

Revisiting the Second Largest Forest of Guinea a Decade Later: Conservation Status, Chimpanzee Presence, and Threats in Diécké, Korohouan Area

Katarina Almeida-Warren^{1,2}, Henry Didier Camara³, Paquilé Cherif^{3†}, Jules Doré³, Pascal Goumy³, Justin Kpomi⁴, Cê Koti Mamy^{4†}, Clement Mamy⁴, Boniface Zogbila³, Susana Carvalho^{1,2,5}, and Maegan Fitzgerald⁶

¹ Primate Models for Behavioural Evolution Lab, Institute of Human Sciences, University of Oxford, Oxford, UK; ² Interdisciplinary Center for Archaeology and Evolution of Human Behaviour, Universidade do Algarve, Faro, Portugal; ³ Institut de Recherche Environnementale de Bossou, Bossou, Republic of Guinea; ⁴ Korohouan Village, Diécké, Republic of Guinea; ⁵ Department of Scientific Services, Gorongosa National Park, Sofala, Mozambique; ⁶ Re:wild, Austin, TX, USA; [†] Deceased

Abstract: The Diécké Forest is the second largest classified forest in Guinea and is an area of high conservation significance for many species including the western chimpanzee, *Pan troglodytes verus*. It has attracted several research expeditions focusing on chimpanzee presence and tool use since 1993. These studies also identified several instances of human activities impacting primates and other wildlife. Aside from Bossou, Diécké is the only other locality in Guinea where chimpanzees are known to crack nuts with tools. We visited the Diécké Forest in November 2018 to review the status of chimpanzee presence, nut-cracking activity, and conservation threats. We report our findings along with an up-to-date overview of relevant historical, socio-political, environmental, and scientific developments in the vicinity. Our survey took place in the vicinity of Korohouan village where research on chimpanzee nut-cracking had previously been conducted. We found scarce evidence of chimpanzee presence in the area (n = 3) with no recent traces of nut-cracking or other activities. Conversely, we found a high incidence of hunting (6.31/km) within the protected area, with small-scale agriculture and commercial activities predominating forest fragments outside the protected area. The intensification of human activities in Diécké pose a serious threat to one of the largest remaining lowland evergreen forests of West Africa and the endangered species that inhabit it, such as the Western chimpanzee. Our study highlights the need for urgent and concerted conservation action and provides an important case study on the disappearing cultural heritage of a chimpanzee population in a human-impacted habitat.

Key words: anthropogenic disturbance; chimpanzee; conservation; habitat fragmentation; human activity; nut-cracking; population decline

Résumé: La forêt de Diécké est la deuxième plus grande forêt classée de Guinée et constitue une zone de haute importance pour la conservation de nombreuses espèces, y compris le chimpanzé de l'Ouest, *Pan troglodytes verus*. Hormis Bossou, Diécké est le seul autre endroit de Guinée où les chimpanzés sont connus pour concasser des noix avec des outils. Plusieurs expéditions de recherche axées sur la présence des chimpanzés et l'utilisation d'outils ont eu lieu depuis 1993 jusqu'en 2011. Ces études ayant également identifié plusieurs cas d'activités humaines qui ayant un impact sur les primates et d'autres animaux sauvages. Nous avons visité la forêt de Diécké en novembre 2018 pour examiner l'état de la présence des chimpanzés, l'activité de concassage de noix et les menaces pour la conservation. Nous accompagnons nos découvertes d'un aperçu des derniers développements historiques, sociopolitiques, environnementaux et scientifiques dans la région. Notre enquête a eu lieu près du village de Korohouan où des recherches sur le concassage des noix par les chimpanzés avaient déjà été menées. Nous avons trouvé seulement 3 preuves de la présence de chimpanzés, mais aucune trace récente de concassage

de noix ou d'autres activités. Bien au contraire, nous avons enregistré une incidence élevée de chasse (6,31/km) dans la zone protégée, et une prédominance de l'agriculture à petite échelle et des activités commerciales dans les fragments forestiers autour de la zone protégée. L'intensification des activités humaines à Diécké constitue une menace sérieuse pour l'une des plus grandes forêts sempervirentes d'Afrique de l'Ouest et pour les espèces menacées qui y habitent, comme le chimpanzé de l'Ouest. Notre étude souligne la nécessité d'une action concertée de conservation urgente et fournit une étude de cas importante sur la disparition du patrimoine culturel d'une population de chimpanzés dans un habitat anthropique.

Mots clés: *perturbation anthropique; chimpanzé; conservation; fragmentation de l'habitat; activité humaine; concassage des noix; déclin de la population*

INTRODUCTION

The Diécké Forest in Guinea was first recognized as an important area for studies of chimpanzee culture following a nationwide chimpanzee and large mammal census in the late 1990s, which found evidence of chimpanzee nut-cracking activities alongside other indirect traces of chimpanzee presence (Ham 1998). Subsequent research focusing on chimpanzee tool use revealed that the techno-cultural traditions of Diécké chimpanzees differed from that of the nearby long-term field site of Bossou, establishing Diécké as a locality of interest for comparative research on chimpanzee technology and culture (Matsuzawa *et al.* 1999; Humle & Matsuzawa 2001; Carvalho *et al.* 2007, 2008; Carvalho 2011).

Despite these promising beginnings, partly due to a period of political instability and the 2013 Ebola outbreak, research on the chimpanzees of Diécké, their technology, and culture remained stagnant between 2009 and 2018. We returned to Diécké in November 2018 on a reconnaissance expedition to check the status of chimpanzee presence and nut-cracking activity in the forest near Korohouan. In the present study, we provide the first up-to-date overview of the historical, socio-political, environmental, and scientific developments around the Diécké Forest since the 1990s and examine our findings within this context. We assess the potential for future research in this Classified Forest and discuss implications for conservation.

Diécké Forest

The Diécké Forest is located in the Yomou prefecture of the Guinée Forestière region (Figure 1; Ham 1998). It extends over 700 km², spanning approximately 35 km across north to south and east to west (Humle & Matsuzawa 2001; Kormos *et al.* 2003), and borders Liberia to the southeast. The landscape is characterized by a large collection of small hills with elevation ranging 50-800 m above

sea level (Carvalho *et al.* 2007; Carvalho 2011). It is part of the Western Guinean Lowland Ecoregion and is composed predominantly of a moist evergreen forest, where large girth timber species form a dense canopy, interspersed by pockets of riparian forest and swamp-forests dominated by *Raphia* palms (Robertson 2001; Brugiere & Kormos 2009; Carvalho 2011; Haba & Couch 2018). This region has an annual rainfall of 1,730-2,250 mm (calculated from 2000-2018 data - see Supplementary Online Material*; Harris *et al.* 2020), and experiences a long wet season between April and December followed by a very short dry season between December and March (Carvalho *et al.* 2007). It has two main rivers running southwest, but there are also many smaller streams that flood, creating swamps that restrict access to some parts of the forest (Robertson 2001; Carvalho *et al.* 2007).

Conservation status and initiatives

There are currently 162 Classified Forests (*forêts classées*) in Guinea and Diécké is one of the 40 in Guinée Forestière (Ministère de l'Environnement, des Eaux et Forêts 2019b). It is the largest near-pristine lowland evergreen forest in Guinée Forestière and one of the few remaining near-pristine forest mosaics of the Upper Guinean Forest ecosystem (Couch & Haba 2018; Akobi & Poissonnier 2021; Fauna & Flora International 2021), a part of the Western Guinean Lowland Ecoregion that persisted through the glaciation cycles and global cooling of the Pleistocene (Carvalho *et al.* 2008; Kalan *et al.* 2020). Today, the Western Guinean Lowland Ecoregion is the most threatened ecoregion in Guinea (Brugiere & Kormos 2009). As such, Diécké represents an ancient and important forest refuge that has provided a stable tropical climate and habitat to a range of taxa, including chimpanzees, for thousands of years (Kalan *et al.* 2020; Barratt *et al.* 2021).

