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Human-wildlife conflict in the Campo-Ma'an Technical Operational Unit, Southern Cameroon

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Human-Wildlife Conflict (HWC) is increasing in the Campo-Ma'an Conservation Area located in the southern region of Cameroon, thus threatening human livelihoods and wildlife; yet the sources and consequences of HWC in this region remain poorly understood. 127 households from three subdivisions were interviewed to investigate the extent of wildlife crop damage and identify humans' impact on wildlife. Most surveyed households (98%) reported wildlife crop damage, mainly by eighteen species. The severity level's distribution differed among subdivisions. Out of 23 plant species grown, 14 suffered damage, five being staple foods; suggesting that HWC can threaten food security. Elephants (*Loxodonta cyclotis*) were the second most cited crop raiders, after cane rats (*Thryonomys swinderianus*), causing the greatest economic loss. None of the mitigation measures implemented effectively reduced crop raiding. The main human effects on wildlife were poaching and habitat loss, threatening biodiversity. Crop damage and illegal activities must be monitored and mitigations established, to reduce human-wildlife interferences. This requires setting up adaptive land-use systems and modifying and empowering wildlife legislation.

Key words: Forest elephants, Crop raiding, Campo-Ma'an National Park, mitigation, wildlife policy.

INTRODUCTION

Human-Wildlife Conflict (HWC) is a situation that occurs when the presence or behaviour of wildlife poses an actual or perceived, direct and recurring threat to human interests or needs, leading to disagreements between groups of people and negative impacts on people and wildlife (International Union for Conservation of Nature [IUCN], 2020). The negative consequences on human's livelihood may involve wildlife damage to crops (Torres et al., 2018; Granados and Weladji, 2012 Pant et al. 2016), livestock (Weladji and Tchamba, 2003; Karanth et al. 2013a; Torres et al., 2018), or attacks on humans (Karanth et al., 2013b; Karanth and Kudalkar, 2017). Conflicts also occur when people retaliate against the species blamed or compete with wildlife for resources such as space, water and food (Hoare, 2015; Mariki et al., 2015; Conover et al., 2018). Humans have lived alongside and interacted with wild animals throughout the evolutionary history and HWC with its long historical existence is receiving increasing attention from conservation biologists across the globe (Messmer, 2000;

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Barua et al., 2013; Anand and Radhakrishna, 2017). Despite these efforts, HWC remains a global phenomenon, with nearly 90% of the countries currently affected (Messmer, 2000; Anand and Radhakrishna, 2017). Most of Africa's protected areas (PAs) were created by colonial administrators without considering the concerns of local communities, and in most cases, people were displaced or deprived of the traditional use of resources, causing them to suffer economic hardship (Weladji and Tchamba, 2003; Matseketsa et al., 2019). On the other hand, the animals that are to be considered "protected", mostly abundant in the PAs (Ole, 2011), often find themselves roaming outside PAs, creating further damages to crops and livestock (Granados and Weladji, 2012; Karanth and Vanamamalai, 2020). This generates conflicts around PAs, where land has become a scarce resource. Yet, the human population adjacent to wildlife habitats is generally growing, and with it, the demand for more farming lands and more resources from the PAs (Mekonen, 2020). Moreover, local communities illegally herd and graze livestock into PAs (Bobo and Weladji, 2011; Karanth et al., 2013b), and have engaged in poaching, often also killing species listed as threatened (Mwakatobe et al., 2014; Mariki et al., 2015). For humans living adjacent to PAs, crop raiding is one of the most reported forms of HWC (Granados and Weladji, 2012; Karanth and Vanamamalai, 2020; Govind and Jayson, 2021), and a variety of species groups are the culprits including, but not limited to, elephants (*Loxodonta spp*), primates, rodents and birds (Mwakatobe et al., 2014; IUCN, 2020). Among the many wildlife species involved in HWC, elephants are the most reported (Naughton-Treves, 1998; Granados and Weladji, 2012; Anand and Radhakrishna, 2017) and generally have a bad reputation among local people as they damage a lot in a single raiding event (Naughton-Treves, 1998; King, 2010; Ngama et al., 2018). Indeed, although being currently listed as Endangered or Critically Endangered in Africa (IUCN, 2021), conflict with humans is one of the major causes of the decline of elephant populations, hampering their long-term conservation (Granados and Weladji, 2012; Pant et al., 2016).

