Forest elephant habitat use and interactions with humans in the Campo-Ma'an landscape, southern Cameroon

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ABSTRACT

Forest elephant habitat use and interactions with humans in the Campo-Ma'an landscape, southern Cameroon

Léa Mimeault

Habitat loss from forest conversion to agriculture threatens tropical biodiversity. While wildlife typically avoids human-mediated risk, some species may adopt riskier strategies to access food in human-dominated landscapes. The recent conversion of a protected area into an agro-industrial plantation near Campo-Ma'an National Park, Cameroon, coincides with increased forest elephant sightings near human settlements, suggesting a change in habitat use. Camera traps were deployed and reconnaissance walks were conducted between camera trap stations to examine the influence of human activity on forest elephant habitat use. Households were interviewed to assess local experiences with human-elephant conflict and attitudes toward elephant conservation. Reconnaissance walks provided a greater amount of data than camera traps. Elephants tended to avoid sites with higher human activity and were less active during the midday peak in human activity. However, their proximity to settlements suggests an overall risk-taking behavior in their habitat use which, combined with site-level avoidance and distinct activity patterns that reduce encounters, points to a complex trade-off between human-mediated risk and resource access. Most households reported increased elephant presence and crop damage, often attributing it to the agro-industrial plantation. Vulnerability to crop damage better predicted attitudes toward elephant conservation than actual damage, and past interactions with wildlife and conservation authorities also appeared to influence perceptions. Despite increased human-elephant conflict, attitudes toward elephant conservation remained generally positive but could deteriorate if conflicts persist. Continued monitoring of forest elephants in human-dominated landscapes, effective land-use planning, and incorporating local perspectives into conservation strategies are crucial for sustainable coexistence between humans and wildlife.

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GENERAL INTRODUCTION

Habitat loss through land-use change, particularly through the conversion of forest to agriculture, is one of the most prevalent threats to tropical biodiversity (FAO, 2020; Hald-Mortensen, 2023; Nunes et al., 2022; Perrings & Halkos, 2015). As wildlife habitat shrinks, animals may be forced to move into areas closer to human settlements and agricultural fields (Liu et al., 2017; Sharma, Chettri, et al., 2020). This competition between wildlife and humans for resources and space increases the frequency of human-wildlife encounters across various landscapes, including urban zones, farmland, and around protected areas like national parks and wildlife reserves (Basak et al., 2023; Naughton-Treves & Treves, 2005; Seoraj-Pillai & Pillay, 2016; Storch et al., 2025). When these encounters result in costs to local communities, frustration may build towards the species involved, making it difficult to resolve human-wildlife conflict and undermining conservation efforts (Dickman, 2010; Tiller & Williams, 2021).

Elephants (*Loxodonta* sp.) are amongst the most difficult animals for humans to live alongside, due to the severe crop damage they can cause within a short period (Djoko, Weladji, & Paré, 2022b; Gross et al., 2018; Naughton-Treves & Treves, 2005; Ngama et al., 2019). Although elephant spatial risk avoidance through aversion of areas and infrastructures associated with humans is well-documented (Blake et al., 2008; Buij et al., 2007; Laurance et al., 2006; Wrege et al., 2024), risk-taking behaviors often emerge in human-dominated landscapes when the easy access and nutritional benefits of crops and secondary forest resources may outweigh the risk of interacting with humans (Djoko, Weladji, Granados, et al., 2022; Mills et al., 2018; Tiller et al., 2021). Even in the absence of lethal consequences, animals can perceive humans as a source of risk, often responding to nonlethal human disturbances similarly to how they respond to predators (Frid & Dill, 2002; Gaynor, Hojnowski, et al., 2018). For elephants, perceived risk can arise from both indirect human interactions like human-generated noise (Mortimer et al., 2021; Wrege et al., 2024) and direct encounters with humans, such as being chased or threatened with fire by people protecting their farms (Nelson et al., 2003; Ram et al., 2021). However, elephants may mitigate this risk by adapting their activity patterns to minimize such interactions, such as by increasing their nocturnal activity in areas associated with humans (Adams et al., 2022; Gaynor, Branco, et al., 2018; Hahn et al., 2022; Smit et al., 2023; Tiller et al., 2021; Wrege et al., 2010, 2024). Over time, this landscape of fear selects for species with flexible behavior, sometimes leading to habituation to nonlethal human presence (Gaynor et al., 2019).

In recent years, the Campo-Ma'an Technical Operational Unit (CMTOU) in southern Cameroon has faced significant pressure from the development of large-scale exploitation projects encroaching on wildlife habitats, including the construction of an agro-industrial plantation in a previously protected area in the Campo subdivision (AWF, 2022; Ayuk et al., 2023; Engolo et al., 2024; Forje et al., 2021). This area was found to be home to an important density of forest elephants (*Loxodonta cyclotis*) (AWF, 2022; Ayuk et al., 2023; Beukou-Choumbou et al., 2021). The establishment of the plantation is bound to exacerbate existing human-wildlife dynamics or generate new ones as elephants adapt to the changing landscape.

In the first chapter of this thesis, we deployed camera traps and conducted reconnaissance walks along the border between the declassified protected area and the community land of the Campo subdivision to assess the influence of human activity on forest elephant occurrence, as well as the overlap in activity patterns of both species. We explored whether elephants exhibit risk-avoidance or risk-taking strategies in response to humans. Given the varying results regarding the effectiveness and accuracy of camera traps compared to other survey methods (Gaugris et al., 2022; Nuñez et al., 2019; Wearn & Glover-Kapfer, 2019), we also compared results between the two monitoring methods to evaluate the effectiveness of each in documenting elephant and human occurrence in densely forested habitats.

In the second chapter, we conducted household surveys in the Campo subdivision to assess the change in elephant presence and elephant crop damage since the establishment of the agro-industry in the area, as well as identify local attitudes toward elephant conservation and report on people's preferences for mitigation solutions to the human-elephant conflict.

Overall, our aim was to understand how forest elephants use their habitat and interact with humans amidst habitat loss, and how local communities experience and perceive these interactions in an area where elephant and human habitats increasingly overlap. Ultimately, effective conflict resolution requires a comprehensive and interdisciplinary approach.

Chapter 1 Forest elephants in a human-dominated landscape: are they risk-takers?

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1.1 Abstract

Habitat loss from forest conversion to agriculture threatens tropical biodiversity. Despite documented risk-avoidance behaviors, some species may adopt riskier strategies to gain access to food. Recent conversion of a protected area in southern Cameroon to an agro-industrial plantation coincides with increased sightings of forest elephants near human settlements, which is unusual and suggests a drastic change in their habitat use. This study aims to examine the influence of human activity on forest elephant habitat use and evaluate the effectiveness of two survey methods in documenting elephant and human occurrence. Twenty-one camera traps were deployed along the border between the declassified protected area and the community land, and reconnaissance walks were conducted between camera trap stations. Results from both methods were compared. Elephant occurrence tended to be negatively affected by human activity, and elephants were inactive during peak human activity. However, their presence near human settlements suggests a general risk-taking behavior in habitat use. Moreover, reconnaissance walks proved more effective than camera traps in providing a greater amount of data. This risky proximity to humans points to a complex trade-off between risk and access to food resources, where the nutritional benefits and easy access of crops and secondary forest resources may outweigh the perceived human-mediated risk. At the same time, elephants may adopt strategies to minimize direct interactions with humans. Further habitat fragmentation and human encroachment on elephant habitats are expected in the near future. As elephant presence near human settlements often lead to increased conflict, continued monitoring of elephant habitat use in human-dominated landscapes using efficient survey methods is crucial to design up-to-date and effective management and conservation strategies.

Keywords: activity pattern, camera trap, Central Africa, elephant, human activity, reconnaissance walks

1.2 Introduction

Habitat loss through land-use change, particularly through the conversion of forest to agriculture, is one of the most prevalent threats to tropical biodiversity (FAO, 2020; Hald-Mortensen, 2023; Nunes et al., 2022; Perrings & Halkos, 2015). As wildlife habitat shrinks, animals may be forced to occupy areas in closer proximity with nearby human settlements and agricultural fields (Liu et al., 2017; Sharma, Chettri, et al., 2020), intensifying human-wildlife tensions and undermining conservation efforts (Dickman, 2010). Elephant movement patterns are driven by food and water distribution (Adams et al., 2022; Beirne et al., 2020; Blake, 2002; Blake & Maisels, 2023; Djoko, Weladji, Granados, et al., 2022), yet when elephant and human habitat overlap, human activity may outweigh the ecological determinants of their distribution (Blake, 2002; Blake & Maisels, 2023; Buij et al., 2007). Although elephant spatial risk avoidance through avoidance of areas and infrastructures associated with humans is well-documented (Blake et al., 2008; Buij et al., 2007; Gaugris et al., 2022; Laurance et al., 2006; Wrege et al., 2024), risk-taking behaviors often emerge in human-dominated landscapes as elephants venture into human areas and crop fields in search of food and water (Djoko, Weladji, & Paré, 2022b; Gaynor, Branco, et al., 2018; Mills et al., 2018; Poulsen et al., 2011; Shaffer et al., 2019; Tiller et al., 2021), when the easy access and nutritional benefits of crops and secondary forest resources may outweigh the risk of interacting with humans (Djoko, Weladji, Granados, et al., 2022; Mills et al., 2018; Tiller et al., 2021). However, elephants may mitigate this risk by adapting their activity patterns in areas associated with humans, such as by increasing night-time activity (Adams et al., 2022; Gaynor, Branco, et al., 2018; Hahn et al., 2022; Smit et al., 2023; Tiller et al., 2021; Wrege et al., 2010, 2024).

In the Campo-Ma'an Technical Operational Unit (CMTOU) in southern Cameroon, the critically endangered forest elephant (*Loxodonta cyclotis*) faces a rapidly changing environment. In recent years, the area has come under significant pressure from the development of large-scale exploitation projects, including the construction of an agro-industrial plantation in a previously protected area in the Campo subdivision (AWF, 2022; Engolo et al., 2024; Forje et al., 2021), which had revealed to be home to an important density of forest elephants (AWF, 2022; Ayuk et al., 2023; Beukou-Choumbou et al., 2021). Prior to the establishment of the agro-industry in the CMTOU, Djoko, Weladji, Granados, et al. (2022) found that elephant relative abundance was negatively affected by human activities such as hunting and logging. However, elephants were more likely to be present in areas with higher human presence, suggesting a trade-off between risk associated with human presence and access to food resources in secondary forest. Elephant temporal response to risk in this area has not yet been studied. The establishment of the plantation in this human-dominated landscape is bound to exacerbate existing or generate new human-wildlife dynamics (Ayuk et al., 2023). This is already suggested by the increasing number and frequency of reports of elephants venturing into community crop fields (African Wildlife Foundation, 2022; Urbain Nzitouo, Head of the Community and Participatory Management Service of MINFOF, personal communication, May 2023), which points to a drastic shift in their habitat use patterns as they adapt to the new landscape. The main aim of this study is to explore whether elephants in the Campo subdivision of the CMTOU exhibit spatial and temporal risk-avoidance or risk-taking strategies in response to humans. To do so, we will examine the influence of human activity on forest elephant occurrence and assess the overlap in diel activity patterns between the two species.

Monitoring wildlife in densely forested habitats may be challenging using direct observations due to limited visibility in thick understory and the elusive nature and sparse distribution of many species (Zwerts et al., 2021). Over the past decades, camera traps have proven to be a valuable tool in tropical forests by providing direct observations that would otherwise be challenging to collect (Chakraborty et al., 2021; Collins & Weladji, 2024; Djoko, Weladji, Granados, et al., 2022; Sanderson & Trolle, 2005; Tanwar et al., 2021; Wearn & Glover-Kapfer, 2019). Research in Central African rainforests also highlight the benefits of reconnaissance walks (also referred to as "recces"), to enhance data collection efficiency, notably on forest elephant populations (Blake et al., 2007; Fai et al., 2022; Gaugris et al., 2022; Hedges, 2012; Walsh & White, 1999; Whytock et al., 2021). Given the varying results regarding the effectiveness and accuracy of camera traps compared to other survey methods, depending on species, objectives, cost-to-time ratio, and environment (Gaugris et al., 2022; Nuñez et al., 2019; Wearn & Glover-Kapfer, 2019), our second research objective is to compare results from camera trapping with those from recces to evaluate the effectiveness of each method in documenting elephant and human occurrence. Understanding how forest elephants use space and interact with humans in light of recent rapid habitat loss is crucial for the development of up to date and effective management and conservation strategies (Shaffer et al., 2019), and selecting the appropriate method to report on it given the research objectives and resources at hand is imperative (Wearn & Glover-Kapfer, 2019; Zwerts et al., 2021).

1.3 Methods

1.3.1 Study area

The study was carried out in the Campo subdivision (~300,000 ha) of the Campo-Ma'an Technical Operational Unit (CMTOU) (771,000 ha) in southern Cameroon (Figure 1.1). This subdivision is located on the Atlantic coast, north of the mouth of Ntem River which marks the border with Equatorial Guinea. The climate is coastal equatorial, which is characterized by two dry seasons (July to mid-August and November to March) and two rainy seasons (April to June and mid-August to October) (Ayamba et al., 2024). The average annual rainfall generally decreases with increasing distance from the coast, with an average annual rainfall of 2800 mm in Campo (MINFOF, 2014b). Temperatures range between 24°C and 28°C along the coast. The CMTOU comprises unfenced land uses such as the Campo Ma'an National Park (CMNP, 264,000 ha), Forest Management Units (FMUs) for timber production, agro-industrial plantations, and a multipurpose Community Land area (CL) where farming, housing, infrastructures and activities for domestic purposes (hunting, fishing, artisanal logging of wood, and gathering) are permitted (AWF, 2022; Djoko, Weladji, Granados, et al., 2022; MINFOF, 2014b). Agriculture, primarily practiced as shifting cultivation using slash-and-burn methods, is the main local economic activity in the area (MINFOF, 2014b). Staple food crops such as manioc, plantain, corn, yam, and cocoyam, are grown during the two annual rainy seasons, and farmers experience interactions with wildlife from the Park all year round (Eyebe et al., 2012).

The Campo subdivision population is estimated at 7,000 habitants, reflecting an important increase over the past decade due to the growing demand for labor for large-scale projects in the CMTOU (Adolphe Edjabe, Election Cameroon manager for the Campo subdivision, personal communication, March 2025). However, it has a low population density compared to the rest of the CMTOU (MINAT, 2014). The CMTOU has been facing significant pressure from the development of large-scale projects such as the Kribi deep seaport, the Memve'élé hydroelectric dam, the agro-industrial development of HEVECAM (rubber company) and SOCAPALM (palm oil company), and mining exploration activities of SINOSTEEL (Engolo et al., 2024; Forje et al., 2021). Moreover, in 2019, the 60,000-ha protected area FMU 09-025 in the Campo subdivision was allocated to the agro-industry CAMVERT-SA for forest conversion into a palm oil plantation (Engolo et al., 2024; Forje et al., 2021; Mesmin et al., 2021). The latest inventory estimated the

CMTOU forest elephant population at 243 individuals, representing a decline of 55% in under six years (Beukou-Choumbou et al., 2021). With the second largest number of elephants within the CMTOU found in the FMU 09-025, after Dipikar Island in the CMNP (Ayamba et al., 2024; Beukou-Choumbou et al., 2021), increasing reports of elephants visiting the small-scale farms in the Campo subdivision coincide with the establishment of the plantation, suggesting a drastic change in elephant habitat use which leads to increased human-elephant interactions (AWF, 2022; Dhiaulhaq et al., 2024).

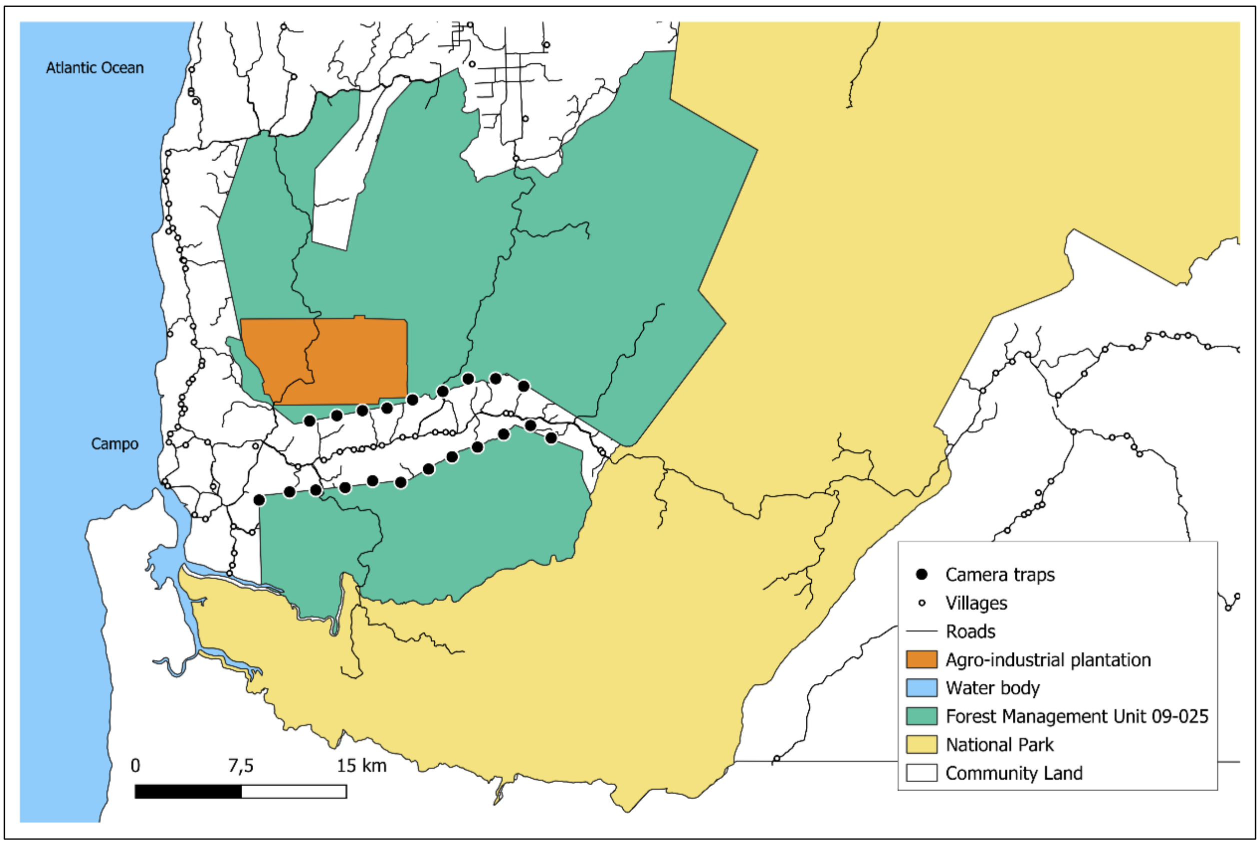

Figure 1.1. Study area in the Campo subdivision of the Campo-Ma'an Technical Operational Unit, Cameroon, displaying the Forest Management Unit that was allocated to an agro-industry currently being converted into a plantation, the Community Land, and the camera trap stations (in between which reconnaissance walks were conducted).