*<http://primates.squarespace.com/storage/afrikan-primates-journal/volume-181/Almeida-WarrenSupplementaryMaterial.pdf>

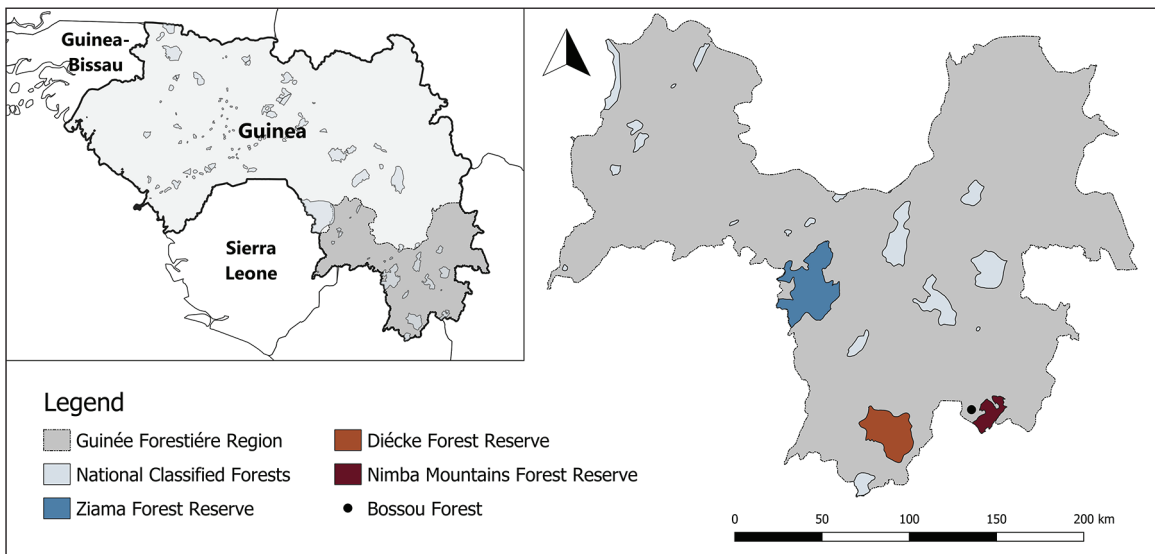


Figure 1. Map of the national Classified Forests of Guinea and the locations of the Zياما, Diécké, Nimba, and Bossou forests.

The Diécké Forest has been ranked as one of the highest Key Biodiversity Areas for West Africa and is among the top five plant biodiversity areas at a national level (Brugiere & Kormos 2009; Haba & Couch 2018; Haba *et al.* 2018; Fauna & Flora International 2021). Additionally, Diécké has been identified as part of one of four transboundary areas of importance for the conservation of the critically endangered western chimpanzee, *Pan troglodytes verus* (Humble *et al.* 2016; Heinicke *et al.* 2019a). The forest is home to a further 61 species of conservation concern, including the African dwarf crocodile (*Osteolaemus tetraspis*: IUCN Red List: vulnerable) and the tenth largest population of pygmy hippopotamus (*Hexaprotodon liberiensis*: IUCN Red List: endangered) (Robertson 2001; Akobi & Poissonnier 2021; Kormos *et al.* 2003). It is also an Important Bird and Biodiversity Area (IBA), with 141 avian species (Akobi & Poissonnier 2021), such as the threatened Yellow-casqued hornbill (*Ceratogymna elata*: IUCN Red List: vulnerable), Yellow-bearded greenbul (*Criniger olivaceus*: IUCN Red List: vulnerable), Green-tailed bristlebill (*Bleda eximia*: IUCN Red List: near threatened), and White-necked rockfowl (*Picathartes gymnocephalus*: IUCN Red List: near threatened) (Robertson 2001).

Protective legislations have been in place since 1932, when the French colonial administration established the Diécké Forest as a natural reserve, and later as a Classified Forest (Akobi & Poissonnier 2021). Following Guinean independence, Classified Forests, such as Diécké, have remained under State governance with restrictions on human activities

(Brugiere & Kormos 2009). However, the majority of Classified Forests have no formal management plan and are severely degraded (Brugiere & Kormos 2009). The Diécké Forest is one of the few that has been actively managed by government authorities since 1991 via a series of fixed-term projects (1991-1994: PROGEFOR; 1996-2003: PGRR; 2004-2009: PGRF; 2017-2024 MRU-IWRM) aided by funds from financial institutions such as The World Bank, Kreditanstalt für Wiederaufbau (Germany), and the Canadian International Development Agency (The World Bank 1997; IUCN 2016; Ministère de l'Environnement, des Eaux et Forêts 2019a). Now under the remit of the Centre Forestière de N'Zerekoré (CFZ) government wildlife authority, these conservation efforts have sought to restore the forest and prevent further degradation through sustainable rural development, community engagement, reforestation and the monitoring of illegal activities via regular patrols (Diallo 1996; The World Bank 1997; IUCN 2016). Despite these efforts, recent government reports indicate that threats to forest degradation prevail (Bureau de Stratégie et de Développement 2020a; 2020b), which has led some conservation practitioners to recommend that the Diécké Forest is attributed national park status – the highest level of formal national protection (Brugiere & Kormos 2009).

Human impact

Guinea is among the 10 countries in the world most affected by deforestation, with nearly a third

(2.9 million ha) of tree cover lost between 1960 and 2020 (Akobi & Poissonnier 2021). Like many parts of Guinea, the forests of Guinée Forestière have been affected by escalating anthropogenic disturbance, such as agriculture, logging, mining, and hunting, since the beginning of the colonial era in 1905 (Akobi & Poissonnier 2021), although archaeological evidence indicates that small scale land use practices, including food production, have occurred in the area since 200 BCE (Kay *et al.* 2019). While Classified Forest are protected under State legislation, some conservation initiatives have been the subject of negative public perception, with residents complaining of a lack of consideration for local communities and traditional land use rights (Leach 2008).

Accelerated population growth and development of commercial ventures in response to international resource demand in the last 30 years are exacerbating the threats to the Diécké Forest and other natural reserves (Akobi & Poissonnier 2021). In a survey by the Wild Chimpanzee Foundation in 2011, which covered 11 chimpanzee localities in Guinea, Diécké was found to be the third most negatively affected by human pressure, only surpassed by the Nimba Mountains and Ziama, which are also located in Guinée Forestière (Wild Chimpanzee Foundation 2012). The rise of extractive industries and large-scale agriculture has also raised public health and socio-economic concerns among local communities in Guinée Forestière and elsewhere (Baldé 2018a; Human Rights Watch 2018; Balde *et al.* 2019; Guilavogui 2020). The quality of life in the region remains very poor, with the majority of Guinée Forestière inhabitants living on less than \$850 per year and suffering from malnutrition (Akobi & Poissonnier 2021). This highlights the interconnectedness of conservation concerns and socio-economic issues and the need for conservation approaches that acknowledge these realities (Mitani *et al.* 2024).

Across Africa, hunting, agricultural expansion, logging and mining are currently the main human threats affecting African ape populations (Junker *et al.* 2024). The following sections provide an overview of the latest developments of these four activities around the Diécké Forest to contextualize our survey findings and draw attention to the conservation and socio-economic challenges ahead.