HWC is widespread, unevenly distributed, and complex in nature, making it a central issue in biodiversity conservation and wildlife management (Dickman, 2010; Anand and Radhakrishna, 2017; Mekonen, 2020). Different species are involved, causing different types of damage at different times of the year (Conover et al., 2018; Mekonen, 2020). This may be because of animal preferences or may be a consequence of the dominant crop types grown in each area (Weladji and Tchamba, 2003). Also, crop damages and the resulting retaliations are the only visible impacts of HWC, as there are hidden or poorly documented social impacts not often reported (Dickman, 2010; Barua et al., 2013; Redpath et al., 2015). For example, people have given up some of their rights because of having proximity to wild animals or conservation areas (Thirgood et al., 2005; Dickman, 2010) on which they are dependent for fuelwood, thatch, fish, bushmeat, medicinal plants, and pasture (Weladji and Tchamba, 2003; Granados and Weladji, 2012). Furthermore, various mitigation strategies developed against wildlife damages are limited with different levels of efficiency depending on the target species (Hoare, 2015; King, 2010; Nelson et al., 2003). HWC is exacerbated in Central Africa, where wildlife is often considered state property (Naughton-Treves 1998; Ole, 2011), with dramatic consequences on both wildlife and local communities (Weladji and Tchamba, 2003; Granados and Weladji, 2012; Ngama et al., 2018). Despite recent efforts to involve local people and other stakeholders, frustrations remain (Bobo and Weladji, 2011). In the Democratic Republic of Congo, elephant damage to crops was reported to decrease farmers' annual revenues by 77% (Inogwabini et al., 2013). In Northern Cameroon, 87% of households complained of crop damage with 31% of crop income lost to wildlife around the Bénoué Wildlife Conservation Area (Weladji and Tchamba, 2003), whereas elephant damages to crops have been estimated between US$40,000 to US$75,000 per year (Tchamba, 1996). On the other hand, 62% of the forest elephant population of the Congo basin was decimated because of the illegal ivory trade between 2002 and 2011 (Maisels et al., 2013). The negative reputation local people have for wildlife could also be present in the Campo-Ma'an region where local people heavily rely on the nearby forest for their livelihood and HWC is reported, mostly from large and medium size mammals including elephants (Ole, 2011, Eyebe et al., 2012), and effective mitigation strategies are lacking. Indeed, Eyebe et al. (2012) reported a couple of villages facing damage from elephants in Campo-Ma'an. Human population has increased in the Campo-Ma'an region in recent years in response to the development and establishment of agro-industrial and logging companies (Tiani et al., 2005), and major development projects such as the dam and port constructions (Ministère des Forêts et de la Faune [MINFOF], (2014). Moreover, the recent creation of an industrial oil palm plantation in the region has resulted in the reclassification of about 60,000 ha and the slash of all the trees in the logging concession n°09025, situated in the west of the National Park. These may increase the frustration by imposing greater restrictions on the use of resources on which local peoples rely, thereby increasing HWC. Accordingly, this study aims to identify the main source of conflicts between people and wildlife, as a prerequisite to framing an adaptive management policy through the development of effective mitigation techniques to alleviate potential problems. More specifically, the study assess: the crop damage experience and severity level; the types and stages of growth of crop raided; the wildlife species involved; the factors influencing crop damage occurrence and mitigation strategies used by farmers; the

