Conservation Program funded by the European Union, Jean-Pierre and Annie launched a research program in the Salonga National Park, Democratic Republic of Congo. The political situation forced them to leave the country and resettle in Gabon. In 1986, a new species of forest monkey, the sun-tailed (*Cercopithecus solatus*), was discovered in the Forêt de Abeilles (Harrison 1988), a very isolated area in central Gabon where the fauna and flora had never been studied. The Forêt de Abeilles was then entirely included in forest

concessions. Annie and Jean-Pierre negotiated with a forestry company to create a research site dedicated to studying the fauna and flora and the impact of logging on forest biodiversity: this would be the Makandé Research Station (MRS) (Brugière & Gautier 1995).



Jean-Pierre Gautier and David Brugière, 2022.

Set up in partnership with IRET and two Belgian universities and partly funded by the European Union, this station welcomed many Gabonese and international students and researchers during its six years of operation (1991-1997). Jean-Pierre was appointed director of the station. It was on this occasion, in 1993, that I met Jean-Pierre and

Annie, when they decided to entrust me with a study to assess the density of Cercopithecines at the MRS. This collaboration, which was only supposed to last a few months, ultimately lasted seven years. During this period, Jean-Pierre worked at the MRS on the sun-tailed monkey, several specimens of which were captured and fitted with transmitter collars that he manufactured himself (Gautier *et al.* 1992; Fleury & Gautier 1998; Gautier 1998; Brugière & Gautier 1999). He also fitted several black-colobus monkeys (*Colobus satanas*), a species that was little known at the time and which would be the subject of a doctoral thesis (Fleury 1998) and several publications (Fleury & Gautier-Hion 1997, 1999).

The collaboration between the CNRS and the forestry company for the management of the MRS ended in early 1997. Jean-Pierre then continued to work on the exploitation of field data acquired on the sun-tailed monkey and on the numerous sound recordings of Cercopithecine vocalizations. In 1999, he contributed to the publication, with Annie Gautier-Hion, of a reference book on the primates of Central Africa, for which he wrote the chapter dedicated to vocalizations (Gautier-Hion *et al.* 1999). This beautifully illustrated book included a CD allowing listeners to hear the main vocalizations of 20 primate species from the Congo Basin.

Jean-Pierre retired from the CNRS in 2000. He continued to work and exchange ideas with the scientific community on his favorite subject, the vocal communication of guenons (Gautier *et al.* 2002). His last field mission took place in Gabon in 2010, where he was part of a research mission aimed at retracing the 19th-century journey of the Franco-American explorer Paul du Chaillu. In the book presenting the results of this mission, he wrote a remarkable article

on the history of the discovery of lowland gorillas in Central Africa (Gautier 2007).

I had the opportunity to work with Jean-Pierre from 1993 to 2000, in Gabon at the MRS and then at the Paimpont Biology Station. Together with Annie, he co-supervised my thesis on the determinants of Cercopithecine densities in tropical forests, which I presented in 1998 at University of Rennes. I have always admired Jean-Pierre's immense scientific and literary culture, his dynamism, his humanism, and his unwavering sense of humor. Jean-Pierre was one of those researchers who loved to share their knowledge with a unique sense of storytelling and popularization. His pioneering studies on the acoustic communication of Cercopithecines in the wild remain a reference work in the field of bioacoustics to this day.

I hope that the hum of the rainforest and the vocalizations of the African primates he studied so extensively accompany him where he now rests.

The memory of Jean-Pierre Gautier lives on through his daughter Nacha and his granddaughter Axel.