1.3.2 Data collection

Camera trapping. We deployed 21 Bushnell camera traps in the Campo subdivision of the CMTOU from May to October 2023. Camera trap stations were systematically placed at 2-km distances from one another along the border between the declassified FMU 09-025 and the Campo CL

(Figure 1.1). If the grid point was deemed unsuitable to position the camera, a more appropriate area was chosen within 100 m of the initial point based on accessibility and wildlife or human activity potential. Camera trap stations were placed along trails created and maintained by wildlife or near fruiting trees, at a distance of 5 to 15 meters from the target feature (trail or tree). Because one camera trap did not work for the totality of the survey duration, we dropped data from the camera trap and reported data from the remaining 20 camera traps stations. Three cameras got stolen and did not get replaced, as survey ended shortly after. Camera stations were visited on average once every 35 days to replace batteries and SD cards. Cameras were set at 80-90 cm height, angled horizontally, and set facing north or south to avoid low sunlight interfering with the cameras. Small trees and high foliage were cleared from in front of the cameras to avoid image obstruction. Cameras were active 24 hours/day, and motion sensors were set to trigger immediately when movement is detected, with a delay of 1 second between consecutive photos while movement was still occurring. Photos were date and time stamped (see Figure 1.2). To account for bias arising from multiple triggers of the same individual or group by the same camera, photos at a site within a 30-minute interval were counted as a single independent detection event (Chakraborty et al., 2021; Collins & Weladji, 2024; Djoko, Weladji, Granados, et al., 2022; Li et al., 2012; Tanwar et al., 2021). Camera trap images were processed using Timelapse 2.0 v 2.3.0.8 (Greenberg, 2022).

Reconnaissance walks. Reconnaissance walks are often used in tropical rainforests, notably to monitor forest elephant populations (Blake et al., 2007; Fai et al., 2022; Gaugris et al., 2022; Hedges, 2012; Omoregie et al., 2020; Walsh & White, 1999; Whytock et al., 2021). As line transects are inefficient in thick forest vegetation, walks were conducted following a general compass bearing using a path of least resistance along hunting trails and natural features like watercourses (Hedges, 2012; Walsh & White, 1999). This method minimizes damage to vegetation and creation of new access routes for hunters and paths for wildlife. Recces were carried out between consecutive camera trap stations (2-km transect length) when stations were visited to replace batteries and SD cards. Trained team of two surveyors walked at a pace of approximately 1 km/h recording elephant signs (e.g., footprints, dung, trails, direct contact, vocalization and smell, feeding activity, CT damage, tree used for scratching) and anthropogenic signs (e.g., hunting and logging trails and camps, snares, direct contact, gunshot and chainsaw sounds, knife, empty cartridge shell, tree cut, stolen CT) (Djoko, Weladji, Granados, et al., 2022; Gaugris et al., 2022), but only fresh signs were analyzed as to be able to avoid recounting the same sign during subsequent sampling periods (Fragoso et al., 2016; Hedges, 2012). Same species' signs found within 15 m of each other were treated as a single encounter (Gaugris et al., 2022). Each 2-km recce transect was surveyed within 16 hours, with interruptions for camera trap maintenance and for setting up camp at night when a suitable site was found.

Permits and ethics. Authorizations required for this study were provided by the Cameroonian Ministry of Scientific Research and Innovation (MINRESI), Ministry of Forestry and Wildlife (MINFOF), and Concordia University. Chiefs from the villages we would be crossing during our survey were met beforehand, informed of our work, and shown the corresponding authorization letters. We also took the time to visit them each time we passed through their village. Following the ethical guidelines suggested by Sharma, Fiechter, et al. (2020), community members were informed that their privacy would be respected, and no camera trap images would be published or shared with park staff for prosecution. Field assistants were local community members, contacted directly by our research team, and were paid for their work.

Figure 1.2. Sample camera trap images of forest elephants from the Campo subdivision, Campo-Ma'an Technical Operational Unit, Cameroon.

1.3.3 Data analysis

1.3.3.1 Influence of human activity on elephant occurrence

We were interested in testing the effect of human activity on elephant occurrence using direct (camera traps) and indirect (recces) observations. We ran a separate model for each field method. To allow non-linear relations to be considered, we performed generalized additive mixed models (GAMMs) using the MGCV package version 1.9-1 (Wood, 2023) with the restricted maximum likelihood method. Models were fitted with a negative binomial distribution and logistic link function to account for the overdispersion in our data. Covariates were tested for multicollinearity using Variance Inflated Factor (VIF) using car package version 3.1-2 (Fox & Weisberg, 2019). For each model, the independent variable of human activity was log-transformed to provide a better fit model than untransformed data. The smoothing parameter was set to be k = 4 based on the expected degrees of freedom (Pedersen et al., 2019). Increasing k did not change the fit of the model.

Camera trapping. Number of independent elephant detections per month at each camera station was used as the response variable, and human detection rate was used as a fixed effect (continuous variable). Human detection rate was determined as the number of independent human detections per month at a camera station, divided by the number of camera trap days multiplied by 100 (Collins & Weladji, 2024; Djoko, Weladji, Granados, et al., 2022; Li et al., 2012; Rovero & Marshall, 2009). The number of independent detections of a species and the corresponding detection rates can be interpreted as an index of species activity (Sollmann, 2018) and density (Rovero & Marshall, 2009) at a given site when subject to rigorous sampling procedures, and may be used to examine whether covariates explain variation in detection rates (Collins & Weladji, 2024; Sollmann, 2018). Camera trap station ID and month were modeled as random effects to account for spatial and temporal autocorrelation, and the log-transformed number of camera trap days per month at the station (a measure of the effort) was included as an offset term.

Reconnaissance walks. Number of encountered elephant signs along recces per month within each camera zone was used as the response variable, and human sign density was used as a fixed effect (continuous variable). For easier comparison of results between camera traps and recces, the number of encountered human signs along recces was divided by each camera trap zone area (Ahrestani et al., 2018; Djoko, Weladji, Granados, et al., 2022; Walsh et al., 2001; Yackulic et al., 2011), i.e. 1-km^2 centered on each camera station. Zone ID and month were modeled as random effects, and the log-transformed estimated linear distance traveled per month per zone (a measure of the effort) was included as an offset term. Due to hardware problems, we did not have access to the tracking data for each month, so we estimated the linear distance traveled by measuring the distance between all recorded signs using QGIS 3.32.3 (QGIS© software by QGIS Association). All types of activity signs were weighted equally in the analyses. To further compare the results obtained from the two survey methods, Spearman correlation coefficients were measured to assess the relationship between the number of detections and number of sign encounters for elephants and humans separately.

1.3.3.2 Activity patterns of elephants and humans

We were interested in comparing the diel activity patterns of elephants and humans using our camera trap data. Following the procedure developed by Ridout & Linkie (2009), activity patterns were estimated nonparametrically using kernel density estimates (probability of a detection event occurring at any given time). Overlap coefficient between activity patterns, which ranges from 0 (no overlap) to 1 (identical activity patterns), was then determined. The estimator of the overlap coefficient ($\widehat{D}$) of 1 was used because the number of events for each species was less than 50. Confidence intervals were generated from 10,000 smoothed bootstrapped samples using the percentile estimation, as it does not assume normality (Meredith & Ridout, 2014). We used percentiles to establish threshold overlap levels, where $\widehat{D_1} \leq$ 50th percentile indicates a low overlap value, 50th < $\widehat{D_1} \leq$ 75th a moderate overlap value, and $\widehat{D_1}$ > 75th percentile a high overlap value (Monterroso et al., 2014). We then performed a Kolmogorov-Smirnov test to determine if the distributions of activity patterns for elephants and humans differed significantly. Analyses were done using the overlap package version 0.3.9 (Meredith et al., 2024), which was developed specifically to visualize and analyze camera trap activity patterns. All statistical analyses were performed using R v. 4.2.3 (R Core Team, 2023), with a 95% level of significance.

1.4 Results

Our camera trap survey included 2164 camera trap days, with elephants being detected in 3001 photos for a total of 44 independent events, and humans in 217 photos for a total of 28 independent events (see Supplementary Table 1.7.1). Elephants were detected at 11 of 20 operational camera trap stations (55%), while humans were detected at 6 stations (30%). In all, around 335 kilometers were surveyed over 39 days for recent elephant and anthropogenic signs in recces, where 439 elephant signs and 102 human signs were encountered. Recent signs of elephants and humans were recorded in 20 of the 21 survey zones (95% each).

1.4.1 Influence of human activity on elephant occurrence

Camera trapping. Human activity had no statistically significant effect on forest elephant occurrence (edf = 1.795, x^2 = 4.873, p = 0.115), although the observed trend suggests a non-linear negative impact of human activity on elephant occurrence once detection rate exceeds a certain threshold (Figure 1.3).

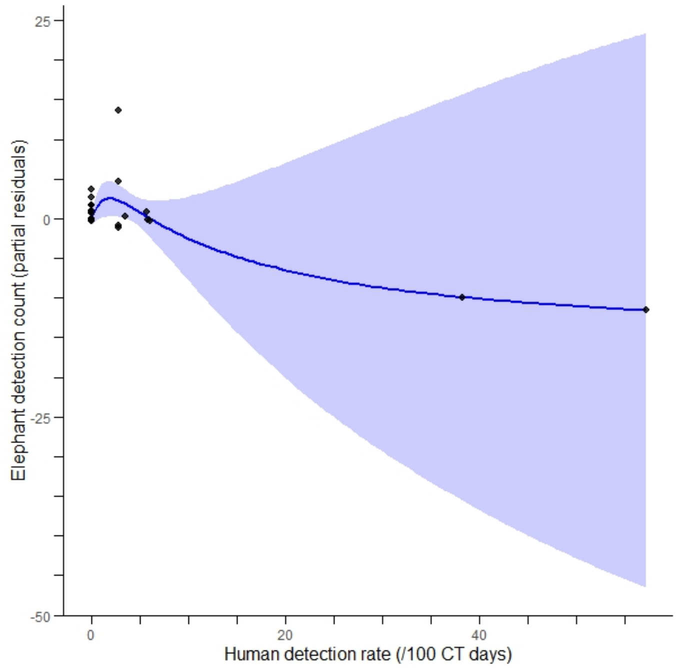

Figure 1.3. Relationship between forest elephant detection count (partial residuals) and human detection rate (count per 100 CT days). Model estimates are based on a generalized additive mixed model regression model. Shaded area corresponds to the 95% confidence interval.

Reconnaissance walks. Human activity had a significant negative effect on forest elephant occurrence (edf = 1.00, x^2 = 3.856, $p < 0.05$) (Figure 1.4).

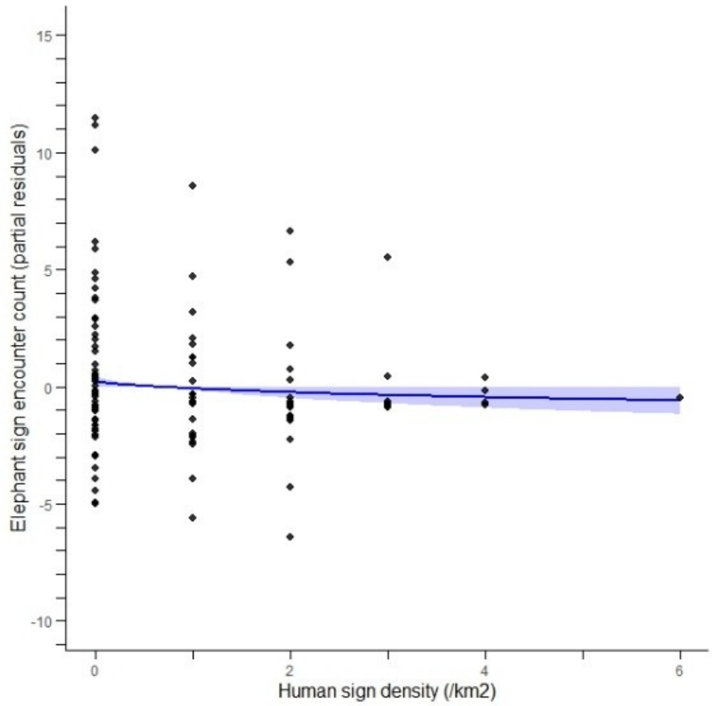

Figure 1.4. Relationship between forest elephant sign encounter count (partial residuals) and human sign density (count per km^2). Model estimates are based on a generalized additive mixed model regression model. Shaded area corresponds to the 95% confidence interval.

Correlation between survey methods. There was a positive Spearman correlation between elephant detection and sign encounter counts (ρ = 0.421, p < 0.001). There was however no correlation between the human detection and sign encounter counts (ρ = -0.108, p = 0.373).

1.4.2 Activity patterns of elephants and humans

Elephants and humans had a low activity overlap ($\widehat{D_1}$ = 0.55, CI = 0.39-0.72), and the distribution of activity differed significantly between the two species (D = 0.338, p = 0.029). Humans were primarily active during the day, with peak activity occurring midday around 11:00 (Figure 1.5). Elephants displayed a more consistent activity pattern across the 24-hour cycle, including nocturnal activity. Their activity showed a lull around 11:00, coinciding with the peak of human activity.

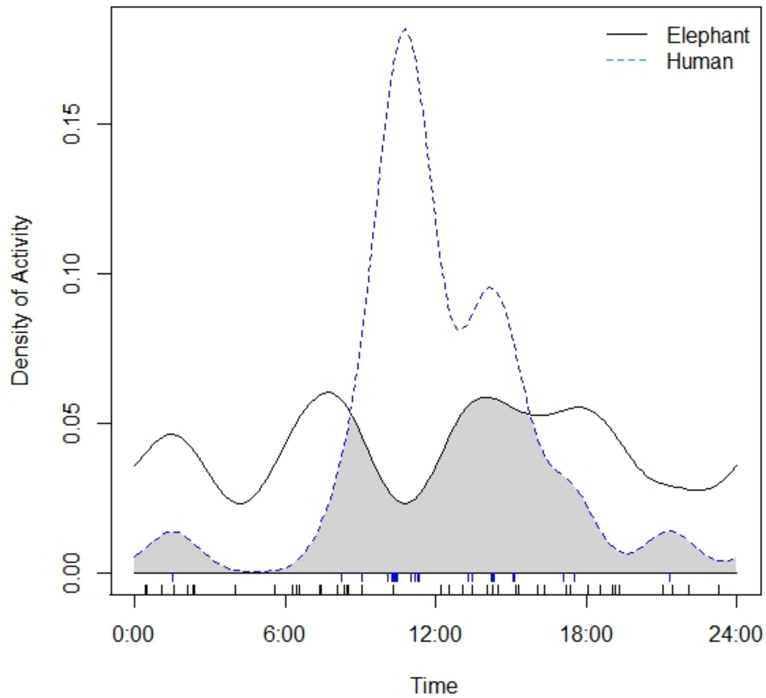

Figure 1.5. Kernel density estimates of the daily activity patterns of forest elephants and humans. Shaded area under both curves represents overlap between activity patterns. The rug at the bottom of the plot shows the distribution of independent detection events.

1.5 Discussion

1.5.1 Influence of human activity on elephant habitat use

Our findings reflect the complexity of the forest elephant's response to human activity in a human-dominated landscape, illustrating a multifaceted interaction between human-mediated risk and food resources. We found some evidence of reduced elephant occurrence as human activity increases from the two different survey methods, suggesting that human and forest elephants may spatially avoid each other to some extent. Our results align with findings in the CMTOU prior to the establishment of the agro-industrial plantation, where elephant relative abundance was negatively correlated with human activity such as hunting and logging (Djoko, Weladji, Granados, et al., 2022). However, the presence of elephants along the border between the Campo CL and the declassified FMU, hence within 2 to 2.5 km from the villages, suggests that elephants may be adopting a general risk-taking tactic by staying near human settlements, at least during the harvest period, which coincided with the timing of our study. This elephant presence is consistent with reports of elephants visiting villages and small-scale crop fields around the CMNP in recent years (African Wildlife Foundation, 2022; Dhiaulhaq et al., 2024; Urbain Nzitouo, Head of the

Community and Participatory Management Service of MINFOF, personal communication, May 2023). It also reflects previous findings in the CMTOU, where the likelihood of elephant presence was higher in the CL than in the FMUs or CMNP, especially during harvest period when crops are mature and farmers report more frequent crop-raiding incidents (Djoko, Weladji, Granados, et al., 2022). This risky proximity to human settlements may be coupled with temporal avoidance, as our findings indicate distinct activity patterns between the two species. Elephants displayed reduced activity during the midday peak in human activity and were active at night while humans were asleep. This suggests that elephants may adjust their activity patterns to minimize encounters with humans. These results align with Davis et al. (2023) in Kasungu National Park, Malawi, who found that while savanna elephants did not avoid sites with higher human activity, they did avoid peak human activity times and exhibit nocturnal behavior when using roads. In areas associated with humans, elephants are indeed found to increase night-time activity (Adams et al., 2022; Gaynor, Branco, et al., 2018; Hahn et al., 2022; Smit et al., 2023; Tiller et al., 2021; Wrege et al., 2010, 2024), as well as decrease crop raiding during the full moon to avoid higher visibility (Gunn et al., 2014), increase walking speed at night (Hahn et al., 2022) or when traversing agricultural areas (Songhurst et al., 2016; Tiller et al., 2021) and roads (Mills et al., 2018), and visit villages for shorter durations (Mbamy et al., 2024; Tiller et al., 2021). Our findings highlight the importance of considering both the spatial and temporal dimensions of forest elephant responses to human activity, as it enhances our understanding of the multifaceted strategies this species employs to mitigate risk in human-dominated landscapes.

Our results suggest a complex interaction between human-mediated risk and food resources, where elephants may be balancing the risks associated with proximity to human settlements against the benefits of accessing high-value food areas like crop fields and secondary forest. At the same time, they may employ temporal strategies to minimize direct interactions with humans. As crops can contain higher digestible energy than wild food plants (Branco et al., 2019), and clumped resources like crop fields provide a high nutritional payback with relatively lower search times (Blake & Inkamba-Nkulu, 2004; Branco et al., 2019), the nutritional benefits and easy access of crops may therefore outweigh the perceived risk of areas with higher human activity (Mills et al., 2018; Tiller et al., 2021), especially when crops are mature (Branco et al., 2019; Djoko, Weladji, & Paré, 2022b; Matsika et al., 2024; Tiller et al., 2021). Elephant habitat selection and movement patterns can be influenced by seasonality (Djoko, Weladji, Granados, et al., 2022; Loarie et al., 2009; Mills et al., 2018), yet if the availability and quality of food in the elephant range declines, notably due to human encroachment, elephants may crop-raid throughout the whole year (Tiller et al., 2021). The observed proximity to human settlements could also be partially due to secondary forest near villages, which has been shown to attract wildlife, including forest elephants (Blake, 2002; Breuer & Ngama, 2021; Djoko, Weladji, Granados, et al., 2022; Poulsen et al., 2011), due to the higher abundance of young trees and secondary species (Poulsen et al., 2011).