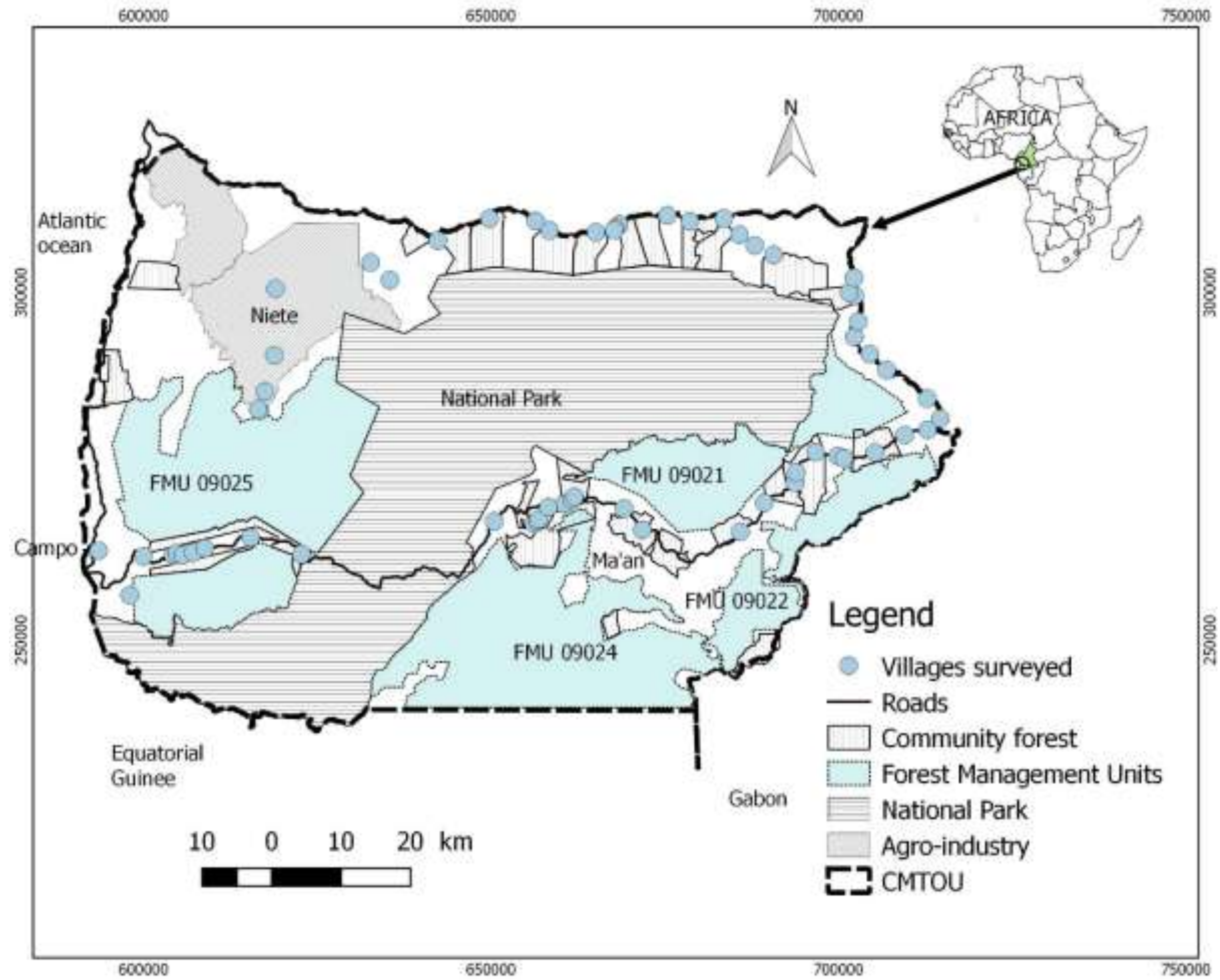

Figure 1. Location of study site and different land use types in the Campo-Ma'an Technical Operational Unit (CMTOU), Southern Cameroon.
Source: Authors

economic impact of crop raiding on farmers' livelihood; and the potential influence of humans on wildlife. Furthermore, the study evaluates whether there were differences in the effects among subdivisions.