REFERENCES

- Brugière, D & J.-P. Gautier. 1995. *La station biologique de la Makandé, Forêt des Abeilles, Gabon*. *African Primates* 1: 54–56.
- Brugière, D. & J.-P. Gautier. 1999. Status and conservation of the sun-tailed guenon *Cercopithecus solatus*, Gabon's endemic guenon. *Oryx* 33: 67–74.
- Fleury, M.-C. 1998. *Ecologie et organisation sociale du colobe satan Colobus satanas*. Thèse de Doctorat, Université de Rennes, France.
- Fleury, M.-C. & J.-P. Gautier. 1998. *Adaptation au milieu naturel d'un jeune Cercopithecus solatus sauvage élevé à la main*. *Revue d'Ecologie* 53: 201–215.
- Fleury, M.-C. & A. Gautier-Hion. 1999. Seminomadic ranging in a population of black colobus (*Colobus satanas*) in Gabon and its ecological correlates. *International Journal of Primatology* 20: 491–509.
- Fleury, M.-C. & A. Gautier-Hion. 1997. Better to live with allogenerics than to live alone? The case of single male *Cercopithecus pogonias* in troops of *Colobus satanas*. *International Journal of Primatology* 18: 967–974.
- Gautier-Hion, A. 1968. *Etude du cycle annuel de reproduction du talapoin vivant dans son milieu naturel*. *Biologica Gabonica* 4: 163–173.
- Gautier-Hion, A. 1970. *L'organisation sociale d'une bande de talapoints (Miopithecus talapoin) dans le nord-est du Gabon*. *Folia Primatologica* 12: 116–141.
- Gautier-Hion, A., F. Bourlière, J.-P. Gautier & J. Kingdon. 1988. *A Primate Radiation. Evolutionary Biology of the African Guenons*. Cambridge University Press, Cambridge.
- Gautier-Hion, A., M. Colin & J.-P. Gautier. 1999. *Histoire naturelle des primates d'Afrique centrale*. Ecofac, Libreville, Gabon.
- Gautier J.-P. 1969. *Emissions sonores d'espace et de ralliement par deux cercopithèques arboricoles*. *Biologica Gabonica* 5: 117–145.
- Gautier J.-P. 1971. *Etude morphologique et fonctionnelle des annexes extralaryngées des Cercopithecinae: liaison avec les cris d'espace*. *Biologica Gabonica* 7: 229–267.
- Gautier J.-P. 1974. Field and laboratory studies of the vocalizations of talapoin monkeys (*Miopithecus talapoin*). *Behaviour* 49: 1–64.
- Gautier J.-P. 1975. *Etude comparée des systèmes d'intercommunication sonore des Cercopithecidae forestiers africains*. Thèse de doctorat, Université de Rennes, France.
- Gautier J.-P. 1978. *Répertoire sonore de Cercopithecus cephus*. *Zeitschrift für Tierpsychologie* 46: 113–169.
- Gautier J.-P. 1983. *Comportement vocal des mâles adultes et organisation supraspécifique dans les troupes polyspécifiques de cercopithèques*. *Folia Primatologica* 40: 161–74.
- Gautier J.-P. 1985. *Quelques caractéristiques écologiques du singe des marais: Allenopithecus nigroviridis Lang 1923*. *Revue d'Écologie* 40: 331–342.
- Gautier, J.-P. 1998. Socioecological features of the sun-tailed monkey (abstract). Proceedings of the XVII International Primatological Society Congress, Antananarivo, Madagascar.
- Gautier, J.-P. 2007. *A la recherche des gorilles. In Coeur d'Afrique. Gorilles, cannibales et Pygmées dans le Gabon de Paul Du Chaillu*. J.-M. Hombert & L. Perrois, eds. CNRS Editions, Paris. Pp. 64–83.
- Gautier, J.P. & A. Gautier-Hion. 1982. Vocal communication within a monkey group: an exhaustive analysis by biotelemetry. In *Primate Communication*. C.T. Snowdon & M.R. Petersen, eds. Cambridge University Press, Cambridge. Pp. 5–29.
- Gautier, J.P. & A. Gautier-Hion. 1983. *Comportement des mâles adultes et organisation supraspécifique dans les troupes polyspécifiques de Cercopithèques*. *Folia Primatologica* 40: 161–174.
- Gautier, J.P. & A. Gautier-Hion, A. 1988. Vocal quavering: a basis for recognition in forest guenons. In: *Primate Vocal Communication*. D. Todt, P. Goedeke, & D. Symmes, eds. Springer, Berlin. Pp. 37–42.
- Gautier, J.P., F. Moysan, A. Feistner, J.N. Loireau & R. Cooper. 1992. The distribution of *Cercopithecus (lhoesti) solatus*, an endemic guenon of Gabon. *Revue d'Ecologie* 47: 367–381.
- Gautier, J.P., R. Vercauteren Drubbel & P. Deleporte. 2002. Phylogeny of the *Cercopithecus lhoesti* group revisited: combining multiple character sets. In *The Guenons: Diversity and Adaptation in African Monkeys*. M.E. Glenn & M. Cords, eds. Springer, Boston. Pp. 37–59.
- Harrison, M. 1988. A new species of guenon (genus *Cercopithecus*) from Gabon. *Journal of Zoology* 215: 561–575.