Poaching

Illegal hunting within the Diécké Forest has remained high throughout the last three decades

(Ham 1998; Kormos *et al.* 2003; Carvalho 2011; Bureau de Stratégie et de Développement 2020a), with Diécké representing one of the chimpanzee localities in Guinea most negatively affected by hunting pressure (Wild Chimpanzee Foundation 2012). Poachers are known to set up camps within the Classified Forest, where they will spend several days trapping and hunting wild animals for bushmeat and other products to sell in larger cities such as N'Zérékoré (Kormos *et al.* 2003; Akobi & Poissonnier 2021). In the past, chimpanzees inhabiting the forest have also fallen victim to this exploitation, with three killings reported by CFZ in 2001 (Kormos *et al.* 2003).

CFZ has implemented several preventative measures in the Diécké Forest, such as monthly patrols by forest rangers (ecoguards) to track down poachers, monitor illegal hunting activities, and raise awareness in local communities (Sangbalamou 2020). However, the ecoguards have said that these missions are constrained by the lack of crucial resources, such as means of transportation, GPS devices, camping equipment, and weapons (Sangbalamou 2020).

Other regions of Guinée Forestière, such as Ziama and Mount Nimba, have benefitted from financial support from the EU/UNOPS, which provided equipment and training to the then Ministère de l'Environnement, des Eaux et Forêts for the launch of a pilot paramilitary conservation scheme – *Projet d'Appui à l'Opérationnalisation d'un Corps Paramilitaire des Conservateurs de la Nature (PAOCPN)* (IUCN 2016). However, these projects are often short-term, and lack funding continuity. An assessment presented at the CITES CoP18 reports that Guinea has no government budget allocated for protected areas, with efforts supported exclusively by foreign governments and international NGOs (Convention on International Trade in Endangered Species of Wild Fauna and Flora 2019). Thus, while the establishment of a more permanent presence would help reduce hunting pressure (Kormos *et al.* 2003), strong political commitment and strategy is needed to ensure long-term allocation of funding and resources (Brugiere & Kormos 2009).

Rubber and palm oil industry

It is estimated that between 2000 and 2018 approximately 25% of the Guinée Forestière region suffered tree cover loss, with agriculture identified as the primary driver (Fitzgerald *et al.* 2021). The Diécké Forest is surrounded by rubber and oil palm plantations that are controlled by the

Société Guinéenne de Palmiers à Huile et d'Hévéa (SOGUIPAH) – the largest rubber and palm oil producer in the country (Balde *et al.* 2019; Fauna & Flora International 2021). SOGUIPAH is an agro-industrial public company that was founded in 1987 to support the sustainable development of industrial and family-owned plantations and promote local development and food security (The World Bank 2016; Fauna & Flora International 2021). Over the years it has received financial support from multiple donors including the African Development Bank, the Arab Bank for Economic Development in Africa, and the European Investment Bank (López-Cálix 2020). Today, SOGUIPAH's land holdings extend across ~230 km², employing over 3,500 workers on its plantations and in its factories for processing rubber, palm oil, and soap (Thompson *et al.* 2021). The company also purchases natural rubber and palm fruits from around 3,000 local smallholders, and supports them by providing training, planting material, and technical assistance (Balde *et al.* 2019; Fauna & Flora International 2021).

Large-scale oil palm plantations have frequently been associated with habitat fragmentation and biodiversity loss, with negative impacts on adjacent intact forests (Wich *et al.* 2014; Linder & Palkovitz 2016; Strona *et al.* 2018). SOGUIPAH's sustainability measures include reforestation areas affected by artisanal slash-and-burn practices, and the establishment of *collines écologiques*, small (~700 ha) protected forests, within their concessions to provide ecosystem services to local communities and wildlife (Keita & Bedinger 2008; GEF 2019). SOGUIPAH reportedly manages these areas and monitors the impact of its activities on the environment (Fauna & Flora International 2021), however, it is presently unclear how successful these measures have been due to absence of published data.

While SOGUIPAH has contributed towards social infrastructure in the region such as health clinics, schools, roads, and access to water (López-Cálix 2020), its operations have been associated with negative socioeconomic impacts (Balde *et al.* 2019). Between 2011 and 2016, SOGUIPAH's oil palm and rubber exports increased by 900% and 50% respectively (López-Cálix 2020), yet employees and small-hold suppliers have claimed that their incomes are increasingly insufficient, accusing the company of enforcing its own pricing system and overriding contractual agreements (Balde *et al.* 2019). In February 2020, workers protested against their employer due to wages in arrears of 2-3 months, an issue that has been recurring since 2013 (Guilavogui 2020).

Logging

Timber is one of the most sought-after natural resources in Guinea. Logging activity in Guinée Forestière has been controlled by Forêt Forte, a subsidiary of the Taiwanese company Coujy Corporation, since 2002 when it was granted exclusive concessionary rights by the Guinean government to exploit the region's surviving forests, including the protected areas of Diécké and Zياما (Akobi & Poissonnier 2021; Fauna & Flora International 2021). While operations in these two forests have been halted by the Ministère de l'Environnement et du Développement Durable (formerly Ministère de l'Environnement, des Eaux et Forêts) (Fauna & Flora International 2021), reports and local media coverage indicate that this could change imminently (Camara 2017; Baldé 2018b; Akobi & Poissonnier 2021).

Forêt Forte is already exploiting classified forests in other parts of Guinea (Akobi & Poissonnier 2021; Forêt Forte 2021a). While it claims to be committed to sustainable and ethical development (Forêt Forte 2021b; Nydegger 2021), the company has been repeatedly accused of abusive logging that could lead to the decimation and irreversible deforestation of the last pristine forests in Guinea (Camara 2017; Baldé 2018b; Guilavogui 2018; Akobi & Poissonnier 2021). The local NGO *Touche pas à ma forêt*, the national green party (*Parti Écologique de Guinée* - PEG), and the local youth centre (*Maison des jeunes et de la culture de N'Zérékoré*) are amongst those that have strongly criticised the latest Forêt Forte agenda, claiming that the company has failed to comply with its reforestation and infrastructure development commitments, did not consult with local communities, nor respect their traditions with regard to the sacred areas of the forest (Akobi & Poissonnier 2021). Beyond the forest and into production, news reports from 2018 impart that workers at the Forêt Forte factory in N'Zérékoré were on strike for over 6 months due to poor living and working conditions (Baldé 2018a, 2018b).

Mining

Guinea harbours the largest bauxite reserves and untapped iron ore deposits in the world (Ministry of Mines and Geology 2021a, 2021b). Historically, the exploitation of mineral resources has been constrained by political conflicts and poor transport infrastructure throughout the country. In recent years, however, mining operations in Guinea, have expanded drastically in response to the growing