MATERIALS AND METHODS

Study area

The Campo-Ma'an National Park (CMNP) and its peripheral zone known as Campo-Ma'an Technical Operational Unit (hereafter designated CMTOU), represents 16% (770 000 ha) of the South region of Cameroon with nine subdivisions and about 111,000 inhabitants. The CMNP is located between 2°10'N, 9°50'E and 2°25'N, 10°48'E (Figure 1) and is surrounded by 162 villages and hamlets along the main road. In addition to the park with 264,064 ha, the CMTOU includes three other land use systems, the Forest Management Units (FMU) for logging (235,485 ha), a state maritime estate (320 ha), and a multipurpose area (275,033 ha) devoted to community forests and human activities (Tiani et al., 2005). This research includes three subdivisions: Campo, Niete, and Ma'an with different socio-cultural backgrounds (MINFOF, 2014). The mean annual precipitation is about 2500 mm (MINFOF, 2014). The mean annual temperature is 25°C and the climatic conditions are favorable for agriculture all year round. There are about 80 species of mammals, including a critically endangered forest elephant (*Loxodonta cyclotis*) having a population of about 544 individuals and 2200 great apes (Nzooh-Dongmo et al., 2015). Table 1 includes most crops grown in the region (Tiani et al., 2005). Figure 1 shows the location of study site and different land use types in the Campo-Ma'an Technical Operational Unit (CMTOU), Southern Cameroon.

Data collection

Data for the human impacts on wildlife were obtained from the park's annual reports (2014-2017) and images from 19 Bushnell camera traps (Trophy Cam HD Essential E3 Trail Brown 16 MP 119837C Model, Bushnell, Kansas) deployed in southwestern Campo-Ma'an. Camera traps data were collected between May and December 2019. Deployment was stratified to have 6 cameras stations in the logging concession, 4 in the community land and 7 in the park. Camera placement was chosen based on expert

Table 1. The distribution of the percentage of reported wildlife incident by crop types.

Types of crops	Overall N=125	Campo n=68	Ma'an n=14	Niete n=43
Cassava: *Manihot esculenta*	89	91	100	81
Maize: *Zea mays*	61	54	71	67
Banana: *Musa paradisiaca*	50	60	64	30
Groundnuts: *Arachis hypogaea*	48	44	86	42
Cocoyam*: Colocasia esculenta*	38	26	50	51
Sweet potatoes*: Ipomea batatas*	19	22	7	19
Squash: *Cucurbita spp*	16	13	43	12
Yam: *Dioscorea spp*	12	12	0	16
Cocoa: *Theobroma cacao*	9	6	36	5
Sugar cane: *Saccharum spp*	10	6	21	12
Palm tree: *Alaeis guineensis*	4	3	0	7
Pepper: *Capsicum frutescens*	1	2	0	0
Okra: *Abelmoschus esculentus*	1	2	0	0
African pear: *Dacryodes edulis*	1	0	0	2

A total of 125 respondents were surveyed in Campo, Ma'an and Niete subdivision from May through August 2018.
Source: Authors

knowledge of a team of field assistants (hunters and wood logging workers) with the goal of maximizing detection of forest elephants when present at camera trap location. No human image from the camera traps would be shared or be published as they may be used for prosecution against them. In fact, community members were informed about the purpose of our work, and that their privacy would be respected (that is, no image would be shared with park authorities), and they helped identify the locations of the cameras (Sandbrook et al., 2018; Sharma et al., 2020). From the images, we extracted those with human presence, and subsequently identified and classified them as hunters (with a hunting device or animal carcasses), forest loggers (with a logging device or with wood products), or others when known (such as park staff or researchers with their crew, Deith and Brodie, 2020). Data on wildlife influence on local communities were collected from May through August 2018 in the CMTOU. We visited 54 communities within the CMTOU based on the availability of their leaders and informed them about the purpose of the research. Among them, 23 (42%) villages, from the above-mentioned three administrative subdivisions (12 villages in Campo, 4 in Ma'an, and 7 in Niete), were selected opportunistically for interviews. Within a village, households were also selected opportunistically based on their presence at the time we were present for the actual interview and willingness to take part in the research, which they confirmed by reading and signing the consent form (Supplementary material 1; Ngama et al., 2019; Mouafo et al., 2021). households heads, their wives, or any adults male or female (≥18 years old) present because adulthood starts at 18 years old in Cameroon were interviewed (Patrice, 2019; Hariohay et al., 2020; Mouafo et al., 2021; Mwakatobe et al., 2014). Overall, 127 households were interviewed, 25% being females. Interviews were conducted in French wherever possible, as most people were fluent in French (Granados and Weladji, 2012; Fopa et al., 2020). In one instance, the respondent, from a *Bagyeli* household, did not speak French, and we used a local interpreter. Following Granados and Weladji (2012) and, Weladji and Tchamba (2003) methods, the interview consisted of a semi-structured questionnaire during which the respondent had to answer several crop damages-related questions (Supplementary material 2).