Obituary:

Jane Goodall (1934 - 2025)

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Jane Goodall passed away on October 1, 2025. Many tributes have chronicled her extraordinary life: her pioneering work with wild chimpanzees in Gombe National Park, Tanzania, and her later emergence as a global advocate for animals, people, and the planet. Here, we write as three scientists currently working at Gombe to reflect specifically on Jane's scientific legacy from the perspectives of our research foci on chimpanzee behavior, development and health.

The origins of Jane's scholarly journey are now well known. A young woman who grew up loving animals dreamed of living among them in Africa. After working as a secretary to save money for passage, she arrived in Kenya and soon met the paleontologist Louis Leakey. Leakey believed that studying living great apes was essential to understanding early human behavior. Undeterred by Jane's lack of formal scientific training, he saw her as a careful observer unencumbered by disciplinary dogma. On July 14, 1960, she arrived at Gombe.

Within months, Jane observed the chimpanzee David Greybeard stripping leaves from a twig and using it to fish for termites—a discovery so significant that it secured long-term funding for the project and provoked a reassessment of what defined humans as separate from other animals. What began as a modest field study became the longest-running observational study of great apes in the wild. Over the decades, Jane reshaped not only how we study animals, but how we understand ourselves.

One of Jane's earliest and most enduring contributions was her insistence on recognizing chimpanzees as individuals. She named them. She described their personalities. She spoke of their histories, relationships, thoughts, and emotions. At



Jane Goodall (Photo by B. Wallauer).

the time, many scientists criticized this approach, preferring numbered subjects and strict emotional distance. Yet Jane understood that individual variation mattered—that life histories, social bonds, and personal temperaments would shape outcomes across the lifespan. By highlighting individuality, she reframed the kinds of questions we ask about behavior, development, and success in both chimpanzees and humans.

Equally transformative was the development of the all-day focal follow system known as the “B-record”. Early observations were necessarily opportunistic. As the project expanded, Jane recognized that understanding chimpanzee lives required systematic, day-long follows of identified individuals. By the early 1970s, trained Tanzanian field assistants from villages surrounding the park were conducting full-day focal follows, recording party composition and location at regular intervals and documenting feeding, grooming, mating, aggression, and rare but consequential events in detailed narrative notes.

From 1974 onward, the B-record became the backbone of data collection at Gombe. Remarkably, the protocol remains essentially unchanged today thanks to the sustained efforts of The Jane Goodall Institute's Gombe Stream Research Center. That methodological continuity—across decades, observers, and generations of chimpanzees—has produced one of the most powerful longitudinal behavioral datasets in the world. The B-record transformed description into quantification. Researchers calculated rates of aggression, mating, hunting, and grooming; constructed dominance hierarchies; and tracked shifting alliances. Because the methods have remained consistent, patterns documented in the 1970s can be directly compared with those observed in the 2020s. Nearly every long-term chimpanzee research site now employs some version of the all-day focal follow, a testament to Jane's influence on field primatology.