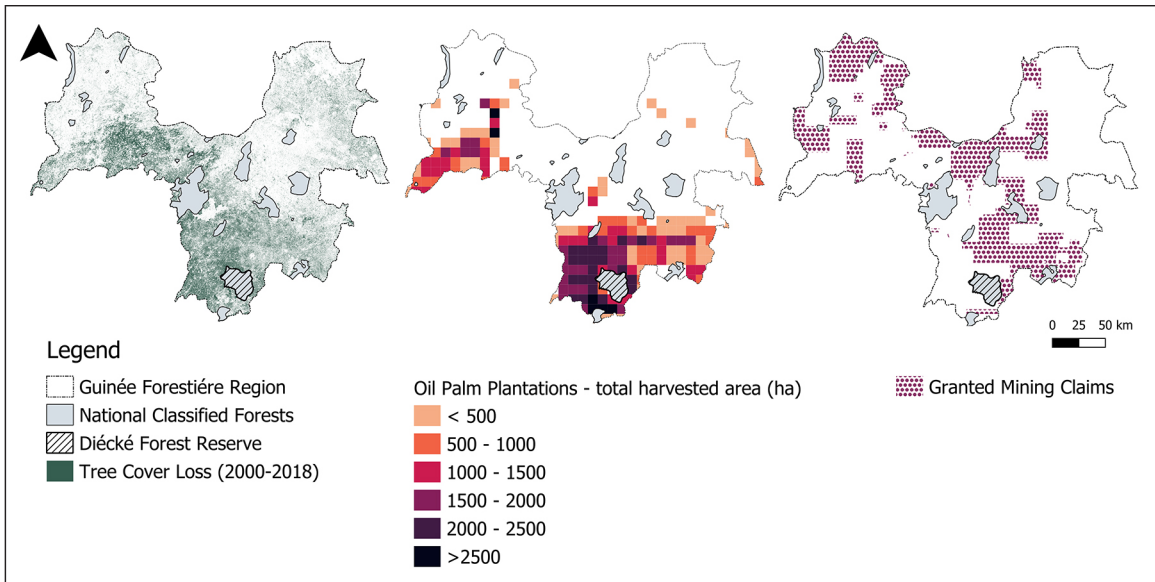


Figure 2. Distribution of main commercial activities and tree cover loss in the Guinée Forestière Region. Tree cover loss in Guinée Forestière from 2000 to 2018 was mapped using Landsat analysis ready data and a regionally calibrated, annual forest change detection model (as per Fitzgerald *et al.* 2021). The map of oil palm plantations is presented as the total area harvested (in hectares) during 2017, with white areas indicating locations where commercial oil palm activities are absent. The original data is available from the Harvard Dataverse, under a CC-by-4.0 license (Online source: International Food Policy Research Institute, 2020; <https://doi.org/10.7910/DVN/FSSKBW>). The map for mining claims is an approximate rendering of the areas where mining exploration and/or extraction has been approved. This includes past, current and future activities. The information was sourced from a publicly available dataset where no interrogation of the data is possible (SNL Metals & Mining, an offering of S&P Global Market Intelligence, 2020; Online source: <https://panda.maps.arcgis.com/home/item.html?id=6f8e17219c354878af009a6cc9a9f571>).

global demand for rare metals and minerals (Fauna & Flora International 2021). The national economy has benefitted greatly from these developments, ranking fifth in the International Council of Mining and Metals (ICMM) Mining Contribution Index of 2020 (ICMM 2020).

Large-scale mining, as well as artisanal and small-scale mining, are now conspicuous across the Guinean landscape, with many mining claims intersecting areas of high biodiversity and carbon value, including regions that harbour endemic forests and threatened species (Fauna & Flora International 2021). Recently, Guinea has been found to have one of the highest overlaps in chimpanzee population abundance and mining areas in West Africa, with over 80% of Guinea chimpanzees estimated to face the impacts of the mining industry in the near future (Junker *et al.* 2024).

The largest active mining concessions in Guinée Forestière are located in the Nimba Mountains (a UNESCO World Heritage Site) and Simandou. Further mining claims have been granted to the South and East of the Diécké Forest (Figure 2). Initial prospection of the deposits to the south of the Diécké Forest has estimated a resource potential

of approximately 1.2 billion tonnes of iron ore (Al Khaldiya Mining 2021). Within Guinée Forestière, the Diécké mining concession is the closest mineral reserve to a working railway with access to the coast (Al Khaldiya Mining 2021), making it an attractive extraction site for quick and direct export of natural resources through Liberia. In 2020, the Kuwaiti-backed Al Khaldiya Mining group signed a memorandum of understanding with the Liberian government to transport 789 million tons of iron from its Diécké project via the Yekepa-Buchanan rail line (Mehnpaine 2020). As of 2023 the permit for exploration at the Diécké iron ore site remains active and has been put forward for renewal (Project code: 22713, Ministère des Mines et de la Géologie and Trimble Land Administration 2023).

With the mining industry expected to surge in the coming years (Sonter *et al.* 2020; Junker *et al.* 2024), the region will attract a large influx of people which will generate greater demand for food, resulting in agricultural expansion (Lanjouw *et al.* 2013). Likewise, increased industrial activities will boost infrastructure developments, particularly transport networks and electricity, providing greater access to the region (Lanjouw *et al.* 2013). While

this may bring positives to local communities, it could have grave consequences for public health and the natural environment, if not properly regulated. In the Boké region (Guinée Maritime, western Guinea), decades of bauxite mining, involving the multinational mining corporations Rio Tinto, Alcoa, and Dadco, is already having devastating impacts on nearby human settlements and the surrounding environment, such as water contamination, air pollution, and soil infertility (Human Rights Watch 2018; Oakes 2019; Rolando Mazzuca 2019; Sidiki 2019). Loss of land and livelihoods, reduced access to clean water, and other threats to public health are amongst the damaging consequences highlighted in the latest Human Rights Watch report (2018) concerning bauxite mining in Guinea. Coupled with the environmental degradation and biodiversity loss in the Boké region, including the plight of chimpanzees (O'Mahony 2019; Bergen 2020), this is a worrying prospect for the future of other mining localities such as Diécké.

Chimpanzee status and tool use

To date, there have been a total of six published chimpanzee surveys and research expeditions in the

Diécké Forest (Figure 3; Table 1). An initial national census in 1988, based on questionnaires, estimated the existence of around 50 chimpanzees in the area (Sugiyama & Soumah 1988). Subsequent transect-based surveys using the number of chimpanzee nests as a proxy for population size, estimated between 209–307 individuals in 1997 (Ham 1998), and 25–253 individuals in 2011 (Wild Chimpanzee Foundation 2012). These are, however, rough estimates. Furthermore, the number of chimpanzee communities in the area remains unknown. Direct observations of chimpanzees have so far only been confirmed by Ham (1998), Humle and Matsuzawa (2001), and Carvalho (2011), who also recorded chimpanzee presence through motion detecting cameras.

It was during the 1997 census in the Yossono area (Figure 3) that evidence of nut-cracking activity was first encountered (Ham 1998) – a collection of stones surrounded by broken nuts in the vicinity of a *Panda oleosa* tree. Subsequent surveys in the Nonah and Yossono areas specifically targeting technological and cultural traces, found additional nut-cracking sites of both *Panda* and *Coula* nuts, confirming cultural divergence relative to the nearby site of Bossou, where chimpanzees only crack oil palm nuts