The extent of crop damage was obtained using the respondents' declarations on the estimated area reported damaged by wildlife (Hariohay et al., 2020; Neupane et al., 2017). We intended to visit all farms where crop damages were reported, but due to logistical reasons, and the difficulty to estimate the extent of the damage for most animals (since most damages had occurred several months prior to our visit), we decided to only visit farms that experienced elephant crop-raiding recently (< 4 months) knowing that elephants signs may last about three months (Nzooh-Dongmo et al., 2015). Accordingly, we visited twelve farms and used data on some previously reported crop raiding events, assessed and compiled by the conservation office, to validate the responses received, thereby minimizing the risk of exaggeration from the responses received. Cassava and bananas are staple foods commonly grown in a slash-and-burn agriculture system in our study area (MINFOF, 2014). Growing these plants require farmers to use the same land for about two years allow it for fallow period for many years (Breuer and Ngama, 2020). Therefore, respondents were asked whether they were victims of crop raiding during the last three years, and if yes, to identify the growth stage of the damaged crops (Supplementary material 2) and to provide an estimate of the farm distance from the village and park boundary (Mwakatobe et al., 2014; Breuer and Ngama, 2020). Most of the respondents were aware of the distance of their villages to the entry of the CMNP by road but ignored the distance to the closest border of the CMNP or FMU. CMNP and FMU are considered wildlife habitats and the presence of wildlife in these two land use types is ideal for coexistence with farmers. Since farmers ignored the distance from their location to the park border, QGIS software (QGIS Development Team, 2020) was used to estimate the linear distances from the closest park border or FMU to each village. We considered the raiding events within the last three years in terms of the estimated percentage of crops damaged by wildlife (Karidozo and Osborn, 2005). Crop losses caused by different animal species were assessed for each cropping season. Following Granados and Weladji (2012), these percentages were grouped into four categories (Supplementary material 2): Moderate (0 to 25%), severe (25 to 50%), more severe (50 to 75%) and extremely severe

(75 to 100%). Other household members were present during the interview and could confirm or refute the information provided, to account for possible loss of information. Multi-cropping system is used for agricultural production in our study area. Therefore, several crops could be damaged simultaneously. In addition, a crop could be subject to multiple raiding events by different wildlife species. To assess the level of involvement of each animal in crop damage, we counted the number of incidents involving each crop type and attributed it to each animal species. The economical assessment of crop damages to people's livelihood was determined by estimating the actual total annual harvest by type of crops for each farmer, the proportion sold as well as the price per unit for each type of crop (Equation 1). This helped to overcome the problem of different units used to measure different types of crops. For example, cocoas are sold in bags of 100kg while cassavas are sold in baskets. Knowing the annual income from agriculture for each farmer, we deducted the monetary loss by dividing the current sale by the average percentage of losses in fields. For this purpose, we considered the mid values of the interval used to classify the extent of damage (12.5 for moderate, 37.5 for severe, 67.5 for more severe, and 87.5 for extremely severe) for all the calculations.

$$\text{Economic losses} = \sum (H_i \times P_i)/\%\text{loss} \quad (1)$$

Where H_i represents the total annual harvest of crop type i and P_i the price of unit sale for crop type i on the local market. This research was performed in accordance with the Certification of Ethical Acceptability for Research Involving Human Subjects n°30009480 delivered by the Concordia University Human Research Ethics Committee. Locally, the research protocol was reviewed and approved by the CMNP manager, and the regional administrative authority (authorization n°025/AR/L/SG/DAAJ/SDAT issued on June 19th, 2018, by the South Region Governor).