Moreover, the presence and development of large-scale projects in the CMTOU implies a population increase in the area due to the demand for labor, which may, in turn, drive greater encroachment on elephant habitats (Billah et al., 2021; Forje et al., 2021), with humans and elephants competing for resources and space (Billah et al., 2021; Granados et al., 2012). This increased human activity and habitat loss in the CMTOU may overall heighten the perceived human-mediated risk level of the area, which could lead to a change in elephant habitat use through increased risk-taking behaviors to gain access to food. Tiller et al. (2021) reported a similar phenomenon in African savanna elephants, where spatial and temporal patterns of crop raiding by savannah elephants had changed seemingly in response to increased agriculture expansion and increased cattle grazing within protected areas in the previous 20 years. However, at fine-scale, human-mediated pressure might be low enough to allow elephants to occur near villages and allow for constant feeding opportunities with low risk (Djoko, Weladji, Granados, et al., 2022), especially as the population density outside key cities like Campo is low (Tchouto et al., 2006). The intensive maintenance and vigilance required by certain mitigation methods to deter elephants from fields at night, such as night-time guarding and chili fires, can create barriers to effective mitigation (Denninger Snyder & Rentsch, 2020; Parker et al., 2007). As such, none of the mitigation techniques implemented in the CMTOU were found to effectively reduce crop raiding by elephants and other wildlife (Djoko, Weladji, & Paré, 2022b). Moreover, hunting regulations prohibit to hunt forest elephants (Ngandjui & Ringuet, 2010) and regular anti-poaching effort is conducted in the CMNP (AWF, 2022), potentially lowering the perceived and real human-mediated risk in the area (Blake & Maisels, 2023). Yet, wildlife poaching offenses in the CMNP has increased drastically from 2008 to 2020 (Engolo et al., 2024), including some elephant poaching occurrences (Djoko, Weladji, & Paré, 2022b).

1.5.2 Comparison between survey methods

Recces proved more effective than camera traps in detecting both species in a greater number of sites and providing a greater amount of data overall. Although camera traps are valuable for detecting a large number of species (Wearn & Glover-Kapfer, 2019) and quickly and confidently identifying them (Thomas et al., 2020), sign encounter data can prove more efficient and effective for assessing species occurrence when number of sites where a species is detected matters (Fragoso et al., 2016, 2019; Gaugris et al., 2022). While the two survey methods produced consistent results for detecting elephants, elephants were detected in a greater number of zones using recces than camera traps, and encounter rates were higher than detection rates. Humans were also detected in a greater number of zones using recces than camera traps, although the two methods did not produce consistent results for detecting human activity. This discrepancy could be attributed to humans avoiding camera traps after first encountering them, especially since cameras may capture illegal activities, making people fearful of being recorded (Sandbrook et al., 2018). This explanation is further supported by the theft of three camera traps during our survey, although community members were informed that their privacy would be respected. Moreover, it was difficult to determine age of certain human signs, such as tree cutting, camps and empty cartridges. Discarding them from the analysis may have led to an underestimation of indirect signs of human activity. Our study highlights the importance of understanding the requirements of different survey methods to select the most appropriate ones based on research objectives, including focal species and environmental context. When possible, researchers still recommend the combination of different survey methods to maximize detection of all species and generate a more complete estimate of the target variables, especially in study sites with low species densities and activity (Fragoso et al., 2016; Moore et al., 2020; Nuñez et al., 2019; Plumptre, 2000).

1.6 Implications for conservation

The spread of industrial logging has significantly transformed elephant habitats in Central Africa (Laporte et al., 2007), with Africa having the highest annual rate of net forest loss in 2010-2020 (FAO, 2020). However, in recent decades, oil palm plantations have increasingly become controversial due to their role in tropical deforestation and biodiversity loss (Oosterveer, 2015). This concern is particularly pronounced in Cameroon, which has the greatest amount of deforestation in Africa due to palm oil plantation expansion (Ordway et al., 2017). Accordingly, it is anticipated that palm oil plantations will soon surpass logging as a primary source of landscape disturbance in the CMTOU (Djoko, Weladji, & Paré, 2022b). The subsequent population increase in the area due to the demand for labor may also increase demand for meat (Nlom, 2021), potentially contributing to rising poaching levels and threatening the survival of critical wildlife species (Engolo et al., 2024). As human disturbances in the CMTOU are increasing drastically as human population and agro-industrial activity increase, our findings highlight the possibility of habituation of elephants to human presence if the potential nutritional rewards outweigh the perceived dangers. That complex interaction between response to risk, food availability and quality, and forest elephant movement likely plays a significant role in one of the most critical issues threatening their conservation: crop raiding and increasing human-elephant conflicts (Blake & Maisels, 2023). Human-wildlife conflict fosters frustration among local communities and may justify retaliatory killings and negative perceptions toward conservation efforts (Dickman, 2010; Djoko, Weladji, & Paré, 2022b). This could threaten the long-term survival of forest elephants, a critically endangered species. This further highlight the need to continue monitoring forest elephants in human-dominated landscapes, as assessing the impacts of habitat changes on their spatial and temporal patterns and strategy choice is essential for developing effective and up-to-date management and conservation strategies (Breuer et al., 2016; Djoko, Weladji, Granados, et al., 2022).

Furthermore, monitoring wildlife in densely forested habitats may be challenging due to limited visibility and the elusive behavior of many species (Zwerts et al., 2021), yet wildlife monitoring is essential for conservation research and evidence-based decision-making. In parallel, given the often limited resources available and insufficient financial capacity for monitoring biodiversity, particularly in tropical countries (Achieng et al., 2023; Gordon & Newton, 2006), it is essential to use the most efficient survey methods. Maximizing data collection while minimizing costs and time can make research more accessible and ultimately support better decision-making in wildlife management and habitat preservation.

1.7 Supplementary material

Table 1.7.1. Summary of camera traps (CT) efforts. CTs that had total data loss were also excluded from analysis. CTs with partial data losses lead to incomplete data collection for some months. Four additional CTs were deployed and set to video mode, but their data were excluded from the analysis.

Total number of CT stations	21
Number of CT that had total data loss	1
Number of CT that had partial data loss	14
Number of CT stolen (without replacement)	3
Expected number of CT days	2940
Realized number of CT days	2165
Percent realized (%)	73.64
Overall number of months realized	4

Chapter 2 Influence of human-elephant conflict on local attitudes toward elephant conservation in the Campo-Ma'an landscape, southern Cameroon

2.1 Abstract

An increase in human-elephant conflict (HEC) in the Campo-Ma'an landscape, southern Cameroon, coincides with the recent conversion of a protected area into an agro-industrial plantation, threatening both locals' livelihood and forest elephants. The consequences of such intensified HEC on local attitudes toward elephant conservation remain poorly understood. Households were interviewed to assess human-elephant dynamics through the scope of elephant presence near villages, crop damage, and local attitudes toward elephant conservation across three subregions. Respondents were also asked to suggest potential solutions to mitigate HEC. Most households reported an increased elephant presence and crop damage, and level of conflict varied across subregions. Many attributed the increase in HEC to the agro-industrial plantation, but few suggested that the agro-industry could play a role in mitigation efforts. Given the intensity of the conflict, communities preferred quick solutions over long-term strategies. Vulnerability to crop damage better predicted attitudes toward elephant conservation than actual damage. Individuals accustomed to elephants visiting their fields tended to be more positive toward elephant conservation than those for whom the conflict was new, highlighting the potential role of past interactions with wildlife and conservation authorities in shaping attitudes toward species conservation. While local attitudes toward elephant conservation remained favorable overall, these attitudes may deteriorate if HEC is not addressed, as unresolved threats to food security and human livelihoods may lead to frustration and undermine conservation efforts. Effective land-use planning, preventing further encroachment, and addressing HEC in a way that considers local preferences are essential for sustainable human welfare and community-driven elephant conservation.

Keywords: attitudes, conservation, crop raiding, human-elephant conflict, forest landscape, mitigation

2.2 Introduction

Habitat loss through agricultural expansion is one of the most prevalent threats to tropical biodiversity (FAO, 2020; Hald-Mortensen, 2023; Kissinger et al., 2012; Perrings & Halkos, 2015), and places farmers on the front lines of conflict with wildlife (Tiller & Williams, 2021). As wildlife habitat shrinks, animals may be forced to move into areas closer to human settlements and agricultural fields (Liu et al., 2017; Sharma, Chettri, et al., 2020), and such agricultural lands can provide high-value and easily accessible food resources for wildlife, especially when crops are mature (Branco et al., 2019; Djoko, Weladji, & Paré, 2022b; Tiller et al., 2021). In the aftermath of crop damage, local communities may be frustrated with wildlife and the responsible species, making it difficult to resolve human-wildlife conflict and undermining conservation efforts (Dickman, 2010). Moreover, human-wildlife conflicts often reflect underlying human-human conflicts, such as those between local communities and authorities, which are often overlooked in conflict studies (Dickman, 2010; Granados & Weladji, 2012; Weladji et al., 2003).

Elephants are a difficult animal for humans to live alongside (Djoko, Weladji, & Paré, 2022b; Granados & Weladji, 2012; Naughton-Treves, 1998; Tiller & Williams, 2021) due to the severe crop damage they can cause within a short period (Djoko, Weladji, & Paré, 2022b; Gross et al., 2018; Naughton-Treves & Treves, 2005; Ngama et al., 2019; Tsegaye et al., 2023). Across much of elephant range in Africa and Asia, remaining elephant habitat is experiencing significant encroachment by humans, with humans and elephants competing for resources and space (Billah et al., 2021; Forje et al., 2021; Liu et al., 2017; Maisels et al., 2013; Mmbaga et al., 2017; Sanare et al., 2022; Thant et al., 2023; Tiller & Williams, 2021). Forest elephant (*Loxodonta cyclotis*) populations in West and Central Africa have significantly declined in the last decades (Beukou-Choumbou et al., 2021; Gobush et al., 2021; Maisels et al., 2013) and most populations exist surrounded by monoculture plantations, timber concessions and human settlements (Melle Ekane et al., 2023; Omoregie et al., 2020; Scalbert et al., 2023). As clumped resources like crop fields provide a high nutritional payback with relatively lower search times (Blake & Inkamba-Nkulu, 2004; Branco et al., 2019), agricultural fields on the edge of elephant habitat make for high-value and easily accessible resources that outweigh the perceived predation risk of areas with higher human activity (Mills et al., 2018; Tiller et al., 2021). Unfortunately, mitigation methods to deter elephants from fields may be difficult to apply due to site inappropriateness or habituation (Djoko, Weladji, & Paré, 2022b; Enukwa, 2017; Nelson et al., 2003).

Human-elephant conflict (HEC) is a significant problem for people near protected areas, such as in the Campo-Ma'an Technical Operational Unit (CMTOU) in southern Cameroon, where HEC arises mainly from crop damages by elephants (Djoko, Weladji, & Paré, 2022b; Forje & Tchamba, 2022). In recent years, the CMTOU has come under significant pressure from the development of large-scale exploitation projects encroaching on elephant habitats, including the construction of an agro-industrial plantation in a previously protected area in the Campo subdivision (AWF, 2022; Ayuk et al., 2023; Engolo et al., 2024; Forje et al., 2021) that was found to be home to an important density of forest elephants (AWF, 2022; Ayuk et al., 2023; Beukou-Choumbou et al., 2021). Prior to the establishment of the agro-industry, Djoko, Weladji, Granados, et al. (2022) had already found elephants were more likely to be present in areas with higher human activity, suggesting a trade-off between risk of mortality associated with human presence and access to food resources. The establishment of the plantation was bound to exacerbate existing or generate new human-wildlife dynamics (Ayuk et al., 2023) as elephants adapt to the new landscape, as is suggested by recent findings of elephant presence near villages and increasing number and frequency of reports of elephants venturing into community crop fields (African Wildlife Foundation, 2022; MINFOF, personal communication, May 2023).

The main challenge in areas with HEC is balancing conservation with human interests (Granados & Weladji, 2012; Liu et al., 2017; Mmbaga et al., 2017). Understanding local communities' attitudes and perceptions provides valuable insights into various forms and predictors of tolerance toward species (Thekaekara et al., 2021) and people's preferences for different management strategies (Hodgson et al., 2020). In the present study, we assess the human-elephant dynamics in the Campo subdivision of the CMTOU using questionnaires, in a context of recent landscape changes. We expect local people to confirm the increase in elephant presence and elephant crop damage reported by conservation organizations and researchers since the establishment of the agro-industry in the area (African Wildlife Foundation, 2022; Urbain Nzitouo, Head of the Community and Participatory Management Service of MINFOF, personal communication, May 2023). As this increase in human-elephant proximity and interactions results in considerable crop and financial losses and increased fear throughout the community, we predict that people most severely affected by crop damage will foster negative attitudes toward elephant conservation (Abdullah et al., 2019; Carroll et al., 2025; Nsonsi et al., 2017; Omoregie et al., 2019). As the potential impacts of resource destruction are intensified by a lack of alternative income sources (Dickman, 2010; Naughton-Treves & Treves, 2005), we also expect people who are solely dependent upon agriculture for their livelihood to hold more negative views toward the conservation of the conflictual species (Tobias Ochieng et al., 2021). However, individuals with experience living alongside wild animals tend to be less fearful of them (Røskaft et al., 2003), and with scientific education efforts aimed at raising awareness about the importance of wildlife (Govind & Jayson, 2021), we predict that those with longer experience of having elephants visit their fields will exhibit higher tolerance for the species (Li et al., 2023), and therefore be more positive toward elephant conservation. Lastly, we will report solutions to mitigate the current human-elephant conflict suggested by respondents, as local people's preferences for different management options are crucial to establish long-lasting, participatory and community-oriented HEC mitigation strategies (Tobias Ochieng et al., 2021). Ultimately, effective conflict resolution requires a comprehensive and interdisciplinary approach, where conservation biologists must consider the wider socio-economic, ecological, and cultural factors that drive conflict (Basak et al., 2023; Dickman, 2010).

2.3 Methods

2.3.1 Study area

The study was carried out in the Campo subdivision (~300,000 ha) of the CMTOU (771,000 ha) in southern Cameroon. This subdivision is located on the Atlantic coast, north of the mouth of Ntem River which marks the border with Equatorial Guinea. It can be divided into three geographical subregions that are east, south, and north of the city of Campo (Figure 2.1). The climate is coastal equatorial, which is characterized by two dry seasons (July to mid-August and November to March) and two rainy seasons (April to June and mid-August to October) (Ayamba et al., 2024). The average annual rainfall generally decreases with increasing distance from the coast, with an average annual rainfall of 2800 mm in Campo (MINFOF, 2014b). Temperatures range between 24°C and 28°C along the coast. The CMTOU comprises unfenced land uses such as the Campo Ma'an National Park (CMNP) (264,000 ha), Forest Management Units (FMUs) for timber production, agro-industrial plantations, and a multipurpose Community Land area (CL) where farming, housing, infrastructures and activities for domestic purposes (hunting, fishing, artisanal logging of wood, and gathering) are permitted (AWF, 2022; MINFOF, 2014b). Agriculture is the main local economic activity in the Campo subdivision, practiced by almost the entire population either as a primary or secondary occupation (MINAT, 2014). It is primarily shifting cultivation using slash-and-burn methods. The most important food crops produced include manioc, plantain, corn, peanut, pepper, yam, okra, and cocoyam. These crops are primarily grown for subsistence, with sales only involving surplus production. Staple food crops are grown during the two annual rainy seasons, and farmers experience interactions with wildlife from the Park all year round (Eyebe et al., 2012).

The Campo subdivision population is estimated at 7,000 inhabitants, reflecting an important increase over the past decade due to the growing demand for labor from large-scale projects in the CMTOU (Adolphe Edjabe, Election Cameroon manager for the Campo subdivision, personal communication, March 2025). However, it has a low population density compared to the rest of the South Region (MINAT, 2014). The CMTOU is facing significant pressure from logging, mining exploration, and agro-industrial activities (rubber and palm oil), as well as from the development of the Kribi deep seaport, the Memve'élé hydroelectric dam, and the Camiron railway line (Dhiaulhaq et al., 2024; Engolo et al., 2024; Forje et al., 2021). In 2019, the 60,000-ha protected FMU 09-025 area in the Campo subdivision was allocated to the agro-industry CAMVERT-SA for forest conversion into a palm oil plantation (Engolo et al., 2024; Forje et al., 2021; Mesmin et al., 2021). The declassified area encompasses two blocks, one covering 40,000 ha to the north and the other 20,000 ha to the south, adjacent to Dipikar Island in CMNP (Mesmin et al., 2021), which is a biodiversity hotspot (Beukou-Choumbou et al., 2021; Tchouto et al., 2006). The latest inventory estimates the CMTOU forest elephant population at 243 individuals, which represents a decrease of 55% in under six years (Beukou-Choumbou et al., 2021). With the second largest number of elephants within the CMTOU found in the FMU 09-025, after Dipikar Island (Ayamba et al., 2024; Beukou-Choumbou et al., 2021), increasing reports of elephants visiting the small-scale farms in the Campo subdivision coincide with the establishment of the plantation, suggesting a drastic change in elephant habitat use, which leads to increased human-elephant interactions (AWF, 2022; Dhiaulhaq et al., 2024).

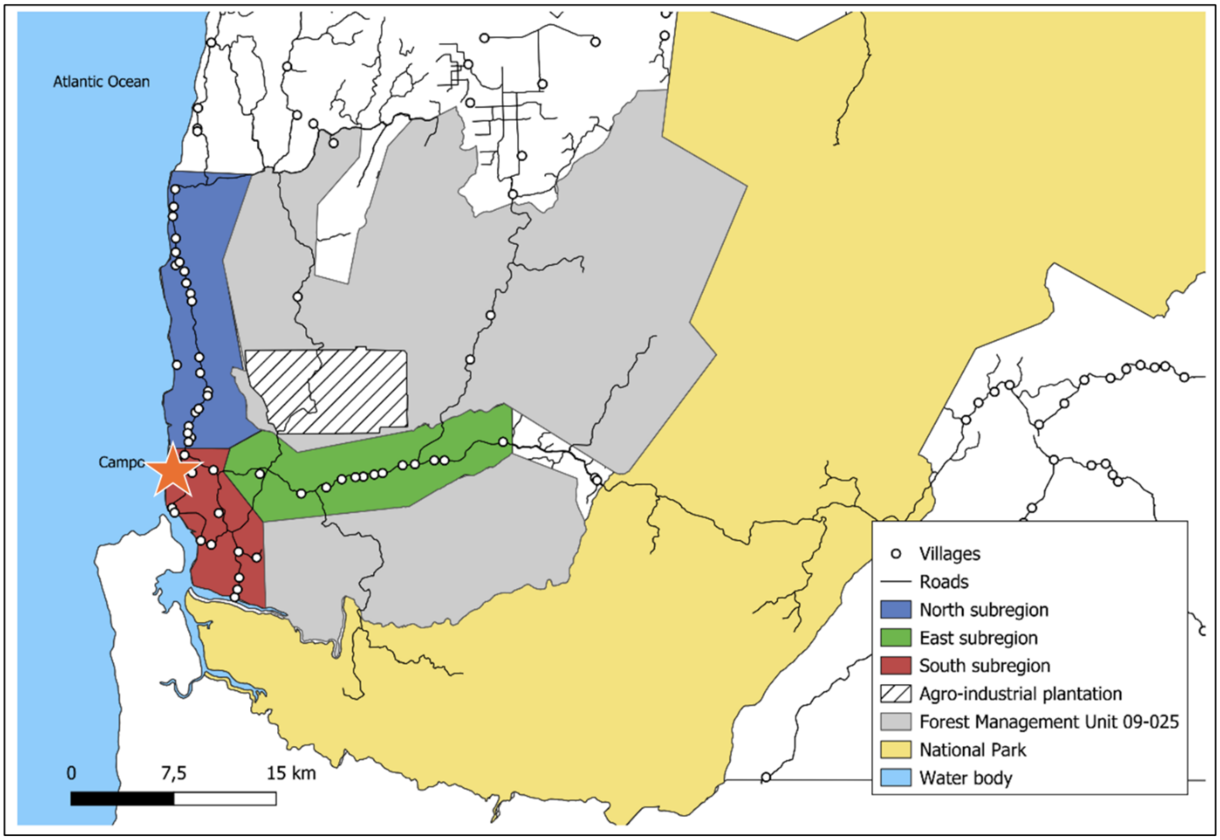

Figure 2.1. Study area in the Campo subdivision of the Campo-Ma'an Technical Operational Unit, Cameroon, displaying the villages of the subdivision, the three subregions that were covered during the household interviews (north, south, and east of the city of Campo), and the Forest Management Unit that was allocated to an agro-industry in 2019 and that is currently being converted into a plantation.