In the mid-1970s, once the B-record was firmly established, Jane initiated another long-term dataset centered on family relationships. Fascinated by maternal care and sibling dynamics, she began systematic observations of mothers, infants, and juveniles. That work continues today and we are now observing the fifth generation of Gombe matriline. Through detailed behavioral data collection on mothers and offspring, we can examine how the experiences of infants and juveniles are manifested in adulthood. Because of the remarkable depth of the study, we can ask new questions about how family characteristics and experiences become embedded across generations.

Integrating knowledge from both long-term behavioral datasets, our scope is now the full chimpanzee lifespan. We know that strong social bonds profoundly shape life trajectories and reproductive success. We know that early trauma—such as maternal loss—shortens lifespan even when it occurs after nutritional independence. We are currently investigating how aging unfolds, and how

social and physiological processes intertwine as individuals grow old. Over time, genetic, hormonal, demographic, geospatial, and epidemiological data were layered onto this behavioral foundation. Each innovation built directly on thousands of painstakingly collected daily follows.

While Jane's foresight in initiating long-term, systematic, individually based datasets transformed how we understand chimpanzee behavior, her later vision expanded the scope of inquiry far beyond. Long before "One Health" and "Planetary Health" became widely adopted frameworks, she recognized that the fates of chimpanzees, forests, and people were inseparable. At Gombe, she saw clearly that conservation could not succeed without attention to human well-being, and that human health could not be protected without safeguarding ecosystems.

Through the Jane Goodall Institute's Tacare approach, she championed community-led conservation, strengthening local health systems and environmental stewardship in villages surrounding Gombe. She understood that



Jane Goodall through the years.



Top photo by H. van Lawick; bottom photo by T. Pickering.
All photographs courtesy of the Jane Goodall Institute.

reducing deforestation, improving sanitation, and expanding access to healthcare were not peripheral to conservation—they were central to it. Her leadership lent moral authority and global visibility to the integration of wildlife health monitoring, public health outreach, and sustainable land use.

Her support was also pivotal in advancing the Gombe Ecosystem Health Project. Over the past two decades, this initiative has integrated field-based disease monitoring with in-country laboratory enhancements, expanding diagnostic

and pathogen surveillance capacity. By establishing sustainable laboratory infrastructure, training in-country personnel in molecular diagnostics, and implementing standardized workflows, the project has improved both response capacity and data comparability. The development of on-site pathology now enables real-time health assessments and rapid responses to emerging disease threats. These efforts have enhanced our ability to assess risks at the human–wildlife interface and protect both chimpanzees and surrounding communities.

Today, this work has expanded into the Gombe One Health Hub, a collaboration between The Jane Goodall Institute and multiple partners which integrates long-term behavioral records with pathogen surveillance, biodiversity monitoring, habitat data, and human land-use information within a unified geospatial framework. In this model, Jane's conviction that compassion and science are inseparable finds operational form. Her insight—that caring for chimpanzees, forests, and people must occur together—helped lay the intellectual and ethical foundation for modern One Health and Planetary Health science.

Finally, Jane's influence cannot be measured solely in datasets or frameworks. The long-term protocols at Gombe have depended on—and empowered—generations of Tanzanian researchers. Their skill, dedication, and intimate knowledge of individual chimpanzees sustained the study through political change, logistical hardship, and the passage of time. Jane recognized that this extraordinary record is as much their achievement as her own. She also transformed who could imagine themselves as scientists. For young girls and women around the world, Jane embodied the possibility of a life spent asking bold questions in wild places. Her presence expanded the boundaries of belonging in science.

Jane did not simply teach us to see chimpanzees differently. She built a system that allowed us to keep seeing—carefully, systematically, and across generations. She created the intellectual and institutional infrastructure through which behavioral science, conservation biology, and global health could converge. And she fostered a scientific community that continues to grow, adapt, and ask new questions rooted in the foundations she laid.

Announcements

Mission Statement

The SHPI is an interdisciplinary group that aims to understand the complex nature of human–primate interactions. We provide conservation practitioners with tools to manage interactions to minimise negative exchanges and promote coexistence in landscapes of increasingly rapid change.