Statistical analysis

Questionnaire responses were summarized and cross tabulated for statistical analysis. A Generalized Linear Models (GLMs) was used with a binomial distribution and logit link to test the occurrence of crop raiding experienced by households across the three subdivisions and by severity level. The response variable in this model had two levels (whether the respondent experienced crop damage or not) and therefore binomial. In the second model, we assessed the impact of crop raiding on individual crop types, the response variable being the total count of raiding events on each crop species grown by the farmers. GLM with a Poisson distribution and a log link function was used to identify whether crop specie and the severity level predicted the frequency of reported damage experienced by a given crop type across the subdivisions. A quasi-Poisson distribution was used instead to account for over-dispersion, and only included data for known crop species in the analysis. For the third model, GLM with Poisson distribution was used to identify whether the wildlife species and the level of severity in crop damage across subdivisions could explain variation in the frequency of reported events caused by a given wildlife species. The total count of wildlife involvement in crop raiding incidents was used as a response variable whereas the severity level of farm damage, the wildlife species, and subdivisions were used as predictors. A quasi-Poisson distribution was also used here to account for over-dispersion. For all GLM, the log-transformed number of respondents per subdivision was used as an offset to account for differences in the statistical population between subdivisions (Agresti, 1996). We also ran separate ANOVA models to compare the mean size of reported land area affected by crop loss caused by wildlife, mean distance to FMU or National Park and average economic loss within each subdivision. Pairwise comparisons were performed using Tukey-Kramer corrections for the difference between the means. We used Pearson chi-squares to compute the difference between the subdivisions in the distribution of the severity level and stages of growth of the crops damaged. Pearson chi-squares were also used to assess the difference between mitigation methods, the differences in elephant's involvement in crop raiding incidents between subdivisions, and the distribution of human presence (total number of independent observations of poachers and loggers from photos) across three land use types (the National Park, the FMU and the community land) and the stage of growth of damaged crops. Unless otherwise specified, we reported means with their standard deviations and estimated difference with their 95% confidence intervals. Statistical analyses were performed using R statistical software (R Core Team 2020) with a significance level set at 0.05.

RESULTS

Crop raiding

From the 12 farms visited 9 (75%) were consistently in accord with the questionnaire responses, while the rest had lower actual damage than reported during the interview. Of the respondents, 98% (n = 127) reported crop damage by wildlife with no significant differences between subdivisions (GLM test, $\chi^2_2 = 1.61$, $p = 0.450$). All respondents from Campo (n = 68), representing 54% of the total, and Ma'an (n = 14) with 11%, suffered crop damages. In contrast, from Niete, only 2% respondents were not affected by crop damage. Across subdivisions, there was no difference among the levels of severity (GLM test, $\chi^2_3 = 6.07$, $p = 0.110$). Overall, 29% (n=36) of the respondents experienced extremely severe crop damages, 22% (n = 27) was more severe, 26% (n = 32) severe and 23% moderately severe. However, the severity level distribution differed significantly between subdivisions (Chi-square test, $\chi^2_6 = 14.85$, $p = 0.021$; Figure 2). Significant differences were observed for households experiencing extremely severe damages between Campo with 35% and Ma'an with 14% ($\chi^2_1 = 8.89$, $p = 0.003$). In comparison, Campo and Niete (with 24%) as well as Ma'an and Niete, were comparable (all $p > 0.1$). Figure 2 shows relative distribution of damages to crops by severity level in three subdivisions of the Campo-Ma'an region, southern Cameroon.