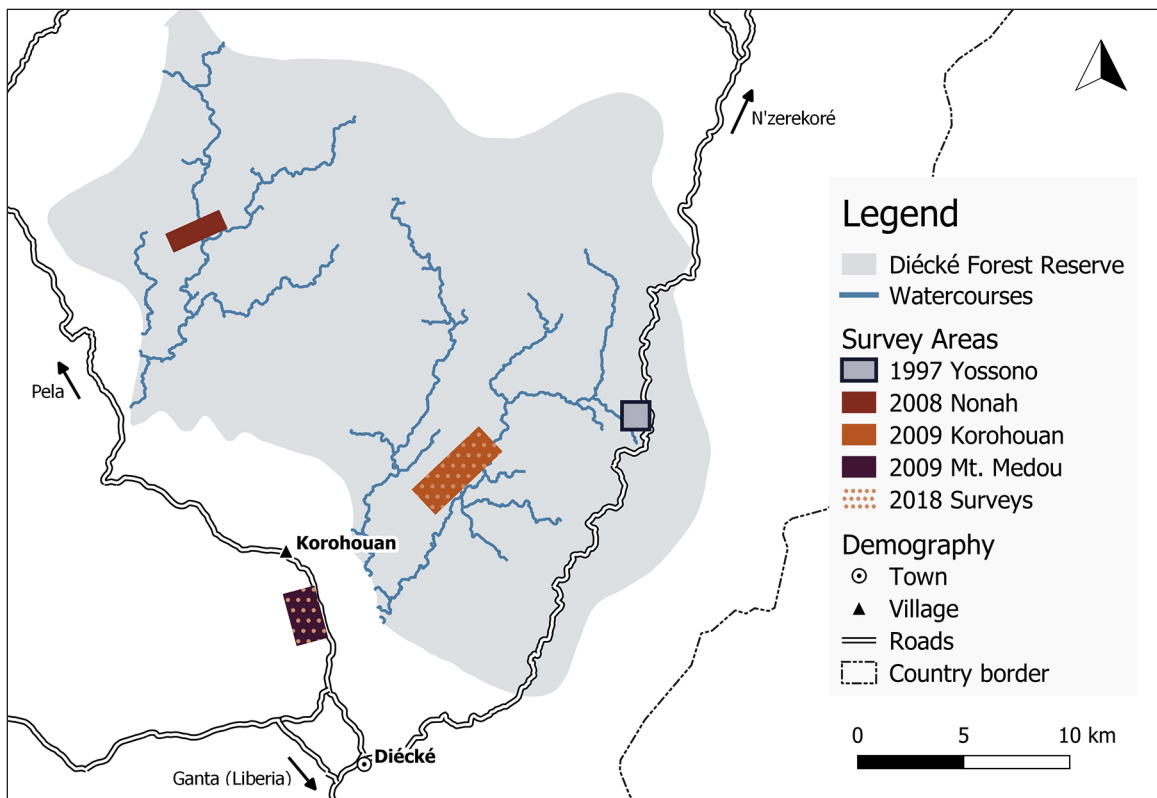


Figure 3. Map of the Diécké Forest highlighting the locations of known survey areas and nearby villages.

Table 1. Summary of the survey activities that have taken place in and around the Diécké Forest region. Empty cells represent unknown or unavailable information.

Year	Survey goals ^a	Method ^b	Forest section ^c	Duration ^d	Distance surveyed ^e	Reference
1988	CP	I				Sugiyama & Soumah 1988
1997	CP, W, H	LT, I	E	1	5.2	Ham 1998
1999	CTU	ES	NE, NW	3		Matsuzawa <i>et al.</i> 1999
2000	CTU	ES	NE, NW	10		Humle & Matsuzawa 2001
2006	CNC, CP	ES, TSM	NW, S	19 (NW: 3 + 8 + 4; S: 6)		Carvalho <i>et al.</i> 2007
2008	CNC, CP	ES, TSM	NW	12 (8 + 4)		Carvalho 2009
2009	CNC, CP, W, H	ES, LT, MTC, TSM	S	37 (12 + 14 + 11)		Carvalho 2009
2011	CP, W, H	LT	FW		144.8	WCF 2012
2018	CP, CNC, W, H	LT, ES	S	5	21.7	This study

^a CP = chimpanzee presence; CNC = chimpanzee nut-cracking; CTU = chimpanzee tool use; H = human activity; W = wildlife.

^b ES = exploratory surveys; I = interviews; LT = line transects; MTC = motion triggered cameras; TSM = tool site monitoring.

^c General survey area: FW = Forest-wide; NE = North-East; NW = North-West; S = South.

^d Values indicate total duration (in days) of each survey effort. Values in parentheses represent the duration of individual trips.

^e Values reported in kilometres.

(Matsuzawa *et al.* 1999; Humle & Matsuzawa 2001).

The most recent and longest research endeavour focusing on the nut-cracking behaviours of the Diécké chimpanzees took place between 2006 and 2009 in the Nonah and Korohouan areas (Carvalho *et al.* 2007; Carvalho 2011). This research aimed to investigate, within a primate archaeology framework, the direct and indirect evidence of nut-cracking and to compare with research being conducted in parallel in Bossou (Carvalho *et al.* 2008, 2011). This was the first archaeological investigation of chimpanzee tool use conducted in the Diécké forest, making it only the third chimpanzee locality to host research of this kind, following Taï and Bossou (Mercader *et al.* 2002; Carvalho *et al.* 2008).

Nine trips occurred during the 2006–2009 period, lasting a total of 68 days (Carvalho 2009, 2011). A total of eight nut-cracking sites were documented, along with traces of chimpanzee feeding, nests, and tracks (Carvalho *et al.* 2007). Comparisons with the Bossou data revealed that the chimpanzees of Diécké used larger tools to crack open nuts and exclusively used fixed outcropping stones as anvils, while Bossou chimpanzees always used smaller, movable tools (Carvalho *et al.* 2008). These differences are likely connected to differences in the number of movable stones available in each respective site, as well as in properties of the target foods (e.g., *Panda* nuts are larger and harder to crack; Boesch & Boesch, 1983).

Korohouan: revisited a decade later

In 2018, nearly a decade after the last primate archaeological research in the area, we returned to the Korohouan locality on a reconnaissance expedition to follow-up on previous work and review the status of chimpanzee presence and technological activity. This included revisiting known nut-cracking sites, searching for new sites, documenting traces of chimpanzee presence, and recording the availability of resources and raw materials targeted by chimpanzees for nut-cracking. An additional goal was to document the presence of other wildlife and traces of human activities (e.g., fishing, hunting) to assess the broader conservation status and threats in the area.

MATERIALS AND METHODS

Study site

Korohouan (7° 26' N; 8° 59' W) is a small village located near the southern border of the Diécké Forest, around 12 km northwest of Diécké town, along the Diécké-Pela Road (Figure 3). The human population is estimated to be approximately 3000 people and predominantly lives off subsistence farming and employment by SOGUIPAH.

The Korohouan survey area includes a section

to the northeast of the village within the classified forest area of the Diécké Forest (Figure 3). To facilitate surveys in this area, we set up a temporary camp at the former site of Camp Lethou (7° 27' N; 8° 54' W), located on the border of the Gbin river, around 18 km from the Korohouan village. Camp Lethou was originally established during the 2008 research activities (Carvalho 2009). The survey area also extends to Mont Medou (hereafter, Mt. Medou; 7° 24' N; 8° 59' W) – a small patch of forest surrounded by cultivation fields to the south of the village (Figure 3), where local people have frequently observed chimpanzees in the past (Carvalho 2006).

Data collection

The 2006–2009 surveys

The Korohouan surveys of 2006–2009, led by SC, took place over four separate field trips, totaling 43 days. These surveys primarily focused on: the mapping and monitoring of chimpanzee nut-cracking sites; transect surveys of raw materials, nut species, and chimpanzee presence (e.g., nests, faeces); and the archaeological excavation of an abandoned chimpanzee nut-cracking site (Carvalho 2011). In 2009 the research team also installed two motion triggered cameras in the Mt. Medou area along two chimpanzee trails, each active for a total of 50 and 25 days, respectively. While data on wildlife abundance and human impact was not collected systematically, the unpublished reports include several accounts of the human activities encountered (Carvalho 2006, 2009). We provide a summary of the unpublished findings pertaining to nut-cracking sites (number of tools, site activity status), chimpanzee traces (nests, feeding, tracks, faeces), and human activities to contextualize the results from the 2018 surveys.