IUCN SSC PRIMATES
**SECTION ON
HUMAN-PRIMATE
INTERACTIONS**

HUMAN-PRIMATE-INTERACTIONS.ORG



Responsible Primate-Watching
for Primate Tourism Professionals



Responsible Primate-Watching
for Tourists



by Chloe Chesney

Best Practice Guidelines

Responsible images of primates

Reading List

Ethnography, inclusivity and ethics in conservation

Position Statements

Human provisioning of primates
Primate consumption for wild meat
Primates in agroecosystems
The use of primates in biomedical research

Recommendations for Responsible Primate Tourism

Documents for (1) tourists, (2) tourism professionals and (3) case studies

Advice for Conservation Practitioners

Unregulated human provisioning of primates

COMING SOON...

Recommendations for the construction and maintenance of canopy bridges for primates

ARTIS
AMSTERDAM
ROYAL ZOO



Announcements

New IUCN Best Practice Guidance to Protect Great Ape Population Health

IUCN SSC Primate Specialist Group, Section on Great Apes

Across their range, great apes are severely threatened by habitat loss, poaching, disease and the impacts of climate change, with all 14 great ape taxa classified as Endangered or Critically Endangered on the IUCN Red List of Threatened Species (IUCN 2026). Anthropogenic pressures drive great ape population declines and as humans encroach further into their habitats, closer proximity and more frequent overlap between humans and great apes occur, increasing opportunities for disease transmission. In parallel, interest in great ape tourism continues to increase and, while this should serve as an important tool to support conservation, tourism can also elevate the risks of disease transmission if not adequately managed. As our closest genetic relatives, great apes are highly vulnerable to human diseases, many of which do not naturally occur in wild great apes. It is therefore critical to ensure that disease mitigation strategies are strictly implemented.

To support those working to conserve great apes, including protected area authorities, conservation practitioners, scientists, researchers, and others working in or close to great ape habitat, the first guidelines dedicated to great ape health were published by the International Union for Conservation of Nature (IUCN) in 2015 (Gilardi *et al.* 2015). This open access publication provides detailed recommendations for disease prevention, and health monitoring, and remains highly relevant today. Since then, a great deal of new scientific research on diseases—viruses, bacteria, and parasites—that impact great apes has been published, new diagnostic tools developed, and real-world disease outbreaks experienced, including the global COVID-19 pandemic and Ebola in West Africa and in eastern Democratic Republic of the Congo. A synthesis of critical new information to aid practitioners in managing health in great ape populations is now available in a new supplement (Gilardi *et al.* 2025), which can be downloaded from the IUCN website and the African Primates' website (here).



[Click to download the supplement](#)

REFERENCES

- Gilardi, K.V., Gillespie, T.R., Leendertz, F.H., Macfie, E.J., Travis, D.A., Whittier, C.A. & Williamson, E.A. (2015). *Best Practice Guidelines for Health Monitoring and Disease Control in Great Ape Populations*. Gland, Switzerland: IUCN SSC Primate Specialist Group. <https://doi.org/10.2305/IUCN.CH.2015.SSC-OP.56.en>
- Gilardi, K.V., Düx, A., Gillespie, T.R., Kalema-Zikusoka, G., Leendertz, F., Nze-Nkogue, C., Patrono, L.V., Raphael, J., Sulistyo, F., Syaluha, E.K. & Whittier, C. (2025). *An Update on Great Ape Population Health, Disease Control and Outbreak Response. Supplement to the Best Practice Guidelines for Health Monitoring and Disease Control in Great Ape Populations*. Sunderland-Groves, J.L., Williamson, E.A. & Macfie, E.J. (eds.). Gland, Switzerland: IUCN SSC Primate Specialist Group. 31 pp. <https://doi.org/10.2305/JEPK4717>
- IUCN. 2026. *The IUCN Red List of Threatened Species*. Version 2026-2. <https://www.iucnredlist.org>