2.3.2 Data collection

Data on local perception of elephants and HEC were collected in June and July 2023 in the Campo subdivision of the CMTOU. A total of 119 households across 14 communities were interviewed, including 43, 45, and 41 households in the east, south, and north subregions of Campo, respectively. Six people refused to participate in the interview. Most respondents were male (67%) and most were older than 46 years old (72%). Households within a village were interviewed based on their availability at the time we were present and willingness to take part in the research. We interviewed households' heads, their wives, or any adult (≥18 years old) present. Following Djoko, Weladji, & Paré (2022b)'s methods, the interview consisted of a semi-structured questionnaire (see Household questionnaire in Supplementary material). The topics covered included: elephant presence in the region (within 4 years of interview), elephant crop damage (current and within 4 years of interview), current attitude toward elephant conservation, and solutions to attenuate HEC. A four-year period was used to relate to the 2019 establishment of the plantation in an objective way. Estimations of wildlife and elephant crop damage were grouped into three categories of damage severity: Low (< 25%), moderate (25-75%), and severe (> 75%) based on Djoko, Weladji, & Paré (2022b) and Granados & Weladji (2012), and a data clustering method was used to confirm observed patterns. We conducted the interviews in an informal, conversational style to ensure a non-intimidating exchange between the interview team and respondents (Liu et al., 2011). The main interviewer (Lea Mimeault) was accompanied by a local person to help create a trusting atmosphere. Interviews were conducted in French whenever possible, as most respondents were fluent. Otherwise, a local interpreter assisted with communication. Furthermore, the topic of the agro-industry was only addressed if the respondent brought it up first, as to not risk inadvertently raising conflict (Dickman, 2010).

This research was performed in accordance with the Certification of Ethical Acceptability for Research Involving Human Subjects n°30018218 delivered by the Concordia University Human Research Ethics Committee. Locally, the research protocol was approved by MINFOF (Ministry of Forestry and Wildlife, Cameroon), and the research permit was granted by MINRESI (Ministry of Research, Cameroon). Chiefs from the villages we would be visiting were informed beforehand and informed of our work and the corresponding authorization letters. Interview team members were community members, contacted directly by our research team, and were paid for their work.

2.3.3 Data analysis

As the number of respondents in some villages was often low, villages were grouped into three geographical subregions based on field surveys. Chi-square tests (or Fisher's exact tests were used if counts were lower than five) were used to compare across subregions 1) perceptions of respondents regarding a change in elephant presence in the area from 2019 to 2023, 2) proportions of respondents who mentioned the palm plantation as a reason for an increase in elephant presence, 3) perceived level of crop damage by wildlife and elephants, 4) time since elephants first began visiting their fields, 5) proportions of mentions of elephants as a crop raiders, 6) perceived change in elephant crop damages from 2019 to 2023, and 7) proportions of mentions of different mitigation techniques. When the response distribution differed significantly, pairwise comparison tests with

Bonferroni correction were used to examine which subregions differed. Analyses were performed using the stats package version 4.2.3 (R Core Team, 2023). People having been living in the region for less than four years at the time of the interview were excluded from the analysis for time-related question, and only people that had crop fields were considered in analyses on crop damage.

We categorized people's attitudes toward elephant conservation as either positive, neutral, or negative, and we assigned scores of 1, 0, and -1 to positive, neutral, and negative attitudes, respectively. We then conducted an ordinal logistic regression using the MASS package version 7.3-58.2 (Venables & Ripley, 2002) to examine whether the following variables predicted perceptions toward elephant conservation: perceived level of elephant crop damage, time since elephants first began visiting their fields, whether agriculture is the sole income source, gender, and age. Stepwise model selection using a significance threshold of $\alpha = 0.10$ was applied. The fittest model retained only whether agriculture is the sole income source. To preserve interpretability, we retained variables in the final model that were associated with our hypotheses, regardless of statistical significance: perceived level of elephant crop damage, time since elephants first began visiting their fields, and whether agriculture is the sole income source. A Fisher's exact test was then used to test whether attitudes differed across subregions. The predictor variables were tested for multicollinearity using Variance Inflation Factor (VIF) with the car package version 3.1-2 (Fox & Weisberg, 2019). The proportional odds assumption was tested using the packages brant version 0.3-0 (Schlegel & Steenbergen, 2020) and ordinal version 2023.12-4 (Christensen, 2023). All statistical analyses were performed using R v. 4.2.3 (R Core Team, 2023), with a 95% level of significance.

2.4 Results

2.4.1 Elephant presence

Seventy-eight percent of respondents in the Campo subdivision noticed an increase in elephant presence in the area from 2019 to 2023. Perceptions of respondents differed across subregions (Fisher's Exact Test, $p < 0.001$), where perceptions in the north subregion differed from the east and south subregions ($p < 0.001$ for both), but no difference was observed between the east and south subregions ($p = 0.599$). Most respondents in the east and south subregions thought elephant presence had recently increased in the area (94% and 100% of respondents, respectively) (Figure 2.2), whereas respondents in the north subregion exhibited a broad range of responses, with 41%

noticing an increase in elephant presence in the area and 38% reporting presence had remained relatively constant.

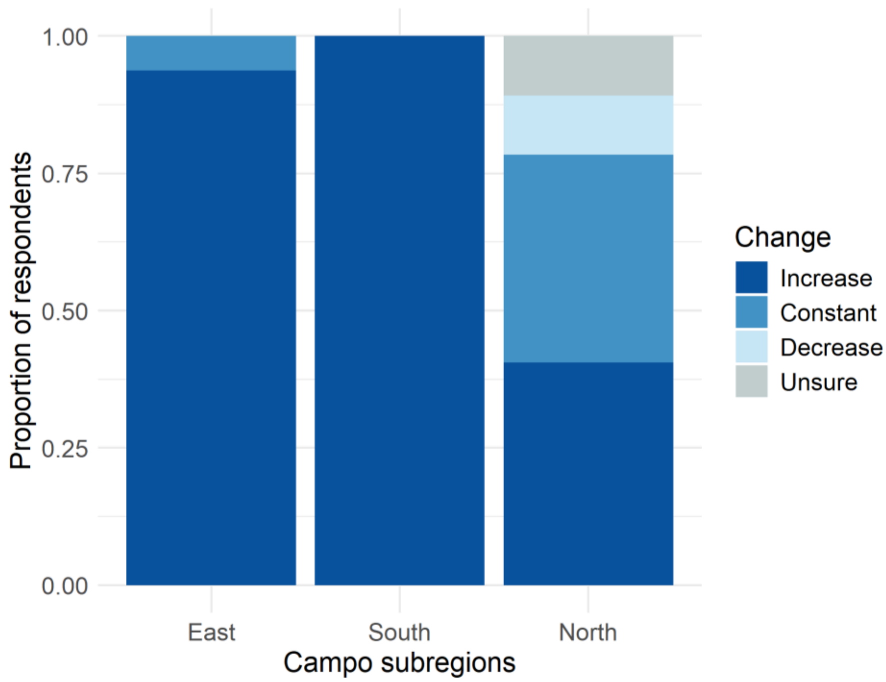

Figure 2.2. Proportion of respondents reporting changes in elephant presence in the region from 2019-2023, according to 108 respondents in the east (N=32), south (N=39), and north (N=37) subregions of the Campo subdivision. Respondents who had been living in the region for less than four years were removed from this analysis.

Of the respondents reporting an increase in elephant presence, 73% mentioned the establishment of the palm plantation as an explanatory factor (Table 2.1). Proportions of respondents who mentioned the plantation did not differ across the three subregions (Fisher's Test, $p = 0.321$), yet respondents in the east subregion had a broad range of responses, with the protected status of forest elephants (e.g. regulations prohibiting hunting) and other forest exploitation activities causing habitat loss (e.g. logging activity) being the second and third most suggested explanations for the perceived elephant presence increase in the area.

Table 2.1. Percentage of respondents attributing certain factors to the elephant presence increase in the region from 2019-2023, according to 84 respondents in the east (N=30), south (N=39) and north (N=15) subregions of the Campo subdivision. Respondents could report more than one factor, resulting in a total of 103 responses.

Reason	**Total**	**East**	**South**	**North**
Palm plantation	73	63	80	73
Other forest exploitation activities	11	20	8	0
Protected status	12	23	8	0
Unfenced park	6	10	0	13
Do not know	8	3	13	7
Other	13	27	5	7

2.4.2 Elephant crop damage

Elephant was the second most reported crop raider (56%), following the cane rat (88%) (Table 2.2). Proportions of respondents mentioning elephants as a crop raider differed across the three subregions (Fisher's Exact Test, $p < 0.001$), where fewer households in the north subregion reported crop raiding by elephants (10%) than in the east and south subregions (76% and 86% of respondents, respectively).

Table 2.2. Percentage of respondents mentioning different species responsible for crop raiding incidents, according to 112 respondents in the east (N=30), south (N=42), and north (N=40) subregions of the Campo subdivision. Respondents could mention multiple species, resulting in a total of 357 responses.

Animal	**Total**	**East**	**South**	**North**
Cane rat (*Thryonomys swinderianus)*	88	87	83	93
Elephant (*Loxodonta cyclotis*)	56	76	86	10
Porcupine (*Atherurus africanus*)	43	28	24	75
Small monkeys	43	41	41	48
Other rodents	29	27	10	50
Other ungulates	22	30	12	28
Reptiles	19	7	21	25
Apes and large monkeys	18	14	14	25
Other species	5	3	5	8

Sixty-eight percent of respondents reported losing 25-75% of crop fields in the most recent harvesting season due to wildlife, while 18% lost <25% and 14% lost >75% of their fields. Perceived level of damage to crop fields by wildlife did not differ across subregions (Fisher's Exact Test, $p = 0.203$). Fifty-two percent of respondents reported that <25% of wildlife damage was caused by elephants specifically, while 19% reported their damage to 25-75% and 29% to >75%

of their fields. In addition to consumption, trampling and footing were also observed as causes of crop damage. Perceived level of damage differed across subregions (Fisher's Exact Test, $p < 0.001$), where perceptions in the north subregion differed from the east and south subregions ($p \leq 0.001$ for both), but no difference was observed between the east and south subregions ($p = 0.107$) (Figure 2.3). Only 14% of respondents in the north subregion reported any crop damage by elephants, with most of the reported damages being low (86%), and none were severe. On the other hand, 25% of respondents in the east and 56% in the south reported severe damages.

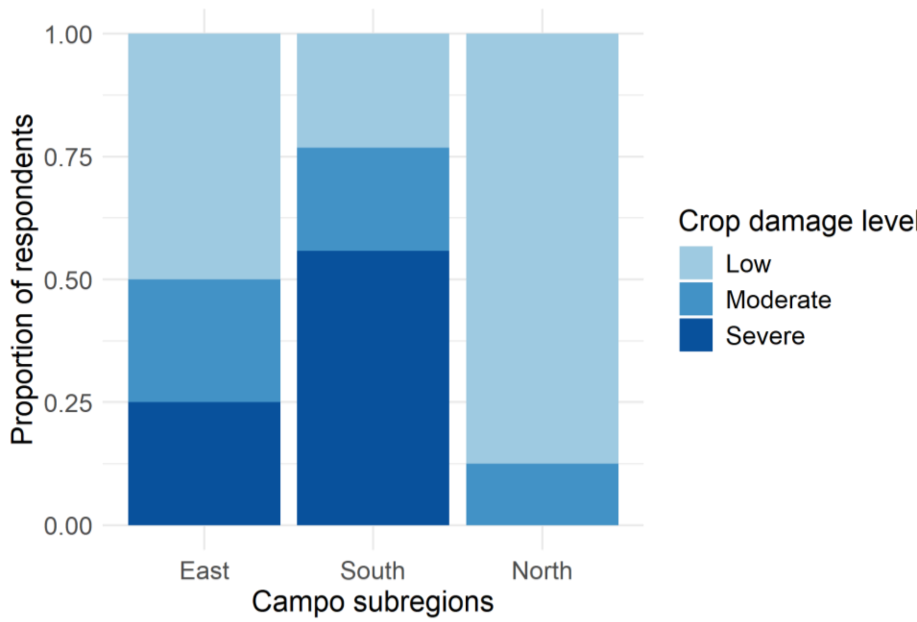

Figure 2.3. Proportion of respondents reporting different crop damage levels by elephants, according to 103 respondents with crop fields in the east (N=24), south (N=43), and north (N=36) subregions of the Campo subdivision.

Of the respondents reporting elephant crop damage, 88% of respondents perceived an increase in such damages from 2019 to 2023. Perceptions of respondents differed across subregions (Fisher's Exact Test, $p < 0.01$), where all respondents in the south perceived an increase, versus 80% and 75% of respondents in the north and east subregions, respectively.

Time since elephants first began visiting fields differed across subregions ($X^2 = 97.80$, $df = 6$, $p < 0.001$). Most respondents in the east subregion (67%) said they had been visited by elephants for the first time more than four years ago, with 69% of them saying elephants had been in the area "since forever". Most respondents in the south subregion (81%) said they had been visited for the first time in the last 4 years, with 41% of them reporting it had been in the last year and a half. Most of respondents in the north subregion (85%) said they had never been visited by elephants.

Forty-three percent of respondents who had crops depended solely on them for income. Staple crops like plantain and manioc were the most reported damaged crops, with 61% of households cultivating plantain and 39% of households cultivating manioc experiencing crop losses to elephants. Other commonly reported damaged crop types included pistachio, palm trees, yam, cucumbers, and fruit trees such as banana, papaya, and pineapple trees.

Noise making (35%) and fire around the farm (33%) were the most reported methods employed to protect their crops from elephants (Supplementary Table 2.7.1). Thirty-two percent of respondents reported not having tried any mitigation technique or not knowing of any against elephants. Proportions of respondents not using any mitigation techniques differed across subregions (Fisher's Exact Test, $p < 0.001$), where more respondents in the south and north subregions (51% and 56%, respectively) had not used any mitigation techniques to deter elephants from fields, compared to the east subregion (7%).

2.4.3 Local attitudes toward elephant conservation

Sixty-nine percent of respondents across the Campo subdivision did not see any benefits to having elephants in the area. Yet 63% of respondents still showed a positive attitude toward elephant conservation, whereas 29% had a negative outlook, and 8% were neutral. No difference was found in attitudes across subregions (Fisher's Exact Test, $p = 0.255$). When asked for the reason for their positive attitude, most respondents mentioned their desire for their children and future generations to be able to see elephants. However, most respondents also made it clear that their favorable attitude was conditional on how the elephant crop damage conflict would develop, that is if elephants stopped being near the village and causing damage.

The level of elephant crop damage to one's fields did not predict local attitudes toward elephant conservation (Table 2.3). However, whether agriculture was the sole source of income predicted attitudes, with individuals who depended on agriculture being more likely to have a negative perception of elephant conservation (estimate = -0.932, $p = 0.045$) (Table 2.3, Figure 2.4). There was a trend suggesting perceptions were also predicted by time since elephants first began visiting their fields, where individuals who had experienced elephant visits to their fields for over four years tended to be more likely to have a positive attitude compared to those who had started being visited in the last 4 years (estimate = 1.179, $p = 0.073$). No difference was found between those with no experience and those for whom conflict had started in the last 4 years (p = 0.122) (Table 2.3).

Table 2.3. Coefficient estimates from ordinal logistic regression of people's attitudes toward elephant conservation (response variable). The reference levels are Low level of elephant crop damage, Recent start of having elephants visiting their fields (≤ 4 years), and Agriculture not being the respondent's only income. Significant estimates are noted in bold.

Variable	Coeff.	t-value	Std. error	p-value
Moderate crop damage	0.148	0.178	0.830	0.858
Severe crop damage	0.974	1.201	0.810	0.230
Never have been visited	1.239	1.546	0.801	0.122
Visits since > 4 years	1.179	1.794	0.657	0.073
Agriculture as sole income	-0.950	-2.129	0.446	**0.033**

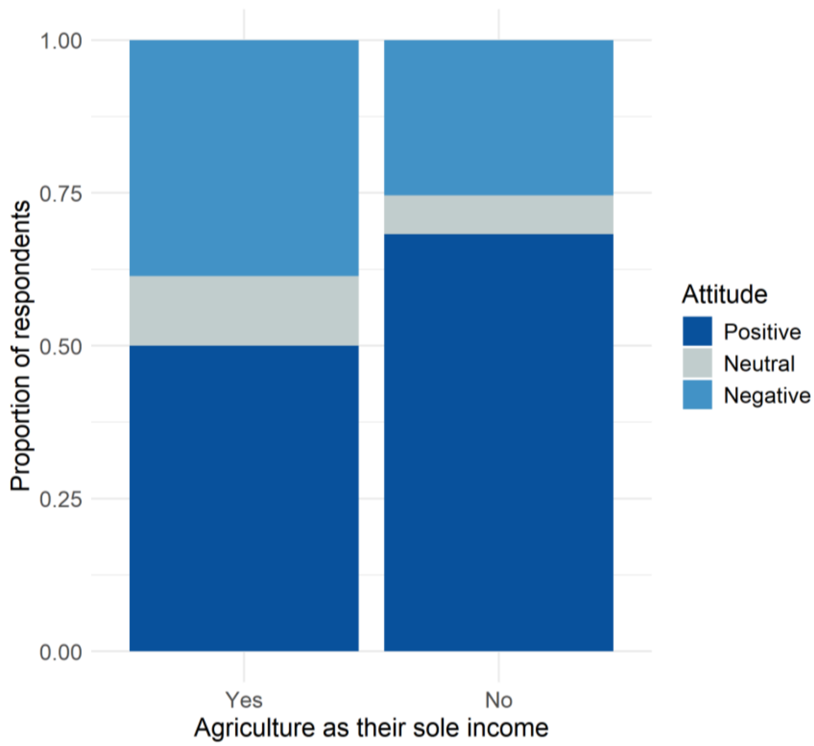

Figure 2.4. Local attitudes toward elephant conservation (proportion of respondents) based on whether agriculture is their sole source of income, as reported by 107 respondents across the Campo subdivision.