The 2018 surveys

In November of 2018, KAW and MF organised a six-day reconnaissance expedition to the Korohouan area. The research team spent 5 days in the Classified Forest (25 Nov 2018 – 29 Nov 2018) and one day surveying Mt. Medou (01 Dec 2018). Surveys were initially conducted by navigating towards the four known nut-cracking sites and other features of interest documented between 2006–2009 (e.g., chimpanzee nests, traces of other primates, camera trap locations). We also carried out a 1.3-km line transect intersecting the two nut-cracking sites with the most recent traces of activity. In total we surveyed a distance of 21.7 km. For all nut-cracking sites encountered during surveys, we recorded the

number of tools and raw materials present, and characterised the associated (source) *Panda* and *Coula* trees (within a 5-m radius) according to each of the following binomial attributes: alive (tree is producing leaves/flowers and has no visible sign of disease or significant damage/injury); bearing fruit (fruits/nuts are visible in the tree and/or on the ground). We compare the data to that collected during the 2006–2009 surveys led by SC.

All evidence of wildlife and human presence found during the survey was logged on a handheld GPS device and described by source (i.e., taxa), type of trace (e.g., footprint, feeding, snare, hunting camp, shotgun shells), as well as approximate age. Because the 2006–2009 surveys did not record these data, we use the data from the 2011 WCF wildlife status report to provide historical context and a baseline for examining general trends. To enable this comparison, we calculated our total travel distance from live tracks recorded during fieldwork, after overlapping segments and stationary logs had been removed during post-processing in QGIS. We also recorded any concurrent traces of the same source and age as one observation, as these were likely to be the product of the same event.

Data sharing statement

All data generated or analysed during this study are included in this article and its Supplementary Online Material. They can also be found in the IUCN Database and A.P.E.S. Wiki. Further enquiries can be directed to the corresponding author.

RESULTS

To provide context and a baseline for inferring general trends we present the results from the 2018 surveys alongside data and other relevant findings from the last known surveys which, to date, have largely remained unpublished or confined to grey literature (except for Carvalho *et al.* 2007; Carvalho 2011). We compare data on chimpanzee presence and nut-cracking activity primarily to the data from the 2006–2009 Korohouan surveys. For traces of other wildlife and human activities we refer to the 2011 WCF survey as a point of comparison.

Chimpanzee presence

During the 2006–2009 surveys, the research team identified several chimpanzee traces in the Korohouan area of the Classified Forest (hereafter classified forest area), including nut-cracking sites,

arboreal nests, faecal remains, feeding traces, and trails (Carvalho 2006, 2009) (Table 2; Figure 4). In the Mt. Medou area, the team found an additional nut-cracking site, as well as several chimpanzee nests (Table 2). In 2009, six chimpanzees were encountered while feeding on a *Landolphia owarensis* tree in the classified forest area. Chimpanzees were also captured once on each of the two motion triggered cameras installed in 2009. To our knowledge, these remain the only direct sightings to be filmed by researchers in the Diécké Forest region.

In 2018, we found two traces of nut-cracking activity and one decayed nest in the classified forest area, both estimated to be around 1 year old. Evidence of chimpanzee presence in Mt. Medou was limited to four potential chimpanzee trails (Table 2). No further chimpanzee traces were found during the 2018 surveys. Compared to the 2006 and 2009 absolute encounter rates, the 2018 surveys yielded the lowest records of chimpanzee presence in both the classified and Mt. Medou areas (Table 2). This decline is even starker when compared to the nest data recoded in 2011 by the WCF (Wild Chimpanzee Foundation 2012). When adjusted by the distance surveyed, the number of nests per km in the classified forest area was 90% lower than encounter rates reported in 2011 (Table 3).

Chimpanzee nut-cracking activity

During the 2006–2009 surveys, the research team identified a total of four nut-cracking sites in the surveyed areas. Two of the sites had month-old traces of nut-cracking (SB4, SB5; Figure 4e), and one other site (SB3) appeared to have been inactive for several years as a number of tools were buried

under soil (Carvalho *et al.* 2007). SB3 comprised of a large lithic assemblage ($n = 40$) and was the target of an archaeological excavation in 2009 (Figure 4f; Carvalho 2006, 2009).

During the 2018 survey, all four previously recorded nut-cracking sites of the 2006–2009 surveys were found, a few of which still bore traces of previous work such as white ink numbers on tools, and remnants of the test pits dug during the excavation at SB3. Two additional nut-cracking sites were encountered in the classified forest area. *Panda* and *Coula* trees at all nut-cracking sites were healthy and yielding fruits at the time of data collection, except for the tree located at the Mt. Medou nut-cracking site (SB6; Table 4). Furthermore, all sites had multiple stones that would be suitable to use as nut-cracking tools (Table 4). Nevertheless, only two out of six sites showed moderately recent traces of nut-cracking, including the excavated site (SB3) and a newly discovered site nearby (~250 m south; Table 4). Based on the state of decay of cracked nuts and weathering of traces on the tools, we estimate that these two sites were last active around one year earlier. The remaining four sites showed very little evidence of recent nut-cracking, with severely weathered moss-covered tools and no visible nut-shell debris, suggesting these sites have been inactive for several years.

Traces of other wildlife

During the 2006–2009 surveys, SC recorded the presence of pygmy hippopotamus, dwarf crocodile, dwarf forest buffalo (*Syncerus caffer nanus*) and bay duiker (*Cephalophus dorsalis*) (Carvalho 2011). Unpublished data from the 2006–2009 field reports

Table 2. Evidence of chimpanzee traces documented in the Korohouan area during the 2006–2009 and the 2018 surveys. Values indicate number of unique individuals/traces encountered during each survey period. Brackets represent observations recorded by motion-triggered cameras. Question marks (?) indicate potential traces.

Evidence type	Classified forest area				Mt. Medou			
	04/06	03/09	04/09	11/18	04/06	03/09	04/09	11/18
chimpanzee sightings			6				(2)	
nut-cracking traces	3	1		2	1			
nests	6	8	7	1	25	3	6	
feeding traces	2		3					
tracks	1		2			1		4?
faeces			2			1		
TOTAL	12	9	16	3	26	5	7	4?



Figure 4. Direct and indirect evidence of chimpanzee presence in the Diécké Forest, recorded in 2009. a) juvenile male chimpanzee; b) Adult male chimpanzee; c) chimpanzee nest; d) chimpanzee feeding traces; e) stone anvil and hammer used by chimpanzees to crack nuts; f) excavation of a nut-cracking site, SB3. Photographs by Susana Carvalho.

also noted direct sightings of northern bushbuck (*Tragelaphus scriptus*; Figure 5a), feeding traces of a monkey (species unknown; Figure 5b), and tracks from a leopard (*Panthera pardus*), which is now facing rapid decline throughout West Africa, with

only a few small remnant populations reported for Guinea (Stein *et al.* 2020). The photographic record also captured amphibians and reptiles (Figure 5c and 5d; see Supplementary Online Material for a full list of fauna and flora encountered). The 2011 WCF data

Table 3. Summary of mammalian traces documented in 2011 by the WCF (144.8 km), compared with traces encountered during the 2018 survey in the Korohouan classified forest area (21.7 km). Note that the 2018 chimpanzee data refers only to nests encountered to enable comparison with the 2011 chimpanzee data, for which only nests were recorded.

Taxa	2011 – Diécké Forest		2018 – Korohouan	
	n	n/km	n	n/km
Carnivores	3	0.02	0	0.00
Chimpanzees	44	0.30	1	0.05
Other primates	41	0.29	1	0.05
Bovids	420	2.90	2	0.09
Suids	23	0.16	4	0.18
Small mammals	21	0.14	14	0.65

categorized traces into carnivores, primates, bovids, suids, and small mammals (e.g., rodents).