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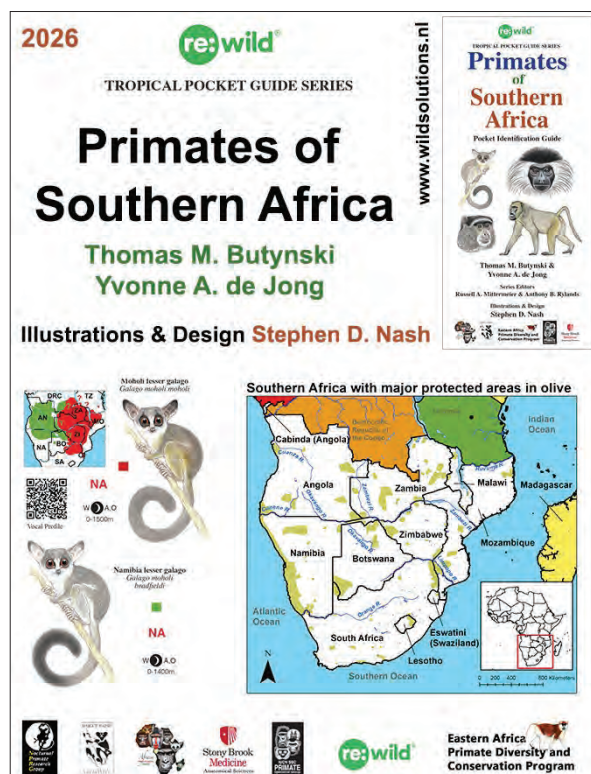
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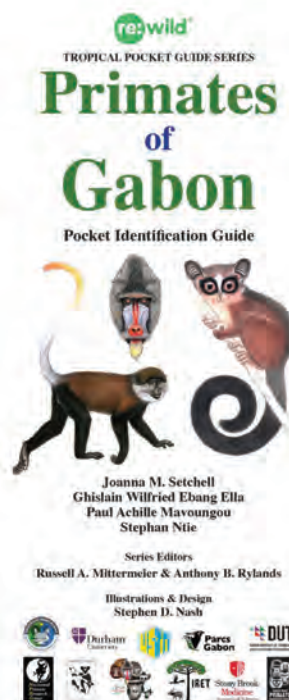
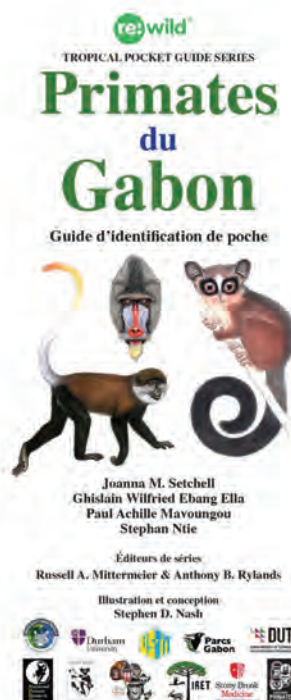
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Announcements



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Connections: E-News, Web Sites, and Social Media

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 YouTube: www.youtube.com/AfricanWildlife

Amboseli Baboon Research Project

Website: www.amboselibaboons.nd.edu
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 Bluesky: amboselibaboonrnp.bsky.social

Barbary Macaque Awareness and Conservation

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Chimpanzee Sanctuary & Wildlife Conservation Trust (Ngamba Island)

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 Instagram: instagram.com/colobusconservation
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Comoé Monkey Project

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Conservation through Public Health

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Website: www.gracegorillas.org
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Goulougo Triangle Ape Project

Website: www.congo-apes.org/
 Facebook: facebook.com/Goulougo-Triangle-Ape-Project-282194681876/
 YouTube: youtube.com/user/Goulougo

Great Ape Survival Partnership (GRASP)

Website: www.un-grasp.org
 Facebook: facebook.com/graspunep?ref=stream
 X/Twitter: twitter.com/graspunep

Greater Mahale Ecosystem Research and Conservation

Website: www.gmerc.org
 YouTube: youtube.com/user/UgallaSokwe
 Instagram: instagram.com/gmerc/

Guenon Conservation Community

Facebook: facebook.com/GuenonConservationCommunity

HELP Congo (Chimpanzee Sanctuary)