2.4.4 Mitigation solutions to HEC

When asked about solutions to minimize human-elephant conflict, 56% of respondents suggested spatial exclusion, either by pushing elephants away from the villages (42%) or more specifically keeping them within the National Park boundaries (22%). Moreover, 48% of respondents suggested assistance programs and resources, in the form of crop damage compensation through food or money to purchase food (29%), increased support for their agricultural activities (17%), assistance in developing alternative income sources (12%), or support for waiving school tuition fees (5%). Overall, 19% of respondents mentioned elephant killing. Only two respondents mentioned the agro-industry as part of their solution, either by having it provide assistance in local agricultural endeavors or by halting the operation of the palm plantation altogether.

2.5 Discussion

2.5.1 Increase in HEC and the influence of agro-industrial expansion

Our findings align with the increasing number and frequency of reports of elephant proximity and damages to community crop fields in the CMTOU (AWF, 2022; Urbain Nzitouo, Head of the Community and Participatory Management Service of MINFOF, personal communication, May 2023), and confirm the reportedly increasing HEC worldwide (Granados & Weladji, 2012; Guarnieri et al., 2024; Prakash et al., 2020; Sitati et al., 2003), notably as a consequence of land use change (Billah et al., 2021; Chen et al., 2016; Rathnayake et al., 2022; Suba et al., 2017; Tiller et al., 2021). Although rodents were common crop raiders, severity of damages from them seemed to be negligible compared to elephants', which is consistent with the broad idea of extreme damage severity associated with elephant raiding events (Djoko, Weladji, & Paré, 2022b; Gross et al., 2018; Naughton-Treves & Treves, 2005; Ngama et al., 2019; Tsegaye et al., 2023). We found that perceived change in elephant presence and crop damage level differed between subregions and therefore can be site-specific, with the observed patterns matching elephant's distribution. The north subregion, where elephant density is lowest (Beukou-Choumbou et al., 2021), was the least affected by elephants. In contrast, the south subregion was previously not experiencing elephant conflict (Eyebe et al., 2012; Nzooh-Dongmo et al., 2015) and became a new conflict area in recent years (Beukou-Choumbou et al., 2021). The eastern subregion is bordered by FMUs, and has a history of HEC with documented elephant movements passing through the area, particularly near the villages of Akak and Nkoelon (Beukou-Choumbou et al., 2021; Eyebe et al., 2012; Nzooh-

Dongmo et al., 2015). While conflicts have been ongoing, residents also reported a rise in HEC since the start of the agro-industry activity in the region.

The increase in elephant presence near villages in the Campo subdivision was largely attributed to the activity of the agro-industry, particularly due to habitat loss and fragmentation of existing elephant movement corridors. The agro-industrial plantation was established in a previously protected area, which was known to be home to an important density of forest elephants (AWF, 2022; Ayuk et al., 2023; Beukou-Choumbou et al., 2021; Nzooh-Dongmo et al., 2015) and to be traversed by elephant migration corridors (Beukou-Choumbou et al., 2021; Eyebe et al., 2012; Nzooh-Dongmo et al., 2015). These major landscape disturbances force elephants to change their habitat use patterns as they adapt to the new landscape, seemingly reducing their ranges in the CMTOU (Beukou-Choumbou et al., 2021). While elephants typically avoid human settlements (Blake et al., 2008; Buij et al., 2007; Laurance et al., 2006), they may be drawn to crop fields (Djoko, Weladji, & Paré, 2022b; Mills et al., 2018; Ngama et al., 2019; Tiller et al., 2021), especially when crops are mature (Branco et al., 2019; Djoko, Weladji, & Paré, 2022b; Gross et al., 2018; Tiller et al., 2021). Clumped resources like crop fields provide a high nutritional payback with relatively lower search times (Blake & Inkamba-Nkulu, 2004; Branco et al., 2019), making agricultural fields on the edge of elephant habitat high-value and easily accessible resources that may outweigh the perceived human-mediated risk of these areas (Hahn et al., 2022; Mills et al., 2018; Tiller et al., 2021). Human-mediated pressure in the Campo community land might be low enough to allow for constant feeding opportunities with low risk for elephants (Djoko, Weladji, Granados, et al., 2022), as the area has a low population density (MINAT, 2014; Tchouto et al., 2006). Suba et al. (2017) reported a similar case in Borneo, Indonesia, where rapid expansion of oil palm plantations has led to increased elephant crop raiding incidents, as elephants are forced to compete with humans for available space. Similarly, the high abundance of young trees and secondary species makes secondary forests attractive feeding spots for wildlife (Blake, 2002; Breuer & Ngama, 2021; Djoko, Weladji, Granados, et al., 2022; Poulsen et al., 2011). The creation of plantations opens the canopy and may create attractive feeding spots (Wunderle, 1997), as supported by reports of elephants visiting the agro-industrial plantation (Mohamadou Dialo, Sustainable Development Manager of CAMVERT-SA, personal communication, August 2023). Accordingly, we suspect the increase in elephant presence and crop damages in the Campo subdivision of the CMTOU may be due to the greater palatability and accessibility of crops and secondary species to elephants in comparison to the forage in other parts of the CMTOU (Djoko, Weladji, Granados, et al., 2022; Granados & Weladji, 2012). Amid elephant habitat loss and fragmentation in a human-dominated landscape (Ayuk et al., 2023; Beukou-Choumbou et al., 2021), elephants are forced to compete with humans for space and resources, resulting in changes in forest elephant habitat use and food choice strategies.

2.5.2 Local attitudes toward elephant conservation

Despite the strong emotions, such as anger, expressed by many respondents, especially those whose crops were recently raided, we found that level of elephant crop damage did not influence attitudes toward elephant conservation. This was contrary to our prediction and observations elsewhere (Abdullah et al., 2019; Carroll et al., 2025; Nsonsi et al., 2017; Omoregie et al., 2019), and suggests a disconnect between negative experiences with elephants and attitudes toward the species' conservation. This mismatch was found in Granados & Weladji (2012) in the Bénoué Wildlife Conservation Area, Cameroon, where whether households had suffered crop losses by elephants did not predict attitudes toward the species. However, individuals who relied solely on agriculture for income were more likely to foster negative views of elephant conservation. Tobias Ochieng et al. (2021) reported a similar influence in a district adjacent to the Masai Mara National Reserve in southwestern Kenya, where individuals with few income sources tended to have less favorable attitudes toward conservation than those with more diverse income streams. Having diverse income streams spreads out the risks associated with conservation costs, such as crop damage (Tobias Ochieng et al., 2021). Consequently, individuals with fewer alternative income sources are more vulnerable than others (Naughton-Treves & Treves, 2005). Our findings suggest that vulnerability to a threat may better predict attitudes toward conservation than the actual extent of damage.

Individuals with a longer experience of elephants visiting their fields tended to be more positive toward elephant conservation than those for whom the conflict was new. On the one hand, it is normal for people encountering a new conflict to have intense feelings, as was observed in the village of Mabiogo in the south subregion, where 3 individuals refused to answer the questionnaire, and our questions were generally met with frustration and despair. On the other hand, individuals with experience living alongside wild animals have had more interactions with conservation authorities and organisations, potentially gaining more awareness concerning the importance of wildlife (Govind & Jayson, 2021), and therefore potentially leading to a higher tolerance toward conflictual species, despite the damage they cause (Li et al., 2023).

We therefore suspect that attitudes in the Campo subdivision might be shaped more by past experiences with conservation authorities than by interactions with elephants. Conflicts involving wildlife are often conflicts between human stakeholders, where factors such as trust, representation, communication, and information sharing all play a role in resolving contentious issues (Marshall et al., 2007). The Campo subdivision is bordered by land uses and protected areas with varying levels of regulation (MINFOF, 2014b), and as a result, local conservation organizations and Park authorities frequently interact with communities, particularly in raising awareness and enforcing laws related to hunting, fishing, and logging rights. Additionally, NGOs have been active in the CMTOU, often conducting scientific education efforts and helping develop alternative income sources (Etoga, 2021; MINFOF, 2014a), with an awareness campaign for the various stakeholders involved in park management at least once a year (MINFOF, 2014a). Conservation projects may also create job opportunities for locals, such as forest guides for monitoring projects and anti-poaching efforts (e.g. conducted by AWF or WWF), and ecotourism offers alternative employment opportunities for locals while supporting conservation efforts through environmental education and revenue-sharing (Cheung, 2015). Moreover, household interviews are often conducted in the area (e.g. Ayuk et al., 2023; Dhiaulhaq et al., 2024; Djoko, Weladji, & Paré, 2022b; Forje et al., 2021), which may increase awareness on conservation efforts, encourage local involvement and foster a sense of ownership over conservation initiatives. Benefits associated with conservation efforts can be vital motivational factors for local people to change their attitudes and support conservation (Govind & Jayson, 2021; Tobias Ochieng et al., 2021), and positive interactions with conservation authorities and NGOs can help foster positive attitudes toward conservation, despite the challenges such as crop damage. For example, Nsonsi et al. (2017) found that attitudes toward forest elephant conservation around a protected area in northern Congo were more positive in a village where a conservation project was based, and particularly among those employed in the project.

Although most respondents did not perceive any direct benefits from having elephants in the area, attitudes toward elephant conservation remained mostly favorable. A common reason for this favorable outlook was the desire for future generations to witness elephants, which suggests a strong nature-oriented and community-focused mindset. Similarly, Sampson et al. (2019) reported that most respondents, farmers and non-farmers alike, were favorable to the conservation of

Myanmar's wild elephant population, the main reason being that they perceived elephants to be an important part of nature. Sociocultural and ecological values associated with elephants can be strong predictors of wildlife-related attitudes, with the precedent of coexistence with wildlife being seen as a practice that should be upheld (Carroll et al., 2025). However, positive attitudes were largely conditional on how the conflict would develop, where protecting elephants was considered important, but not at the expense of human livelihoods. Attitudes could therefore deteriorate if HEC is not addressed. It is common to have communities develop negative attitudes toward the presence of elephants when their continued impact harms local livelihoods (Granados & Weladji, 2012; Tsegaye et al., 2023), especially in the absence of support or compensation from the government (Nchanji et al., 2023; Nsonsi et al., 2017; Omoregie et al., 2019). This may, in turn, strain relationships between local communities and park authorities (Dhiaulhaq et al., 2024; Omoregie et al., 2019). Moreover, hunting and logging regulations in Cameroon are strict, limiting access to forest resources such as wild meat and medicinal plants (Dhiaulhaq et al., 2024). People are prohibited from engaging in traditional activities, under the paternalistic mindset of "You must not do this or that." In the absence of community involvement in decision-making about resource use and permits, conservation efforts adopt a centralized approach, where park authorities hold the power to issue and control exploitation permits (Nchanji et al., 2023).

2.5.3 Mitigation solutions to HEC

Similarly to other findings (Djoko, Weladji, & Paré, 2022b; Sitati et al., 2005; Tsegaye et al., 2023), residents found most mitigation techniques to deter elephants from fields ineffective, believing that elephants had already adapted and no longer responded to these methods. Noise making and fire around the farm were commonly used to repel elephants, however these methods require a physical presence near the fields, which renders them ineffective without a constant vigilance (Denninger Snyder & Rentsch, 2020; Parker et al., 2007). Although local people were open to recommendations from the conservation organizations and authorities, we observed a desire for quick solutions, which sometimes led to short-sightedness and abandonment of efforts before achieving success. For instance, beehive fences are used to deter elephants from entering fields (Djoko, Weladji, & Paré, 2022a; King et al., 2017; Ngama et al., 2016). However, during our visits to households, we noticed that many beehives that had been given to people had been abandoned because they were perceived as ineffective. Upon further questioning, it became clear that the bees had not been given enough time to reproduce and establish themselves as a viable population before the hives were abandoned. We observed that most respondents in the south and north subregions had limited knowledge of mitigation techniques, as frequent elephant visits had been unusual in these areas until the past few years (Beukou-Choumbou et al., 2021; Eyebe et al., 2012; Nzooh-Dongmo et al., 2015). In response to ineffectiveness of mitigation measures, we noticed some respondents resorting to early harvesting of crops, abandoning damaged agricultural plots, and showing a lack of enthusiasm in establishing new plots. The effectiveness of mitigation techniques is site-specific, and what succeeds in deterring elephants in one area may not work elsewhere. The authors highlight the need to increase engagement with local communities and to develop income-generating activities such as beekeeping and chili farming, which can also serve as mitigation techniques. Although Djoko, Weladji, & Paré (2022a) found mixed results regarding the effectiveness of beehive fences in the CMTOU, beehive fences were still recommended to be used in combination with other methods. We therefore recommend more efforts to integrate beehive fences as part of a mitigation technique by allowing time for colonies to establish themselves and by including strings between hives so that they shake and agitate bees when an animal passes between them. In parallel, we encourage efforts to integrate the use of chili-pepper fences, as both chili pepper crop fences and rope fences at field edges have proven effective in several sites across Africa and Asia (Chang'a et al., 2016; Chelliah et al., 2010; Montgomery et al., 2022). Chili pepper-based deterrents are already used by some farmers in the Campo subdivision through pepper crops, pepper-infused fabric fences, and burning pepper in fire, although their effectiveness remains to be fully assessed. .

Longer-term solutions suggested by local people to mitigate HEC reflected the context of food insecurity and a desire for a rapid outcome. Communities relied on authorities to know better and be better equipped to address the issue. Similarly to Sampson et al. (2019) and Tsegaye et al. (2023), spatial exclusion was suggested as a solution to HEC, whether through removing elephants from the area or keeping them within the CMNP bounds using physical barriers. However, a common misconception amongst respondents wanting to keep elephants within the CMNP was that the park is a zoological institution, either already surrounded by fences from which elephants had escaped, or small enough to allow the implementation of such barriers. Multiple times throughout our study, teams of eco-guards from the MINFOF were sent in the Campo subdivision to "push back" elephants from fields. These administrative procedures are permitted following strict rules.

The request for such action can be made by the community or administration if they are under threat from a wild animal, must be approved by the Regional or Departmental Delegate, as well as the MINFOF, and will be executed by a specialized team from the local management service (MINFOF, 2012). These measures typically include the use of warning gunshots (Moumbock et al., 2020; Tsegaye et al., 2023). However, these pushback efforts can be ineffective or temporary, as it is difficult to direct the movement of elephants toward CMNP as intended. The same groups of elephants would sometimes reappear in the crop fields of other parts of the subdivision a few days later. Additionally, eco-guards teams sometimes arrive too late on-site for the method to be effective (Tsegaye et al., 2023). However, some people consider them effective at the field level, which is enough to ease their minds, and the pushbacks correspond to a quick response to damages and show communities that the authorities take their complaints seriously.

The establishment of assistance programs and resources was also suggested, mostly through compensation for crop damage, either through staple foods or funding to purchase such food. When property is destroyed by elephants, the immediate response is often a demand for compensation, particularly when the animals are legally or considered the state's responsibility (Nelson et al., 2003). Since most of the damaged crops are staple foods essential to the livelihoods of individuals and communities, people are forced to change their eating habits and rely on more expensive imported products, some of which they are not accustomed to eating (Djoko, Weladji, & Paré, 2022b). Following a protest by farmers in front of the conservation offices during our study, a public meeting was organized by MINFOF and led by the Campo subdivision officer to listen to the opinions of those affected and work toward implementing a new scheme. This suggested scheme involved the gathering of individual farmers into groups to facilitate compensation, official complaints, and visits to the crop field by a MINFOF delegate to assess monetary losses. Nelson et al. (2003) argue that compensation schemes are difficult to implement successfully because they address the effects rather than the root causes of conflict. These schemes face several challenges, including an increase in claims, often inflated or fraudulent, an inability to cover all claims, unequal distribution that create social disputes and resentment, difficulty in quantifying socioeconomic costs, no clear end point, and a lack of impact on improving the relationship between local communities and wildlife authorities (Nelson et al., 2003).

Surprisingly, although the establishment of the agro-industrial plantation was widely mentioned as an explanatory factor for the recent increase in HEC, only two individuals suggested that the agro-industry could play a role in mitigation efforts. One person suggested that the company provide and fund assistance for the communities' agricultural endeavors, such as helping to clear new fields, while the other called for a stop to the plantation's operations altogether. This leads back to a preference for solutions with rapid results rather than long-term and sustainable changes, as the local people's daily livelihoods are threatened. The lack of mention of the agro-industry as a potential actor in mitigation efforts, despite being identified as the root cause of the increase in HEC by many, highlights a mismatch between the perceived cause of the problem and the proposed solutions.

2.6 Conclusion

In recent decades, oil palm plantations have been a major driver of tropical deforestation and biodiversity loss (Oosterveer, 2015), notably in Cameroon which has the greatest amount of deforestation on the continent due to palm oil plantation expansion (Ordway et al., 2017). Such conversion of forests into agricultural land increases human encroachment into elephant habitats, intensifying HEC (Billah et al., 2021; Chen et al., 2016; Rathnayake et al., 2022; Suba et al., 2017; Tiller et al., 2021). Our findings align with the increasing reports of elephant proximity to villages and crop damages in the CMTOU since the establishment of the plantation, reinforcing the worldwide trend of increased HEC resulting from land use change.

Understanding perceptions and attitudes is integral to grasping the complexity of human-wildlife conflict. These perceptions are shaped not only by personal experiences, but also by a range of cultural, social, political and economical factors (Dickman, 2010; Li et al., 2023; Tobias Ochieng et al., 2021), and cannot be simplified to just positive or negative (Carroll et al., 2025). Positive attitudes of communities toward elephant conservation were conditional to how the conflict would play out. There was a disconnect between negative experiences and attitudes, where vulnerability to the threat better predicted attitudes than actual damage. The potential role of past interactions with wildlife and conservation authorities in shaping attitudes toward species conservation was also highlighted. Misunderstandings, disagreements, and disappointment often arise when human-wildlife conflict mitigation methods do not align with local communities' needs and preferences (Virtanen et al., 2021). Solutions suggested by residents of the Campo subdivision to mitigate HEC reflected the context of food insecurity, and they preferred rapid solutions rather than longer-term changes, as their daily livelihoods are threatened.

The Campo-Ma’an landscape presents a complex and conflicting situation, where different stakeholders pursue diverse interests and agendas (Dhiaulhaq et al., 2024). Resolving human-wildlife conflict requires compromises between competing objectives, and parties are more likely to accept these compromises if they feel recognized as equal partners in the decision-making process (Basak et al., 2023; Virtanen et al., 2021). Effective land-use planning, preventing further encroachment, and addressing HEC in a way that considers local preferences are essential for sustainable human welfare and community-driven elephant conservation.