In 2018, we found 23 traces of other mammalian wildlife (Table 3). This included footprints of mongoose (*Herpestes sanguineus*), duiker (*Cephalophus* sp.), pangolin (*Phataginus tricuspis*), suids (*Hylochoerus meinertzhageni*; *Potamochoerus porcus*), and dwarf forest buffalo, as well as feeding traces of a warthog and a monkey of unknown species (see Supplementary Online Material for a full list of fauna and flora encountered). Encounter rates (n/km) of wildlife were considerably lower than the 2011 records for all taxonomic groups except for suids and small mammals (Table 3).

Human activities

In 2006, SC noted that the hunting frequency in the forest was extremely high and there was evidence that Camp Lethou was once used by illegal hunters in between research visits. Around the forest periphery, commercial activities were already established, with

SOGHIPAH operating in the Korohouan area at the time of the surveys (Carvalho 2011). SC was also informed by local villagers of diamond mining in the vicinity.

During the forest-wide surveys of 2011, hunting was also identified as the main threat to wildlife, averaging an encounter rate of 1.45/km (Table 5; Wild Chimpanzee Foundation 2012). Other notable traces included trails (1.26/km) and agricultural activities (0.3/km). The data from our 2018 surveys also indicated a high incidence of traces associated with hunting activity (e.g., snares, shotgun shells, abandoned hunting camps) in the Korohouan classified area (Figure 6). When adjusted to the distance surveyed, this value was over four times higher than values recorded in the forest-wide survey of 2011. During the time spent at Camp Lethou, we also heard six gunshots over two consecutive nights. These are not included in Table 5 as the location of the shots was indeterminable.

Trails and instances of agricultural activities were not as prevalent within the classified forest

Table 4. Data recorded for nut-cracking sites surveyed in 2006-2009 and 2018.

ID	Year found	Species	2006-2009		2018			
			Activity ^a	Tools (n)	Tree status ^b	Stones available (n)	Activity ^a	Tools (n)
TS42/SB4	2006	Coula	~ 1 mo	6	A, BF	135	I	4
TS43/SB5	2006	Coula	~ 1 mo	11	A, BF	66	I	7
TS44	2018	Panda			A, BF	84	I	2
TS45/SB3	2006	Panda	I	40	A, BF	74	~ 1 yr	37
TS46	2018	Coula			A, BF	86	~ 1 yr	7
TS47/SB6	2006	Panda	U	10	A			3

^a mo = month; yr = year; I = inactive; U = unknown

^b A = alive; BF = bearing fruit

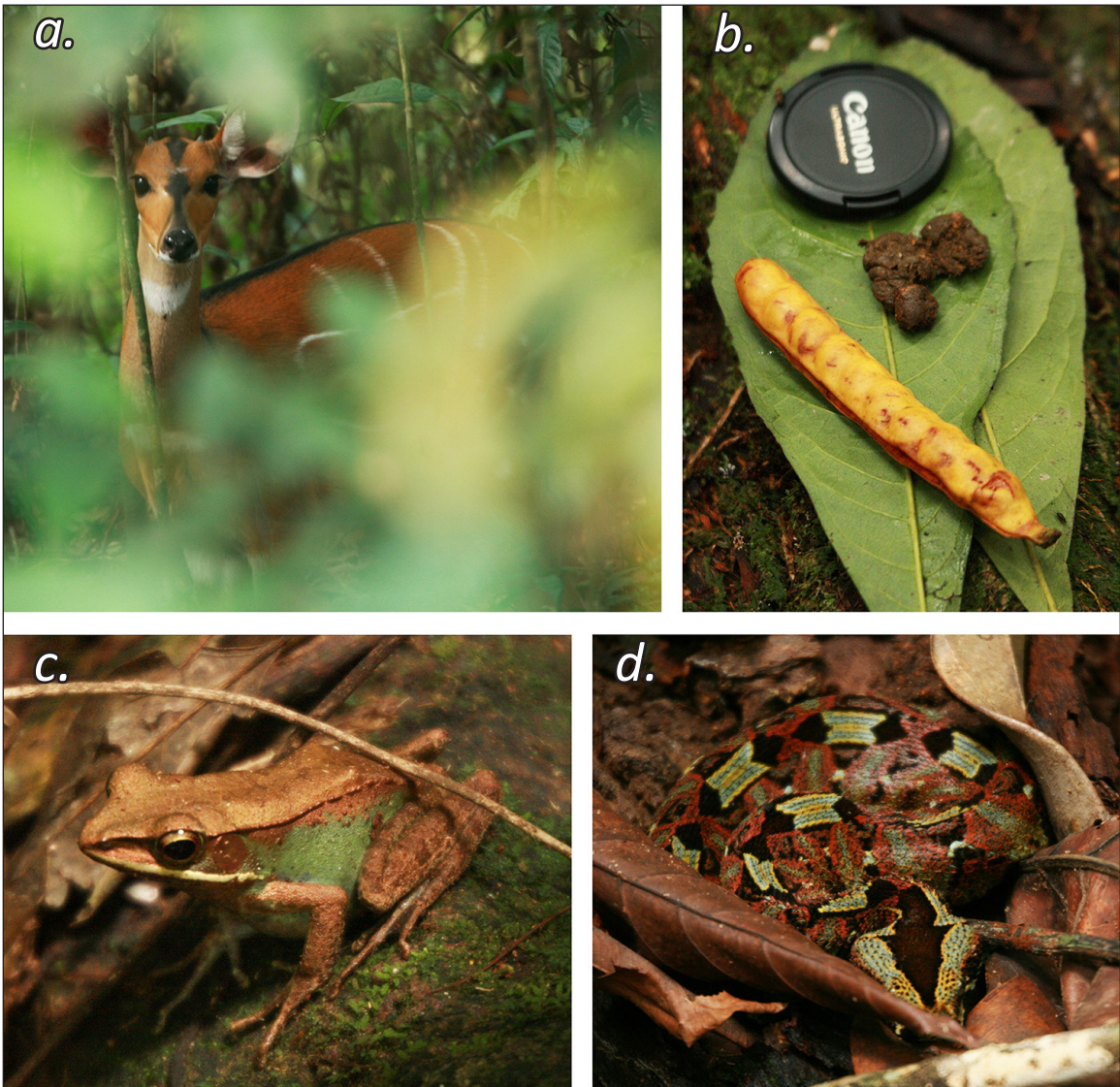


Figure 5. Direct and indirect evidence of other wildlife observed during the 2009 surveys. a) bay duiker; b) faecal remains and feeding traces of a monkey; c) white-lipped frog; d) rhinoceros viper. Photographs by Susana Carvalho.

area in 2018. However, agricultural activities were ubiquitous throughout the forest periphery. We encountered SOGHIPAH rubber and oil palm plantations all along the route to the Diécké Forest, and a large rice field adjoined the entrance to the classified forest area. We also found evidence of logging, including a red timber species – likely *Lophira alata*, which is currently classified as vulnerable in the IUCN red list (Haba & Couch 2018).

The 2018 survey of Mt. Medou revealed that the surviving patch of forest has been further reduced by agricultural expansion. Forest areas surveyed in 2006–2009 were deforested in 2018, and the tree

upon which one of the camera traps was attached had been cut down. Hunting traces found in the area included two shotgun shells and a snare.

DISCUSSION

The Diécké Forest is considered an area of high conservation significance for flora and fauna alike, including the critically endangered western chimpanzee (Akobi & Poissonnier 2021; Fauna & Flora International 2021). Nevertheless, the last published chimpanzee survey took place in 2011, over a decade ago. Our report provides a much-needed update which we hope will be a useful

Table 5. Summary of traces of anthropogenic origin collected in 2011 by the WCF (144.8 km), compared with traces collected during the 2018 survey in the Korohouan classified forest area (21.7 km). Blank cells indicate data that were unavailable/not collected.