Website: www.help-primates.org/
 Instagram: instagram.com/help.congo/
 Facebook: facebook.com/helpcongobeaualnature

International Gorilla Conservation Programme

Website: www.igcp.org
 Facebook: facebook.com/theIGCP
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International Primate Protection League

Website: www.ippl.org
 Facebook: facebook.com/InternationalPrimateProtectionLeague
 X/Twitter: twitter.com/ipplprimate
 Instagram: instagram.com/ipplsummersville/
 Threads: threads.com/@ipplsummersville

International Primatological Society – Conservation

Website: <https://internationalprimatologicalsociety.org/#StartView>
 Bluesky: ips-primatenews.bsky.social

IUCN SSC Primate Specialist Group Section for Human-Primate Interactions

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 Blog: <https://kibalechimpanzees.wordpress.com/>

Kyambura Gorge Chimpanzee Community

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La Société Francophone de Primatologie – SFDPP

X/Twitter: twitter.com/LaSFDP
 Bluesky: lasfdp.bsky.social

Le Projet Gorille Fernan-Vaz (Gabon)

Website: www.gorillasgabon.org/
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 Bluesky: [@limbewildlife.bsky.social](https://limbewildlife.bsky.social)

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Lwiro Sanctuary

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Mandrillus Project

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African Primates, a journal of the IUCN SSC Primate Specialist Group, publishes research articles, field reports, review articles, position papers, book reviews, and other news focused on the nonhuman primates of Africa. We welcome submissions focused on behavior, ecology, taxonomy, or conservation. The journal is produced in both print and digital versions and is provided free of charge. The aim of *African Primates* is to promote conservation of Africa's primates by:

- 1) enhancing interest in Africa's primates and increasing knowledge about them that is relevant to their survival;
- 2) transmitting information about factors and situations that promote or work against conservation of African primate species or populations; and
- 3) providing a forum for discussion and debate regarding all aspects of knowledge relevant to conserving Africa's primate fauna and their habitats.

African Primates encourages submission of relevant information in the form of research findings, field survey results, advances in field and laboratory techniques, field action alerts, and book reviews, as well as notification of events, funding opportunities, grassroots efforts such as letter-writing campaigns, and recent publications in other formats (including reports and theses). All submissions should be sent to the Editor-in-Chief; research articles will be peer-reviewed before acceptance for publication. Contributors may consult past issues of *African Primates* for stylistic guidance. (Previous volumes are accessible through the PSG website. See http://www.primates-sg.org/african_primates/.)

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- Use metric units only and define all abbreviations.
- Current taxonomic classifications should be used. If species or subspecies' names have undergone recent revision, please include mention of recent names as a service to readers adjusting to new naming conventions.
- Tables, figures, and photographs are encouraged. All require accurate and concise captions listed on a separate sheet.
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- References should be provided in an alphabetical list and conform to the format used in previous issues of *African Primates*. Examples are shown below.
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Groves, C.P. 2001. *Primate Taxonomy*. Smithsonian Institution Press, Washington, D.C.

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Book Chapter:

Eniang, E.A. 2003. Effects of habitat fragmentation on the Cross River gorilla (*Gorilla gorilla diehli*): Recommendations for conservation. In *Primates in Fragments: Ecology and Conservation*. L.K. Marsh, ed. Kluwer Academic/Plenum Publishers, New York. Pp. 343–363.

Unpublished Report:

Hearn, G.W., W.A. Morra, M.A. Ela Mba & C. Posa Bohome. 2001. The approaching extinction of monkeys and duikers on Bioko Island, Equatorial Guinea, Africa. Unpublished report of the Bioko Biodiversity Protection Program, Arcadia University, Glenside PA.

Government Document:

Ministry of Environment and Natural Resources. 1994. *The Kenya National Environment Action Plan (NEAP)*. Ministry of Environment and Natural Resources, Nairobi, Kenya.

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African Primates, Editor-in-Chief
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African Primates

A Journal of the IUCN SSC Primate Specialist Group Africa Section
Volume 20 2026



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