2.7 Supplementary material

Household questionnaire

Village_______________ Date___________ Name of respondent (facultative)__________________

How long have you lived here?_______________ Where did you live before?_________________

I- Respondent characteristics

1	Gender	1- Male	2- Female			
2	Age	1- 18-25	2- 26-35	3- 36-45	4- ≥46	
6	Income sources	1- Agriculture	2- Hunting	3- Fishing	4- Other	

II- Perspective on the elephant situation

	Question	**Answer**
12a	What is the tendency of elephant presence in the area over the past four years?	1- Increasing 2- Decreasing 3- Stable 4- Don't know
12b	If there was a change, what could be the cause?	

III- Human-wildlife conflict and crop damage

13a. Do you own and cultivate a field? 1- Yes 2- No **(*If not, go to Q25*).**

13b. Where is your field? ____

13c. Since when do you cultivate that field? ___________________________________

14. What type(s) of crops do you cultivate?

1-	2-	3-
4-	5-	6-

15. What animals are responsible for the most crop damage?

1-	2-	3-
4-	5-	6-

16. During the latest harvest, what proportion of your field got damaged by **WILDLIFE**? ____%

17. What proportion of that damage was caused by **ELEPHANTS**? _________%

18. What type of crop(s) gets damaged by elephants and at what stage of growth?

Type of damaged crop	**Stage of growth (young/intermediate/mature/all)**			
1-				
2-				
3-				
4-				

19. Since when are you having **elephants** visit your field? ________________________________

21. What is the tendency of crop damage **by elephants** over the past four years?

1- Increasing	2- Decreasing	3- Stable

IV- Mitigation techniques

22. What are the methods you have used **to deter elephants specifically**? Name and describe each, including to what extent it was effective.

1- ____

2- ____

3- ____

V- Perceptions

A. Elephants

25a. Are there any benefits from having elephants in the area? 1- Yes 2- No

25b. If so, what? ____

25c. If not, why? ____

B. Elephant conservation

26a. How do you perceive elephant conservation? 1- Good 2- Bad 3- Indifferent

26b. Why? ____

Final question:

If you had a recommendation for the authorities, how do you think we should mitigate HEC?

____

Table 2.7.1. Frequency and percentage distribution of mitigation methods used to deter elephants from fields, according to 75 respondents across the Campo subdivision. Respondents could mention multiple methods, for a total of 122 responses.

Method	**Count**	**% of respondents**
Noise making	26	35
Fire around the farm	25	33
Pepper crops	9	12
Raising bees	9	12
Growing citrus	7	9
Scarecrows	5	7
Pushback by MINFOF	5	7
Abandon the crop type	2	3
Pepper in fire	2	3
Split field into parts	1	1
Early harvest	1	1
Presence of farmer	1	1
Growing cacao	1	1
Pepper-infused fabric	1	1
Feces in fire	1	1
Dry corn in fire	1	1
Fencing	1	1
None	24	32

GENERAL CONCLUSION

Over recent decades, oil palm plantations have emerged as a major driver of deforestation and biodiversity loss, particularly in Cameroon (Ordway et al., 2017). Habitat fragmentation and human encroachment force wildlife into closer contact with humans, intensifying human-wildlife tensions (Dickman, 2010). Our findings align with the rising trend in human-elephant conflict worldwide, notably driven by forest conversion to agriculture. As human disturbances are increasing in the CMTOU, forest elephants seem to be adapting to the new landscape, resulting in increased crop raiding and overall human-elephant tensions. Elephants' proximity to villages suggests a general risk-taking strategy for food resources, balanced with avoidance to minimize encounters with humans. While conservation agencies hold elephants as a flagship species, local communities view them as competitors for resources and threats to livelihoods. This frustration can potentially result in retaliatory killings (Tiller & Williams, 2021) and negative attitudes toward conservation efforts, threatening the long-term survival of the critically endangered forest elephant. Moreover, recces outperformed camera traps in detecting both species in a greater number of sites and providing a greater amount of data overall. However, camera traps proved valuable for behavioral monitoring, as time stamps on images and videos were used for the analysis of activity patterns, something that sign encounter data could not capture. Selecting the most appropriate survey method requires understanding of its requirements and limitations, and when possible, combining multiple methods is recommended to produce more complete estimates, particularly in study sites with low species densities and activity (Fragoso et al., 2016; Nuñez et al., 2019).

Understanding the complexity of human-wildlife conflict requires considering local perceptions and attitudes, which are shaped by personal experiences, cultural factors, social norms, and individual motivations and preferences (Dickman, 2010; Tobias Ochieng et al., 2021). In the Campo subdivision, vulnerability to crop damage and past experiences with elephants (and possibly with conservation authorities) better predicted local attitudes toward elephant conservation than actual damage. As their daily livelihoods are threatened, residents' suggested mitigation solutions reflected the context of food insecurity and their desire for a rapid outcome. In the Campo-Ma'an landscape, competing stakeholder interests create a complex and conflicting situation (Dhiaulhaq et al., 2024). Effective human-wildlife conflict solutions require compromises between competing objectives, ensuring all parties feel recognized in the decision-making process (Basak et al., 2023; Virtanen et al., 2021). Short-term mitigation can ease communities' minds, and show them that authorities take their complaints seriously. Unfortunately, short-term mitigation solutions can only reduce the problem at the site level, and not eliminate it on a larger spatial scale (O'Connell-Rodwell et al., 2000). As further habitat fragmentation and human encroachment on elephant habitats are expected in the near future, continued elephant monitoring, effective land-use planning, and incorporating local perspectives into conservation strategies are essential for long-term coexistence and community-driven conservation.

Limitations of the study

We acknowledge the following limitations to our study. Although our results reveal distinct activity patterns between elephants and humans, with reduced elephant activity during the midday peak in human activity and nocturnal elephant activity while humans are typically asleep, we cannot determine whether this reflects deliberate risk avoidance or natural circadian behavior. Elephants are known to exhibit both diurnal and nocturnal activity (Blake, 2002; Kely et al., 2019; Tutin et al., 1997), but increased nocturnal activity has been reported in areas with high human disturbance (e.g., Adams et al., 2022; Smit et al., 2023; Wrege et al., 2024). While these patterns provide insights into species behavior, a more complete assessment of behaviors and motivations may ultimately be more informative when studying responses to risk (Krebs et al., 2017). Future research could explore activity patterns across areas with varying human pressure, such as crop fields, buffer zones, and protected areas like national parks. Questionnaire surveys are helpful for quickly assessing local perspectives on conservation issues, but are therefore prone to response bias (Sedgwick, 2013). Given the financial and emotional impact of HEC, respondents may experience a "hyper-awareness" of risk, leading to exaggeration of losses and increased fear of damage even if they have never personally experienced it (Dickman, 2010). Respondents' statements may reflect what people have heard rather than personal attitudes (Nsonsi et al., 2017). Additionally, bias may occur when respondents are hesitant to express negative attitudes, especially when speaking to someone involved in conservation, leading to an impression of more favorable attitudes (Nsonsi et al., 2017; Solomon et al., 2015). To reduce such bias, we encouraged respondents to elaborate on their answers to avoid oversimplifying their attitudes toward elephants and conservation as strictly positive or negative (Carroll et al., 2025). Interpretation of survey questions may also have varied by subregion, particularly in the north, where interactions with elephants are limited. For example, some respondents may have viewed "good" and "indifferent" perceptions of conservation to be interchangeable due to a lack of strong opinions on elephant-related topics. Finally, while we cannot directly test whether the plantation's activity is linked to the increase in HEC in the Campo subdivision of the CMTOU, the local perception of this connection remains a crucial element of HEC, and thus crucial to conservation efforts in the region.

Recommendations

Effective solutions to HEC require balancing short-term mitigation efforts to show communities their concerns are heard, with long-term strategies that address the issue at a larger scale. Efforts to reduce HEC require the consideration of crop damage trends, local attitudes and preferences, as well as elephant occurrence in and around protected areas. Given the findings of this study, we recommend:

1. Ensure community participation in the development of strategies to mitigate HEC, where mitigation solutions favored by communities should be considered at least in combination with other mitigation techniques to ensure success. Solutions imposed without community involvement or consent are likely to be resented or poorly implemented (Tsegaye et al., 2023; Virtanen et al., 2021).
2. Halt additional development in the FMU 09-025, particularly in its southern block bordering Dipikar Island in CMNP, where the highest density of elephants is found (Beukou-Choumbou et al., 2021). In addition to this, we recommend the creation of buffer zones between exploited areas, protected areas, and community land to support animal migration from the disrupted natural ecosystem (Forje et al., 2021).
3. Continue monitoring elephant habitat use in the CMTOU using efficient survey methods with minimal costs to obtain a more comprehensive picture of how elephant individuals and herds use the space.

REFERENCES

Abdullah, A., Sayuti, A., Hasanuddin, H., Affan, M., & Wilson, G. (2019). People's perceptions of elephant conservation and the human-elephant conflict in Aceh Jaya, Sumatra, Indonesia. *European Journal of Wildlife Research*, *65*, 1-8.

Achieng, A. O., Arhonditsis, G. B., Mandrack, N. E., Febria, C. M., Opaa, B., Coffey, T. J., Irvine, K., Masese, F. O., Ajode, Z. M., Barasa, J. E., Obiero, K., & Kaunda-Arara, B. (2023). Monitoring biodiversity loss in rapidly changing Afrotropical ecosystems : An emerging imperative for governance and research. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *378*(1881), 20220271. https://doi.org/10.1098/rstb.2022.0271

Adams, T. S. F., Leggett, K. E. A., Chase, M. J., & Tucker, M. A. (2022). Who is adjusting to whom? : Differences in elephant diel activity in wildlife corridors across different human-modified landscapes. *Frontiers in Conservation Science*, *3*. https://www.frontiersin.org/articles/10.3389/fcosc.2022.872472

Ahrestani, F. S., Kumar, N. S., Vaidyanathan, S., Hiby, L., Jathanna, D., & Karanth, K. U. (2018). Estimating densities of large herbivores in tropical forests : Rigorous evaluation of a dung-based method. *Ecology and Evolution*, *8*(15), 7312-7322. https://doi.org/10.1002/ece3.4227

AWF. (2022). *Projet de conservation de la biodiversité dans le Parc national de Campo-Ma'an et sa zone périphérique (Rapport technique)*. African Wildlife Foundation, Cameroon.

Ayamba, A. J., Zeh, A. F., Bumtu, K. P., Juscar, N., Mounir, M. P., & Djike, N. A. (2024). Floristic Diversity in Forest Management Units : Implications for Biodiversity Conservation in FMU 09-025. *Open Journal of Forestry*, *14*(3), Article 3. https://doi.org/10.4236/ojf.2024.143019

Ayuk, A. B., Fuashi, N. A., Maurice, M. E., & Bumtu, K. P. (2023). Species composition and structure of habitats exploited by elephants (Loxodonta africana cyclotis) in the Campo Maan Forest, South Region, Cameroon. *American Journal of Environment Studies*, *6*(1), 19-40.

Basak, S. M., Rostovskaya, E., Birks, J., & Wierzbowska, I. A. (2023). Perceptions and attitudes to understand human-wildlife conflict in an urban landscape – A systematic review. *Ecological Indicators*, *151*, 110319. https://doi.org/10.1016/j.ecolind.2023.110319

Beirne, C., Meier, A. C., Brumagin, G., Jasperse-Sjolander, L., Lewis, M., Masseloux, J., Myers, K., Fay, M., Okouyi, J., & White, L. J. (2020). Climatic and resource determinants of forest elephant movements. *Frontiers in Ecology and Evolution*, *8*, 96. https://doi.org/10.3389/fevo.2020.00096

Beukou-Choumbou, G. B., Nzooh-Dongmo, Z. L., Sombambo, M., Njal-Njock, S., Mbiapa-Tchoumi, T., Ekane, H., Mounga-Abana, A., Nzitouo, U., Sambou-Mambala, P., & N'Goran, K. P. (2021). *Dynamique de la population des grands et moyens mammifères dans le Parc national de Campo Ma'an et sa zone périphérique (Rapport d'inventaire)*. Ministry of Forestry and Wildlife, Cameroon.

Billah, M. M., Rahman, M. M., Abedin, J., & Akter, H. (2021). Land cover change and its impact on human-elephant conflict : A case from Fashiakhali forest reserve in Bangladesh. *SN Applied Sciences*, *3*(6), 649. https://doi.org/10.1007/s42452-021-04625-1

Blake, S. (2002). *The ecology of forest elephant distribution and its implications for conservation* [Doctoral thesis, University of Edinburgh]. https://www.researchgate.net/profile/Stephen-Blake-6/publication/265032366_The_Ecology_of_Forest_Elephant_Distribution_and_Its_Implications_for_Conservation/links/54ad7c6b0cf24aca1c6f5d95/The-Ecology-of-Forest-Elephant-Distribution-and-Its-Implications-for-Conservation.pdf

Blake, S., Deem, S. L., Strindberg, S., Maisels, F., Momont, L., Isia, I.-B., Douglas-Hamilton, I., Karesh, W. B., & Kock, M. D. (2008). Roadless Wilderness Area Determines Forest Elephant Movements in the Congo Basin. *PLoS ONE*, *3*(10), e3546. https://doi.org/10.1371/journal.pone.0003546

Blake, S., & Inkamba-Nkulu, C. (2004). Fruit, Minerals, and Forest Elephant Trails : Do All Roads Lead to Rome? *Biotropica*, *36*(3), 392-401. https://doi.org/10.1111/j.1744-7429.2004.tb00332.x

Blake, S., & Maisels, F. (2023). Forest Elephant Movements in Central Africa : Megafauna Need Megaspaces. In R. Reyna-Hurtado, C. A. Chapman, & M. Melletti (Éds.), *Movement Ecology of Afrotropical Forest Mammals* (p. 27-58). Springer International Publishing. https://doi.org/10.1007/978-3-031-27030-7_3

Blake, S., Strindberg, S., Boudjan, P., Makombo, C., Bila-Isia, I., Ilambu, O., Grossmann, F., Bene-Bene, L., De Semboli, B., Mbenzo, V., S'hwa, D., Bayogo, R., Williamson, L., Fay, M., Hart, J., & Maisels, F. (2007). Forest Elephant Crisis in the Congo Basin. *PLoS Biology*, *5*(4), e111. https://doi.org/10.1371/journal.pbio.0050111

Branco, P. S., Merkle, J. A., Pringle, R. M., Pansu, J., Potter, A. B., Reynolds, A., Stalmans, M., & Long, R. A. (2019). Determinants of elephant foraging behaviour in a coupled human-natural system : Is brown the new green? *Journal of Animal Ecology*, *88*(5), 780-792. https://doi.org/10.1111/1365-2656.12971

Breuer, T., Maisels, F., & Fishlock, V. (2016). The consequences of poaching and anthropogenic change for forest elephants. *Conservation Biology*, *30*(5), 1019-1026. https://doi.org/10.1111/cobi.12679

Breuer, T., & Ngama, S. (2021). Humans and forest elephants in Central Africa : Conflict and co-existence in and around protected areas. In P. F. Doumenge (Éd.), *State of protected area in Central Africa 2020* (p. 174-220). OFAC-COMIFAC/IUCN.

Buij, R., McShea, W. J., Campbell, P., Lee, M. E., Dallmeier, F., Guimondou, S., Mackaga, L., Guisseougou, N., Mboumba, S., Hines, J. E., Nichols, J. D., & Alonso, A. (2007). Patch-occupancy models indicate human activity as major determinant of forest elephant *Loxodonta cyclotis* seasonal distribution in an industrial corridor in Gabon. *Biological Conservation*, *135*(2), 189-201. https://doi.org/10.1016/j.biocon.2006.10.028

Carroll, S. L., Vogel, S. M., Taek, P. N., Tumuti, C., Vasudev, D., Goswami, V. R., Wall, J., Mwiu, S., Reid, R. S., & Salerno, J. (2025). A spatially explicit assessment of factors shaping attitudes toward African elephant conservation. *Conservation Biology*, *39*(1), e14408. https://doi.org/10.1111/cobi.14408

Chakraborty, P., Borah, J., Bora, P. J., Dey, S., Sharma, T., Lalthanpuia, & Rongphar, S. (2021). Camera trap-based monitoring of a key wildlife corridor reveals opportunities and challenges for large mammal conservation in Assam, India. *Tropical Ecology*, *62*(2), 186-196. https://doi.org/10.1007/s42965-020-00138-x

Chang'a, A., Souza de, N., Muya, J., Keyyu, J., Mwakatobe, A., Malugu, L., Ndossi, H. P., Konuche, J., Omondi, R., Mpinge, A., Hahn, N., Palminteri, S., & Olson, D. (2016). Scaling-Up the Use of Chili Fences for Reducing Human-Elephant Conflict Across Landscapes in Tanzania. *Tropical Conservation Science*, *9*(2), 921-930. https://doi.org/10.1177/194008291600900220

Chelliah, K., Kannan, G., Kundu, S., Abilash, N., Madhusudan, A., Baskaran, N., & Sukumar, R. (2010). Testing the efficacy of a chilli-tobacco rope fence as a deterrent against crop-raiding elephants. *Current Science*, *99*(9), 1239-1243.

Chen, Y., Marino, J., Chen, Y., Tao, Q., Sullivan, C. D., Shi, K., & Macdonald, D. W. (2016). Predicting Hotspots of Human-Elephant Conflict to Inform Mitigation Strategies in Xishuangbanna, Southwest China. *PLoS ONE*, *11*(9), e0162035. https://doi.org/10.1371/journal.pone.0162035

Cheung, H. (2015). Ecotourism as a multidisciplinary conservation approach in Africa. *Therya*, *6*(1), 31-41. https://doi.org/10.12933/therya-15-243

Christensen, R. (2023). *ordinal—Regression Models for Ordinal Data*. https://CRAN.R-project.org/package=ordinal.

Collins, E., & Weladji, R. B. (2024). Occupancy of Sympatric Central Chimpanzee (*Pan troglodytes troglodytes*) and Western Lowland Gorilla (*Gorilla gorilla gorilla*) in Campo Ma'an Conservation Area, Southern Cameroon. *International Journal of Primatology*, 1-22.