		2011 – Diécké Forest		2018 – Korohouan	
		n	n/km	n	n/km
Hunting	Total	210	1.45	137	6.31
	- Shotgun shells			118	5.44
	- Snares/traps			18	0.83
	- Camps			3	0.14
Fishing			2	0.09	
Trails		182	1.26	4	0.18
Agriculture		43	0.3	1	0.05
Logging		7	0.05		
Other traces			0.02	5	0.23

starting point for future research and conservation efforts in this key area for biodiversity and western chimpanzees.

A total of seven chimpanzee traces were recorded during the five-day survey period. However, only three of these traces can be attributed to chimpanzees with certainty (Table 1). These values are considerably lower relative to both the 2006–2009 and 2011 records. Additionally, we found a total of six nut-cracking sites in the classified forest area, only two of which showed traces of relatively recent nut-cracking activity. The fact that all six sites had ample raw materials available, and all but one site had *Panda* and/or *Coula* trees that were productive and bearing fruit, eliminates a localized ecological explanation. The two sites were within 250 metres of each other, and all traces were around 1 year old. This pattern is not much different from the 2006 records that documented two, albeit different, active sites with month-old traces that were around 50 m apart. While new activity was observed at a site that was thought to be permanently abandoned in previous surveys, it was also evident that traces on tools at other previously recorded nut-cracking sites were becoming inconspicuous.

Given that the 2006–2009 Korohouan surveys were conducted in March–April and the present survey (2018) took place in November, it is possible that chimpanzee presence, and therefore nut-cracking activity, in this region of the Diécké Forest is seasonal. The 2011 WCF survey took place in March, but the targeted chimpanzee population survey using nest counts only covered the northeast portion of the Diécké Forest (Wild Chimpanzee

Foundation 2012). While this provides some scope for optimism, the chimpanzee data when combined with results from other wildlife and human activities pose a much starker outlook.

Comparisons with data collected by the WCF in 2011 across the Diécké Forest suggest that other primate species and bovids have dropped by similar levels when adjusted for distance surveyed. Additionally, the forest around Camp Lethou is suffering from an inordinately high incidence of hunting when compared to the forest-wide data of 2011. Whether this reflects a trend across the entire Diécké Forest remains to be determined. Nevertheless, our findings emphasize the urgency for a dedicated study to collect additional data on chimpanzee presence and material culture in all areas of the forest in tandem with the distribution of human activities. With the population in the nearby forest of Bossou now down to three individuals (Didier Camara, Dore and Zogbila, pers. obs.), if the Diécké communities follow suit, the cultural heritage of Guinean nut-cracking chimpanzees (currently known to science) may become lost to us forever.

In reports of the 2006–2009 surveys, it was suggested that chimpanzees in the Korohouan area were favouring forest fragments outside the protected area, such as those around Mt. Medou to avoid threats from hunting activities. Studies involving other chimpanzee populations have also documented increased use of buffer zones relative to neighbouring protected areas (Tweh *et al.* 2018), while orangutan research has highlighted the importance of forest fragments to the survival



Figure 6. Material traces of human presence collected during surveys in the classified area. Items include one shoe, a plastic bottle, dozens of wires used for snares, and >100 shotgun shells. Photograph by Katarina Almeida-Warren.

of meta-populations (Ancrenaz *et al.* 2021). Such studies are bringing to light the value of human-modified landscapes to primate conservation (Galán-Acedo *et al.* 2019).

Our observations indicate that agricultural expansion and deforestation remains prevalent in the forest periphery. Added to the elevated levels of hunting pressure in the protected area, this is an indication that viable areas for chimpanzee habitation in the Korohouan vicinity are under increasing threat. Further research seeking to understand the direct impacts on chimpanzee communities both in the Diécké Forest and the forest periphery should provide valuable insights as to the thresholds of habitability by chimpanzees (and other wildlife). Diécké is one of many landscapes at the protected-anthropogenic interface and further research on the ground is crucial to inform conservation practices that support human-wildlife coexistence (Leblan & Soiret 2021).

The WCF report indicates that different parts of the Diécké Forest are affected by distinct types of anthropogenic disturbance to varying extents. This is likely due to the degree of accessibility of different regions of the forest, as well as variation

in topographic and hydrological characteristics throughout the forest (Robertson 2001; Wild Chimpanzee Foundation 2012). However, this has yet to be formally investigated. Given that the evidence from Korohouan points to an overall lower biodiversity and an intensification of human activity relative to the 2011 assessment, it would be important to conduct follow-up forest-wide surveys to monitor changes in human activities and biodiversity in other parts of the forest and determine whether this reflects a localized or global trend. Critically, such surveys should also extend to buffer zones, as these may constitute important strongholds to the surviving chimpanzee populations (Galán-Acedo *et al.* 2019; Leblan & Soiret 2021), especially considering that over 80% of western chimpanzees are estimated to live outside protected areas (Heinicke *et al.* 2019b). It would also be paramount to investigate how humans, chimpanzees, and other animals use different habitat types to help better understand where conservation efforts are most needed and will be most effective.

During our visit to the Diécké Forest we witnessed that the Korohouan area continues to attract a high degree of commercial activity, particularly from

the palm oil and rubber industry. Recent news reports also allude to the commencement of logging operations in the Diécké Forest, as well as iron ore mining to the south. With convenient access to Liberia and transport routes to the coast and international trade, industrial operations in Diécké, as well as in other areas Guinée Forestière rich in highly sought-after natural resources, are likely to proliferate for decades to come. This phenomenon is already becoming the norm for many chimpanzee communities, with over 60% of surveyed African ape populations currently affected by hunting, logging, and agricultural expansion, and 34% overlapping with active and prospective mining areas (Junker *et al.* 2024). The growing global demand for palm oil products is also predicted to cause irreversible damage to African ape populations, who overlap with almost all high oil palm suitability areas in Africa (Strona *et al.* 2018).

Future investigations into community perceptions of industrial activities and how they are currently affecting local livelihoods at the interface of biodiversity and resource richness, such as Korohouan, will generate much-needed empirical evidence of their impact beyond the environmental sphere. This will be paramount for driving prospective economic investments towards concerted cross-sector action spanning industry, conservation and human development that meets the needs of the local populations, ensures financial and food security, and empowers community-led, sustainable conservation efforts that build on Indigenous knowledge and foster human-chimpanzee coexistence (Mitani *et al.* 2024).

CONCLUSIONS

The Diécké Forest is one of the largest remaining near-pristine lowland evergreen forests of West Africa, in existence since ~2.5 million-years-ago. It is a Key Biodiversity Area for West Africa and is home to many endemic and threatened species. The chimpanzee population is one of only two communities known to have a nut-cracking tradition within the Republic of Guinea, yet both have distinct cultural heritages in terms of the material characteristics of the tools they use and the nut species they target. Due to the high density of natural resources present in the region, the Diécké Forest is presently at the epicentre of rapidly expanding smallholder and commercial human activities. Additionally, our survey indicates that hunting activities remain extremely high within the Classified Forest. These human activities are having

a detrimental impact on biodiversity within the protected area as well as the forest periphery, where chimpanzee presence has also been documented in the past. With the predicted expansion and escalation of extractive industries and agricultural activities in the coming decades, the ancient Diécké Forest and all the communities that benefit from it, human and nonhuman alike, are at risk. We hope our research provides a helpful starting point for urgent and concerted conservation action.

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