Davis, R. S., Gentle, L. K., Mgoola, W. O., Stone, E. L., Uzal, A., & Yarnell, R. W. (2023). Using camera trap bycatch data to assess habitat use and the influence of human activity on African elephants (*Loxodonta africana*) in Kasungu National Park, Malawi. *Mammalian Biology*, *103*(1), 121-132. https://doi.org/10.1007/s42991-022-00330-7

Denninger Snyder, K., & Rentsch, D. (2020). Rethinking assessment of success of mitigation strategies for elephant-induced crop damage. *Conservation Biology*, *34*(4), 829-842. https://doi.org/10.1111/cobi.13433

Dhiaulhaq, A., Hepp, C. M., Adjoffoin, L. M., Ehowe, C., Assembe-Mvondo, S., & Wong, G. Y. (2024). Environmental justice and human well-being bundles in protected areas : An assessment in Campo Ma'an landscape, Cameroon. *Forest Policy and Economics*, *159*, 103137. https://doi.org/10.1016/j.forpol.2023.103137

Dickman, A. J. (2010). Complexities of conflict : The importance of considering social factors for effectively resolving human-wildlife conflict. *Animal Conservation*, *13*(5), 458-466. https://doi.org/10.1111/j.1469-1795.2010.00368.x

Djoko, I. B., Weladji, R. B., Granados, A., Paré, P., & Body, G. (2022). Fruit Availability Influences Forest Elephant Habitat Use in a Human Dominated Landscape, Campo-Ma'an, Southern Cameroon. *Tropical Conservation Science*, *15*, 194008292211170. https://doi.org/10.1177/19400829221117053

Djoko, I. B., Weladji, R. B., & Paré, P. (2022a). Diurnality in the defensive behaviour of African honeybees *Apis mellifera adansonii* and implications for their potential efficacy in beehive fences. *Oryx*, 1-7. https://doi.org/10.1017/S0030605321001721

Djoko, I. B., Weladji, R. B., & Paré, P. (2022b). Human-wildlife conflict in the Campo-Ma'an Technical Operational Unit, Southern Cameroon. *International Journal of Biodiversity and Conservation*, *14*(4), 190-205. https://doi.org/10.5897/IJBC2022.1560

Engolo, G. M. Z., Abessolo, C. I. M., Yaouba, B., Mbog, S. M., Ngoko, P. P., & Bitondo, D. (2024). *Assessment of wildlife abundance indicators, human activities and their dependence on development projects in the Campo-Ma'an National Park, Southern Cameroon*. https://doi.org/10.21203/rs.3.rs-4800293/v1

Enukwa, E. H. (2017). Human-Elephant conflict mitigation methods : A review of effectiveness and sustainability. *Journal of Wildlife and Biodiversity*, *1*(2), Article 2. https://doi.org/10.22120/jwb.2017.28260

Etoga, H. M. (2021). Territoires du tourisme et COVID-19 dans le Littoral Sud-camerounais. Quelle opportunité pour la redynamisation de la Filière? *Espace Géographique et Société Marocaine*, *43-44*.

Eyebe, A. J., Dkamela, G. P., & Endamana, D. (2012). Overview of Human Wildlife Conflict in Cameroon. *Poverty and Conservation Learning Group Discussion Paper*, *5*, 423.

Fai, C. N., Nguedem, S. F., & Tonjock, R. K. (2022). Feeding pattern of forest elephants in the Nki National Park and its environs, East Region, Cameroon. *International Journal of Biodiversity and Conservation*, *14*(1), 26-34. https://doi.org/10.5897/IJBC2021.1528

FAO. (2020). *Global Forest Resources Assessment 2020*. FAO. https://doi.org/10.4060/ca8753en

Forje, G. W., & Tchamba, M. N. (2022). Ecotourism governance and protected areas sustainability in Cameroon : The case of Campo Ma'an National Park. *Current Research in Environmental Sustainability*, *4*, 100172. https://doi.org/10.1016/j.crsust.2022.100172

Forje, G. W., Tchamba, M. N., & Eno-Nku, M. (2021). Determinants of ecotourism development in and around protected areas : The case of Campo Ma'an National Park in Cameroon. *Scientific African*, *11*, e00663. https://doi.org/10.1016/j.sciaf.2020.e00663

Fox, J., & Weisberg, S. (2019). *An R Companion to Applied Regression, Third edition*. Sage, Thousand Oaks CA. https://www.john-fox.ca/Companion/

Fragoso, J. M. V., Gonçalves, F., Oliveira, L. F. B., Overman, H., Levi, T., & Silvius, K. M. (2019). Visual encounters on line transect surveys under-detect carnivore species : Implications for assessing distribution and conservation status. *PLoS ONE*, *14*(10), e0223922. https://doi.org/10.1371/journal.pone.0223922

Fragoso, J. M. V., Levi, T., Oliveira, L. F. B., Luzar, J. B., Overman, H., Read, J. M., & Silvius, K. M. (2016). Line Transect Surveys Underdetect Terrestrial Mammals : Implications for the Sustainability of Subsistence Hunting. *PLoS ONE*, *11*(4), e0152659. https://doi.org/10.1371/journal.pone.0152659

Frid, A., & Dill, L. (2002). Human-caused Disturbance Stimuli as a Form of Predation Risk. *Conservation Ecology*, *6*(1). https://doi.org/10.5751/ES-00404-060111

Gaugris, J., Orban, B., Niemand, L., Walsh, G., Burger, M., Morley, R., Melville, H., Drescher, K., Kabafouako, G., & Vasicek Gaugris, C. (2022). Short recce transects or camera trap surveys—Short recce surveys highlighted as a useful supplement for rapid biodiversity assessments in the Republic of the Congo. *African Journal of Ecology*, *60*(4), 926-945. https://doi.org/10.1111/aje.13047

Gaynor, K. M., Branco, P. S., Long, R. A., Gonçalves, D. D., Granli, P. K., & Poole, J. H. (2018). Effects of human settlement and roads on diel activity patterns of elephants

(*Loxodonta africana*). *African Journal of Ecology*, *56*(4), 872-881. https://doi.org/10.1111/aje.12552

Gaynor, K. M., Brown, J. S., Middleton, A. D., Power, M. E., & Brashares, J. S. (2019). Landscapes of Fear : Spatial Patterns of Risk Perception and Response. *Trends in Ecology & Evolution*, *34*(4), 355-368. https://doi.org/10.1016/j.tree.2019.01.004

Gaynor, K. M., Hojnowski, C. E., Carter, N. H., & Brashares, J. S. (2018). The influence of human disturbance on wildlife nocturnality. *Science*, *360*(6394), 1232-1235. https://doi.org/10.1126/science.aar7121

Gobush, K., Edwards, C., Maisels, F., Wittemyer, G., Balfour, D., & Taylor, R. (2021). *Loxodonta cyclotis. The IUCN Red List of threatened species 2021 : E. T181007989A181019888*. https://dx.doi.org/10.2305/IUCN.UK.2021-1.RLTS.T181007989A204404464.en

Gordon, J. E., & Newton, A. C. (2006). Efficient floristic inventory for the assessment of tropical tree diversity : A comparative test of four alternative approaches. *Forest Ecology and Management*, *237*(1), 564-573. https://doi.org/10.1016/j.foreco.2006.10.002

Govind, S. K., & Jayson, E. A. (2021). Human-wildlife interactions and people’s attitudes towards conservation : A case study from Central Kerala, India. *Animal Biodiversity and Conservation*, 139-151. https://doi.org/10.32800/abc.2021.44.0139

Granados, A., & Weladji, R. B. (2012). Human-Elephant Conflict Around Bénoué National Park, Cameroon : Influence on Local Attitudes and Implications for Conservation. *Human Dimensions of Wildlife*, *17*(2), 77-90. https://doi.org/10.1080/10871209.2012.639133

Granados, A., Weladji, R. B., & Loomis, M. R. (2012). Movement and Occurrence of Two Elephant Herds in a Human-Dominated Landscape, the Bénoué Wildlife Conservation Area, Cameroon. *Tropical Conservation Science*, *5*(2), 150-162. https://doi.org/10.1177/194008291200500205

Greenberg, S. (2022). *Timelapse Quick Start Guide*. University of Calgary, Canada. https://timelapse.ucalgary.ca/wp-content/uploads/Guides/TimelapseQuickStartGuide.pdf

Gross, E. M., Lahkar, B. P., Subedi, N., Nyirenda, V. R., Lichtenfeld, L. L., & Jakoby, O. (2018). Seasonality, crop type and crop phenology influence crop damage by wildlife herbivores in Africa and Asia. *Biodiversity and Conservation*, *27*, 2029-2050.

Guarnieri, M., Kumaishi, G., Brock, C., Chatterjee, M., Fabiano, E., Katrak-Adefowora, R., Larsen, A., Lockmann, T. M., & Roehrdanz, P. R. (2024). Effects of climate, land use, and human population change on human-elephant conflict risk in Africa and Asia. *Proceedings of the National Academy of Sciences*, *121*(6), e2312569121. https://doi.org/10.1073/pnas.2312569121

Gunn, J., Hawkins, D., Barnes, R. F. W., Mofulu, F., Grant, R. A., & Norton, G. W. (2014). The influence of lunar cycles on crop-raiding elephants; evidence for risk avoidance. *African Journal of Ecology*, *52*(2), 129-137. https://doi.org/10.1111/aje.12091

Hahn, N. R., Wall, J., Denninger-Snyder, K., Goss, M., Sairowua, W., Mbise, N., Estes, A. B., Ndambuki, S., Mjingo, E. E., Douglas-Hamiliton, I., & Wittemyer, G. (2022). Risk perception and tolerance shape variation in agricultural use for a transboundary elephant population. *Journal of Animal Ecology*, *91*(1), 112-123. https://doi.org/10.1111/1365-2656.13605

Hald-Mortensen, C. (2023). The Main Drivers of Biodiversity Loss : A Brief Overview. *Journal of Ecology & Natural Resources*, *7*. https://doi.org/10.23880/jenr-16000346

Hedges, S. (2012). *Monitoring elephants and assessing threats : A manual for researchers, managers and conservationists*. Universities Press (India) Private Limited, Himayatnagar, India.

Hodgson, I. D., Redpath, S. M., Sandstrom, C., & Biggs, D. (2020). *The state of knowledge and practice on human-wildlife conflicts*. Luc Hoffmann Institute, Gland, Switzerland.

Kely, M. R., Kouakou, C. Y., Bene, J.-C. K., Koffi, A. D., N'guessan, K. A., & Tiedoue, M. R. (2019). Spatial distribution and period of activity of the forest elephant (*Loxodonta africana cyclotis*) at Taï National Park, south western Côte d'Ivoire. *Journal of Applied Biosciences*, *133*, 13542-13551.

King, L. E., Lala, F., Nzumu, H., Mwambingu, E., & Douglas-Hamilton, I. (2017). Beehive fences as a multidimensional conflict-mitigation tool for farmers coexisting with elephants. *Conservation Biology*, *31*(4), 743-752.

Kissinger, G., Herold, M., & De Sy, V. (2012). *Drivers of deforestation and forest degradation : A Synthesis Report for REDD+ Policymakers*. Lexeme Consulting, Vancouver, Canada.

Krebs, B. L., Torres ,Erika, Chesney ,Charlie, Kantoniemi Moon ,Veronica, & and Watters, J. V. (2017). Applying Behavioral Conditioning to Identify Anticipatory Behaviors. *Journal of Applied Animal Welfare Science*, *20*(2), 155-175. https://doi.org/10.1080/10888705.2017.1283225

Laporte, N. T., Stabach, J. A., Grosch, R., Lin, T. S., & Goetz, S. J. (2007). Expansion of industrial logging in Central Africa. *Science*, *316*(5830), 1451. https://doi.org/10.1126/science.1141057

Laurance, W. F., Croes, B. M., Tchignoumba, L., Lahm, S. A., Alonso, A., Lee, M. E., Campbell, P., & Ondzeano, C. (2006). Impacts of Roads and Hunting on Central African Rainforest Mammals. *Conservation Biology*, *20*(4), 1251-1261. https://doi.org/10.1111/j.1523-1739.2006.00420.x

Li, M., Jiang, W., Li, B., & Butt, N. (2023). Social and cultural aspects of human-wildlife conflicts : Understanding people's attitudes to crop-raiding animals and other wildlife in agricultural systems of the Tibetan Plateau. *Integrative Conservation*, *2*(4), 214-225. https://doi.org/10.1002/inc3.30

Li, S., McShea, W. J., Wang, D., Huang, J., & Shao, L. (2012). A direct comparison of camera-trapping and sign transects for monitoring wildlife in the Wanglang National Nature Reserve, China. *Wildlife Society Bulletin*, *36*(3), 538-545. https://doi.org/10.1002/wsb.161

Liu, F., McShea, W. J., Garshelis, D. L., Zhu, X., Wang, D., & Shao, L. (2011). Human-wildlife conflicts influence attitudes but not necessarily behaviors : Factors driving the poaching of bears in China. *Biological Conservation*, *144*(1), 538-547.

Liu, P., Wen, H., Harich, F. K., He, C., Wang, L., Guo, X., Zhao, J., Luo, A., Yang, H., Sun, X., Yu, Y., Zheng, S., Guo, J., Li, L., & Zhang, L. (2017). Conflict between conservation and development : Cash forest encroachment in Asian elephant distributions. *Scientific Reports*, *7*(1), Article 1. https://doi.org/10.1038/s41598-017-06751-6

Loarie, S. R., Aarde, R. J. V., & Pimm, S. L. (2009). Fences and artificial water affect African savannah elephant movement patterns. *Biological Conservation*, *142*(12), 3086-3098. https://doi.org/10.1016/j.biocon.2009.08.008

Maisels, F., Strindberg, S., Blake, S., Wittemyer, G., Hart, J., Williamson, E. A., Aba'a, R., Abitsi, G., Ambahe, R. D., Amsini, F., Bakabana, P. C., Hicks, T. C., Bayogo, R. E., Bechem, M., Beyers, R. L., Bezangoye, A. N., Boundja, P., Bout, N., Akou, M. E., … Warren, Y. (2013). Devastating Decline of Forest Elephants in Central Africa. *PLoS ONE*, *8*(3), e59469. https://doi.org/10.1371/journal.pone.0059469

Marshall, K., White, R., & Fischer, A. (2007). Conflicts between humans over wildlife management : On the diversity of stakeholder attitudes and implications for conflict management. *Biodiversity and Conservation*, *16*, 3129-3146.

Matsika, T. A., Adjetey, J. A., Obopile, M., Songhurst, A. C., McCulloch, G., & Stronza, A. (2024). Exploring crop maturity times as a conservation tool for improving resilience to human-elephant conflict : Elephant crop-raiding. *Agroecology and Sustainable Food Systems*, *48*(7), 961-982. https://doi.org/10.1080/21683565.2024.2348627

Mbamy, W., Beirne, C., Froese, G. Z. L., Obiang Ebanega, M., & Poulsen, J. R. (2024). Linking crop availability, forest elephant visitation and perceptions of human-elephant interactions in villages bordering Ivindo National Park, Gabon. *Oryx*, *58*(2), 261-268. https://doi.org/10.1017/S0030605323000704

Melle Ekane, M., Tadida Elvis, C., Kamah Pascal, B., Agbor James, A., Esther Eyong, M. A., Che Scholastica, N., Aganya Benedatte, E., & Tashe Vanesa, N. (2023). Grouping behavior of African forest elephants (*Loxodonta cyclotis*) : A significant habitat exploitation strategy in Mount Cameroon National Park, Southwest region, Cameroon. *Global Journal of Zoology*, *8*(1), 006-014. https://doi.org/10.17352/gjz.000027

Meredith, M., & Ridout, M. (2014). Overlap : Estimates of Coefficient of Overlapping for Animal Activity Patterns. *R package version 0.2*, *4*.

Meredith, M., Ridout, M., & Campbell, L. A. D. (2024). *overlap : Estimates of Coefficient of Overlapping for Animal Activity Patterns*. https://cran.r-project.org/web/packages/overlap/overlap.pdf

Mesmin, T., Iii, L. M., Mboringong, F., Etoga, G., Voundi, E., Ngom, E. P. J., Mesmin, T., Iii, L. M., Mboringong, F., Etoga, G., Voundi, E., & Ngom, E. P. J. (2021). Environmental Impacts of the Oil Palm Cultivation in Cameroon. In *Elaeis guineensis*. IntechOpen. https://doi.org/10.5772/intechopen.97862

Mills, E. C., Poulsen, J. R., Fay, J. M., Morkel, P., Clark, C. J., Meier, A., Beirne, C., & White, L. J. T. (2018). Forest elephant movement and habitat use in a tropical forest-grassland mosaic in Gabon. *PLoS ONE*, *13*(7), e0199387. https://doi.org/10.1371/journal.pone.0199387

MINAT. (2014). *Plan communal de développement de Campo*. Ministry of Territorial Administration and Decentralization, Cameroon. https://www.pndp.org/documents/PCD_Campo.pdf

MINFOF. (2012). *Guide de l'usager*. Ministry of Forestry and Wildlife, Cameroon.

MINFOF. (2014a). *Plan d'affaire et stratégie de mise en œuvre du Parc National de Campo-Ma'an. Période 2015-2019*. Ministry of Forestry and Wildlife, Cameroon.

MINFOF. (2014b). *Plan d'aménagement du Parc National de Campo-Ma'an et de sa zone périphérique. Période 2015-2019*. Ministry of Forestry and Wildlife, Cameroon.

Mmbaga, N. E., Munishi, L. K., & Treydte, A. C. (2017). How dynamics and drivers of land use/land cover change impact elephant conservation and agricultural livelihood development in Rombo, Tanzania. *Journal of Land Use Science*, *12*(2-3), 168-181. https://doi.org/10.1080/1747423X.2017.1313324

Monterroso, P., Alves, P. C., & Ferreras, P. (2014). Plasticity in circadian activity patterns of mesocarnivores in Southwestern Europe : Implications for species coexistence. *Behavioral Ecology and Sociobiology*, *68*, 1403-1417. https://doi.org/10.1007/s00265-014-1748-1

Montgomery, R. A., Raupp, J., Mukhwana, M., Greenleaf, A., Mudumba, T., & Muruthi, P. (2022). The efficacy of interventions to protect crops from raiding elephants. *Ambio*, *51*(3), 716-727.

Moore, J. F., Pine, W. E., Mulindahabi, F., Niyigaba, P., Gatorano, G., Masozera, M. K., & Beaudrot, L. (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

Mortimer, B., Walker, J. A., Lolchuragi, D. S., Reinwald, M., & Daballen, D. (2021). Noise matters : Elephants show risk-avoidance behaviour in response to human-generated seismic cues. *Proceedings of the Royal Society B: Biological Sciences*, *288*(1953), 20210774. https://doi.org/10.1098/rspb.2021.0774

Moumbock, E., Ngaba, J., & Martial, M. (2020). States and perspectives for mitigating conflicts between human and wildlife : Case of the south-western of the Dja faunal reserve (Cameroon). *International Journal of Innovation and Applied Studies*, *29*(3), 650-660.

Naughton-Treves, L. (1998). Predicting Patterns of Crop Damage by Wildlife around Kibale National Park, Uganda. *Conservation Biology*, *12*(1), 156-168. https://doi.org/10.1111/j.1523-1739.1998.96346.x

Naughton-Treves, L., & Treves, A. (2005). Socio-ecological factors shaping local support for wildlife : Crop-raiding by elephants and other wildlife in Africa. *People and Wildlife*, 252-277.

Nchanji, Y. K., Ramcilovic-Suominen, S., Nchanji, E. B., Mala, W. A., & Kotilainen, J. (2023). Tackling conflicts, supporting livelihoods : Convivial conservation in the Campo Ma'an National Park. *Conservation and Society*, *21*(1), 61-72.

Nelson, A., Bidwell, P., & Sillero, C. (2003). *A review of human-elephant conflict management strategies*. People and Wildlife Initiative. Oxford University: Wildlife Conservation Research Unit.

Ngama, S., Bindelle, J., Poulsen, J. R., Hornick, J.-L., Linden, A., Korte, L., Doucet, J.-L., & Vermeulen, C. (2019). Do topography and fruit presence influence occurrence and intensity of crop-raiding by forest elephants (*Loxodonta africana cyclotis*)? *PLoS ONE*, *14*(3), e0213971. https://doi.org/10.1371/journal.pone.0213971

Ngama, S., Korte, L., Bindelle, J., Vermeulen, C., & Poulsen, J. R. (2016). How bees deter elephants : Beehive trials with forest elephants (*Loxodonta africana cyclotis*) in Gabon. *PLoS One*, *11*(5), e0155690.

Ngandjui, G., & Ringuet, S. (2010). *MANUEL ETIS: Le programme ETIS de suivi du commerce illégal de l'ivoire et autres produits de l'éléphant d'Afrique* Loxodonta africana *comme outil de protection de l'éléphant au Cameroun*. TRAFFIC. https://www.traffic.org/site/assets/files/8517/etis-manuel-cameroun.pdf

Nlom, J. H. (2021). A bio-economic analysis of conflicts between illegal hunting and wildlife management in Cameroon : The case of Campo-Ma'an National Park. *Journal for Nature Conservation*, *61*, 126003. https://doi.org/10.1016/j.jnc.2021.126003

Nsonsi, F., Heymans, J.-C., Diamouangana, J., & Breuer, T. (2017). Attitudes Towards Forest Elephant Conservation Around a Protected Area in Northern Congo. *Conservation and Society*, *15*(1), 59. https://doi.org/10.4103/0972-4923.201394

Nunes, C. A., Berenguer, E., França, F., Ferreira, J., Lees, A. C., Louzada, J., Sayer, E. J., Solar, R., Smith, C. C., Aragão, L. E. O. C., Braga, D. D. L., De Camargo, P. B., Cerri, C. E. P., De Oliveira, R. C., Durigan, M., Moura, N., Oliveira, V. H. F., Ribas, C., Vaz-de-Mello, F., … Barlow, J. (2022). Linking land-use and land-cover transitions to their ecological impact in the Amazon. *Proceedings of the National Academy of Sciences*, *119*(27), e2202310119. https://doi.org/10.1073/pnas.2202310119

Nuñez, C. L., Froese, G., Meier, A. C., Beirne, C., Depenthal, J., Kim, S., Mbélé, A. E., Nordseth, A., & Poulsen, J. R. (2019). Stronger together : Comparing and integrating camera trap, visual, and dung survey data in tropical forest communities. *Ecosphere*, *10*(12), e02965. https://doi.org/10.1002/ecs2.2965

Nzooh-Dongmo, Z. N., N'Goran, K. P., Fondja, C., & Nkono, J. (2015). *Évaluation de la dynamique des populations de grands et moyens mammifères dans le domaine forestier permanent de l'Unité Technique Opérationnelle Campo-Ma'an*. Ministry of Forestry and Wildlife, Cameroon.

O'Connell-Rodwell, C. E., Rodwell, T., Rice, M., & Hart, L. A. (2000). Living with the modern conservation paradigm : Can agricultural communities co-exist with elephants? A five-year case study in East Caprivi, Namibia. *Biological Conservation*, *93*(3), 381-391. https://doi.org/10.1016/S0006-3207(99)00108-1

Omoregie, Q., Oboh, B., & Egonmwan, R. (2019). Conservation Attitudes and Challenges : A Study of Forest Elephants In Southern Nigeria Forests. *Egyptian Academic Journal of Biological Sciences, B. Zoology*, *11*(3), 1-11. https://doi.org/10.21608/eajbsz.2019.56367

Omoregie, Q., Oboh, B., & Egonmwan, R. (2020). Presence and distribution of relict *Loxodonta cyclotis* (African forest elephant) populations in southern Nigeria. *UNILAG Journal of Medicine, Science and Technology*, *8*(1), 1-15.

Oosterveer, P. (2015). Promoting sustainable palm oil : Viewed from a global networks and flows perspective. *Journal of Cleaner Production*, *107*, 146-153. https://doi.org/10.1016/j.jclepro.2014.01.019

Ordway, E. M., Naylor, R. L., Nkongho, R. N., & Lambin, E. F. (2017). Oil palm expansion in Cameroon : Insights into sustainability opportunities and challenges in Africa. *Global Environmental Change*, *47*, 190-200. https://doi.org/10.1016/j.gloenvcha.2017.10.009

Parker, G., Osborn, F., Hoare, R., & Niskanen, L. (2007). *Human-Elephant Conflict Mitigation : A training course for Community-based Approaches in Africa*. Participant's manual. Elephant Pepper Development Trust, Livingstone, Zambia and IUCN/SSC AfESG, Nairobi, Kenya.

Pedersen, E. J., Miller, D. L., Simpson, G. L., & Ross, N. (2019). Hierarchical generalized additive models in ecology : An introduction with mgcv. *PeerJ*, *7*, e6876. https://doi.org/10.7717/peerj.6876

Perrings, C., & Halkos, G. (2015). Agriculture and the threat to biodiversity in sub-Saharan Africa. *Environmental Research Letters*, *10*(9), 095015. https://doi.org/10.1088/1748-9326/10/9/095015

Plumptre, A. J. (2000). Monitoring mammal populations with line transect techniques in African forests. *Journal of Applied Ecology*, *37*(2), 356-368. https://doi.org/10.1046/j.1365-2664.2000.00499.x

Poulsen, J. R., Clark, C. J., & Bolker, B. M. (2011). Decoupling the effects of logging and hunting on an Afrotropical animal community. *Ecological Applications*, *21*(5), 1819-1836. https://doi.org/10.1890/10-1083.1

Prakash, T., Wijeratne, A., & Fernando, P. (2020). Human-elephant conflict in Sri Lanka : Patterns and extent. *Gajah*, *51*(12), 16-25.

R Core Team. (2023). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Ram, A. K., Mondol, S., Subedi, N., Lamichhane, B. R., Baral, H. S., Natarajan, L., Amin, R., & Pandav, B. (2021). Patterns and determinants of elephant attacks on humans in Nepal. *Ecology and Evolution*, *11*(17), 11639-11650. https://doi.org/10.1002/ece3.7796

Rathnayake, C. W. M., Jones, S., Soto-Berelov, M., & Wallace, L. (2022). Human-elephant conflict and land cover change in Sri Lanka. *Applied Geography*, *143*, 102685. https://doi.org/10.1016/j.apgeog.2022.102685

Ridout, M. S., & Linkie, M. (2009). Estimating overlap of daily activity patterns from camera trap data. *Journal of Agricultural, Biological, and Environmental Statistics*, *14*(3), 322-337. https://doi.org/10.1198/jabes.2009.08038

Røskaft, E., Bjerke, T., Kaltenborn, B., Linnell, J. D. C., & Andersen, R. (2003). Patterns of self-reported fear towards large carnivores among the Norwegian public. *Evolution and Human Behavior*, *24*(3), 184-198. https://doi.org/10.1016/S1090-5138(03)00011-4

Rovero, F., & Marshall, A. R. (2009). Camera trapping photographic rate as an index of density in forest ungulates. *Journal of Applied Ecology*, *46*(5), 1011-1017. https://doi.org/10.1111/j.1365-2664.2009.01705.x

Sampson, C., Leimgruber, P., Rodriguez, S., McEvoy, J., Sotherden, E., & Tonkyn, D. (2019). Perception of Human-Elephant Conflict and Conservation Attitudes of Affected Communities in Myanmar. *Tropical Conservation Science*, *12*, 1940082919831242. https://doi.org/10.1177/1940082919831242

Sanare, J. E., Valli, D., Leweri, C., Glatzer, G., Fishlock, V., & Treydte, A. C. (2022). A Socio-Ecological Approach to Understanding How Land Use Challenges Human-Elephant

Coexistence in Northern Tanzania. *Diversity*, *14*(7), Article 7. https://doi.org/10.3390/d14070513

Sandbrook, C., Luque-Lora, R., & Adams, W. M. (2018). Human bycatch : Conservation surveillance and the social implications of camera traps. *Conservation and Society*, *16*(4), 493-504.

Sanderson, J. G., & Trolle, M. (2005). Monitoring Elusive Mammals : Unattended cameras reveal secrets of some of the world's wildest places. *American Scientist*, *93*(2), 148-155.

Scalbert, M., Vermeulen, C., Breuer, T., & Doucet, J.-L. (2023). The challenging coexistence of forest elephants Loxodonta cyclotis and timber concessions in central Africa. *Mammal Review*, *53*(1), 15-31. https://doi.org/10.1111/mam.12305

Schlegel, B., & Steenbergen, M. (2020, septembre 22). *brant : Test for Parallel Regression Assumption*. https://cran.r-project.org/web/packages/brant/index.html

Sedgwick, P. (2013). Questionnaire surveys : Sources of bias. *BMJ*, *347*, f5265. https://doi.org/10.1136/bmj.f5265

Seoraj-Pillai, N., & Pillay, N. (2016). A meta-analysis of human-wildlife conflict : South African and global perspectives. *Sustainability*, *9*(1), 34.

Shaffer, L. J., Khadka, K. K., Van Den Hoek, J., & Naithani, K. J. (2019). Human-Elephant Conflict : A Review of Current Management Strategies and Future Directions. *Frontiers in Ecology and Evolution*, *6*. https://doi. org/10.3389/fevo.2018.00235

Sharma, K., Fiechter, M., George, T., Young, J., Alexander, J. S., Bijoor, A., Suryawanshi, K., & Mishra, C. (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

Sharma, P., Chettri, N., Uddin, K., Wangchuk, K., Joshi, R., Tandin, T., Pandey, A., Gaira, K. S., Basnet, K., Wangdi, S., Dorji, T., Wangchuk, N., Chitale, V. S., Uprety, Y., & Sharma, E. (2020). Mapping human–wildlife conflict hotspots in a transboundary landscape, Eastern Himalaya. *Global Ecology and Conservation*, *24*, e01284. https://doi.org/10.1016/j.gecco.2020.e01284

Sitati, N. W., Walpole, M. J., & Leader-Williams, N. (2005). Factors affecting susceptibility of farms to crop raiding by African elephants : Using a predictive model to mitigate conflict. *Journal of Applied Ecology*, *42*(6), 1175-1182. https://doi.org/10.1111/j.1365-2664.2005.01091.x

Sitati, N. W., Walpole, M. J., Smith, R. J., & Leader-Williams, N. (2003). Predicting spatial aspects of human-elephant conflict. *Journal of Applied Ecology*, *40*(4), 667-677. https://doi.org/10.1046/j.1365-2664.2003.00828.x

Smit, J. B., Searle, C. E., Buchanan-Smith, H. M., Strampelli, P., Mkuburo, L., Kakengi, V. A., Kohi, E. M., Dickman, A. J., & Lee, P. C. (2023). Anthropogenic risk increases night-time activities and associations in African elephants (*Loxodonta africana*) in the Ruaha-Rungwa ecosystem, Tanzania. *African Journal of Ecology*, *61*(1), 64-76. https://doi.org/10.1111/aje.13083

Sollmann, R. (2018). A gentle introduction to camera-trap data analysis. *African Journal of Ecology*, *56*(4), 740-749. https://doi.org/10.1111/aje.12557

Solomon, J. N., Gavin, M. C., & Gore, M. L. (2015). Detecting and understanding non-compliance with conservation rules. *Biological Conservation*, *189*, 1-4. https://doi.org/10.1016/j.biocon.2015.04.028

Songhurst, A., McCulloch, G., & Coulson, T. (2016). Finding pathways to human-elephant coexistence : A risky business. *Oryx*, *50*(4), 713-720. https://doi.org/10.1017/S0030605315000344

Storch, I., Cristescu, B., & Fabiano, E. (2025). Human-wildlife conflict and coexistence in the African context. *Wildlife Biology*, *2025*(1), e01432. https://doi.org/10.1002/wlb3.01432

Suba, R. B., Ploeg, J. van der, Zelfde, M. van't, Lau, Y. W., Wissingh, T. F., Kustiawan, W., de Snoo, G. R., & de Iongh, H. H. (2017). Rapid Expansion of Oil Palm Is Leading to Human-Elephant Conflicts in North Kalimantan Province of Indonesia. *Tropical Conservation Science*, *10*, 1940082917703508. https://doi.org/10.1177/1940082917703508

Tanwar, K. S., Sadhu, A., & Jhala, Y. V. (2021). Camera trap placement for evaluating species richness, abundance, and activity. *Scientific Reports*, *11*(1), 23050. https://doi.org/10.1038/s41598-021-02459-w

Tchouto, M. G. P., Yemefack, M., De Boer, W. F., De Wilde, J. J. F. E., Van Der Maesen, L. J. G., & Cleef, A. M. (2006). Biodiversity Hotspots and Conservation Priorities in the Campo-Ma'an Rain Forests, Cameroon. *Biodiversity and Conservation*, *15*(4), 1219-1252. https://doi.org/10.1007/s10531-005-0768-6

Thant, Z. M., Leimgruber, P., Williams, A. C., Oo, Z. M., Røskaft, E., & May, R. (2023). Factors influencing the habitat suitability of wild Asian elephants and their implications for human-elephant conflict in Myanmar. *Global Ecology and Conservation*, *43*, e02468.

Thekaekara, T., Bhagwat, S. A., & Thornton, T. F. (2021). Coexistence and culture : Understanding human diversity and tolerance in human-elephant interactions. *Frontiers in Conservation Science*, *2*, 735929.

Thomas, M. L., Baker, L., Beattie, J. R., & Baker, A. M. (2020). Determining the efficacy of camera traps, live capture traps, and detection dogs for locating cryptic small mammal species. *Ecology and Evolution*, *10*(2), 1054-1068. https://doi.org/10.1002/ece3.5972

Tiller, L. N., Humle, T., Amin, R., Deere, N. J., Lago, B. O., Leader-Williams, N., Sinoni, F. K., Sitati, N., Walpole, M., & Smith, R. J. (2021). Changing seasonal, temporal and spatial crop-raiding trends over 15 years in a human-elephant conflict hotspot. *Biological Conservation*, *254*, 108941. https://doi.org/10.1016/j.biocon.2020.108941

Tiller, L. N., & Williams, H. F. (2021). The elephant in the farm : Long-term solutions are the key to coexistence. *Animal Conservation*, *24*(5), 733-734. https://doi.org/10.1111/acv.12741

Tobias Ochieng, N., Elizabeth, K. N., & Nigel, L.-W. (2021). Measuring the conservation attitudes of local communities towards the African elephant *Loxodonta africana*, a flagship species in the Mara ecosystem. *PLoS ONE*, *16*(6), e0253234. https://doi.org/10.1371/journal.pone.0253234

Tsegaye, A., Bekele, A., & Atikem, A. (2023). Local's attitude towards African elephant conservation in and around Chebra Churchura National Park, Ethiopia. *Plos ONE*, *18*(10), e0292641. https://doi.org/10.1371/journal.pone.0292641

Tutin, C. E. G., White, L. J. T., & Mackanga-Missandzou, A. (1997). The Use by Rain Forest Mammals of Natural Forest Fragments in an Equatorial African Savanna. *Conservation Biology*, *11*(5), 1190-1203. https://doi.org/10.1046/j.1523-1739.1997.96211.x

Venables, W. N., & Ripley, B. D. (2002). *Modern Applied Statistics with S* (Fourth edition). Springer, New York. https://www.stats.ox.ac.uk/pub/MASS4/

Virtanen, P., Macandza, V., Goba, P., Mourinho, J., Roque, D., Mamugy, F., & Langa, B. (2021). Assessing tolerance for wildlife : Human-elephant conflict in Chimanimani, Mozambique. *Human Dimensions of Wildlife*, *26*(5), 411-428. https://doi.org/10.1080/10871209.2020.1834648

Walsh, P. D., & White, L. J. T. (1999). What It Will Take to Monitor Forest Elephant Populations. *Conservation Biology*, *13*(5), 1194-1202. https://doi.org/10.1046/j.1523-1739.1999.98148.x

Walsh, P. D., White, L. J. T., Mbina, C., Idiata, D., Mihindou, Y., Maisels, F., & Thibault, M. (2001). Estimates of forest elephant abundance : Projecting the relationship between precision and effort. *Journal of Applied Ecology*, *38*(1), 217-228. https://doi.org/10.1046/j.1365-2664.2001.00578.x

Wearn, O. R., & Glover-Kapfer, P. (2019). Snap happy : Camera traps are an effective sampling tool when compared with alternative methods. *Royal Society Open Science*, *6*(3), 181748. https://doi.org/10.1098/rsos.181748

Weladji, R. B., Moe, S. R., & Vedeld, P. (2003). Stakeholder attitudes towards wildlife policy and the Bénoué Wildlife Conservation Area, North Cameroon. *Environmental Conservation*, *30*(4), 334-343. https://doi.org/10.1017/S0376892903000353

Whytock, R. C., Abwe, E. E., Mfossa, D. M., Ketchen, M. E., Abwe, A. E., Nguimdo, V. R. V., Maisels, F., Strindberg, S., & Morgan, B. J. (2021). Mammal distribution and trends in the threatened Ebo intact forest landscape, Cameroon. *Global Ecology and Conservation*, *31*, e01833. https://doi.org/10.1016/j.gecco.2021.e01833

Wood, S. (2023). *mgcv : Mixed GAM Computation Vehicle with Automatic Smoothness Estimation* (p. 1.9-1). https://CRAN.R-project.org/package=mgcv

Wrege, P. H., Bambi, F. B.-D., Malonga, P. J. F., Samba, O. J., & Brncic, T. (2024). Early detection of human impacts using acoustic monitoring : An example with forest elephants. *PLoS ONE*, *19*(7), e0306932. https://doi.org/10.1371/journal.pone.0306932

Wrege, P. H., Rowland, E. D., Thompson, B. G., & Batruch, N. (2010). Use of acoustic tools to reveal otherwise cryptic responses of forest elephants to oil exploration. *Conservation Biology*, *24*(6), 1578-1585. https://doi.org/10.1111/j.1523-1739.2010.01559.x

Wunderle, J. M. (1997). The role of animal seed dispersal in accelerating native forest regeneration on degraded tropical lands. *Forest Ecology and Management*, *99*(1), 223-235. https://doi.org/10.1016/S0378-1127(97)00208-9

Yackulic, C. B., Strindberg, S., Maisels, F., & Blake, S. (2011). The spatial structure of hunter access determines the local abundance of forest elephants (*Loxodonta cyclotis*). *Ecological Applications*, *21*(4), 1296-1307. https://doi.org/10.1890/09-1099.1

Zwerts, J. A., Stephenson, P. J., Maisels, F., Rowcliffe, M., Astaras, C., Jansen, P. A., van der Waarde, J., Sterck, L. E. H. M., Verweij, P. A., Bruce, T., Brittain, S., & van Kuijk, M. (2021). Methods for wildlife monitoring in tropical forests : Comparing human observations, camera traps, and passive acoustic sensors. *Conservation Science and Practice*, *3*(12), e568. https://doi.org/10.1111/csp2.568