Types of crops damaged, and wildlife involved

Overall, of the 23 types of crops grown by the respondents, 14 (Table 1) were reported damaged by wildlife. The distribution of incidents reported varied significantly with respect to crop types (GLM test, $\chi^2_{13} = 115.93$, $p < 0.001$) and subdivisions (GLM test, $\chi^2_2 = 134.23$, $p < 0.001$), with a model $R^2 = 0.23$. The five most damaged crops reported (79% of raiding events) were also staple crops, namely cassava, maize, banana, groundnut, and cocoyam. Forty respondents (31%) reported damage to all their crops on farms with 21 in Campo and 19 in Niete. The level of severity did not differ

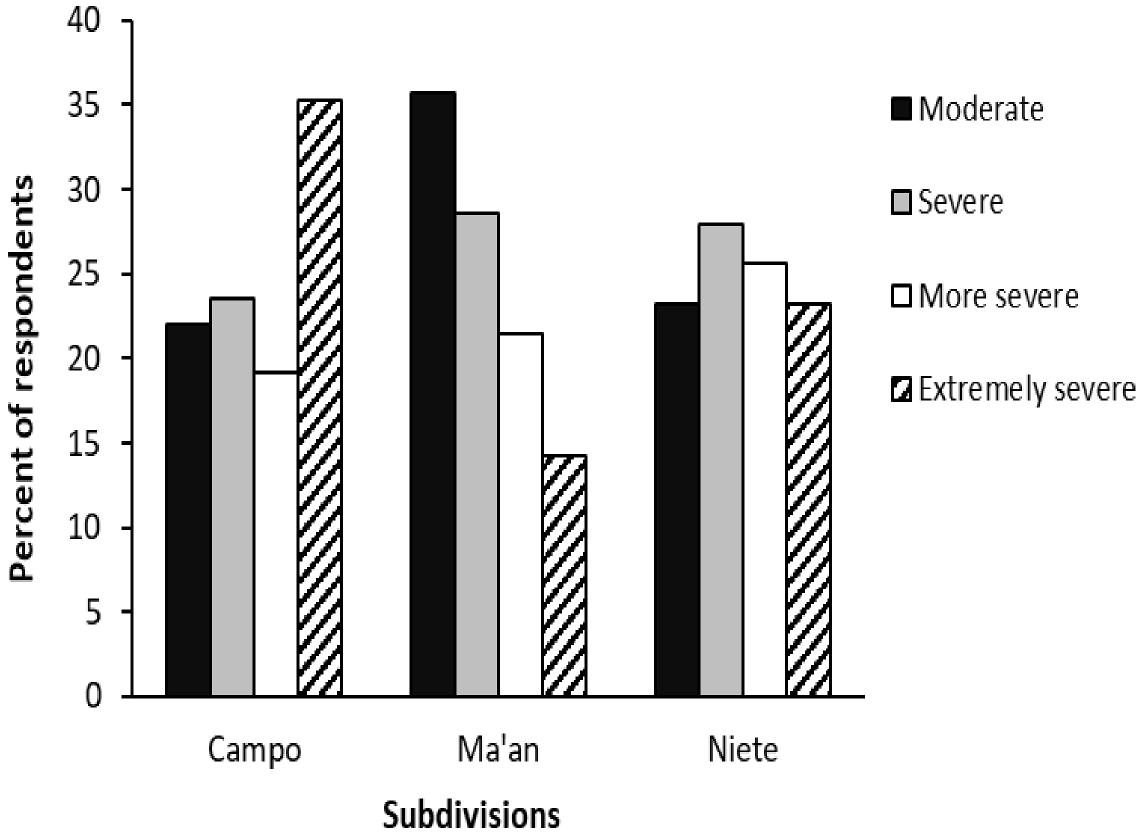

Figure 2. Relative distribution of damages to crops by severity level in three subdivisions of the Campo-Ma'an region, southern Cameroon.
Source: Authors

with respect to crop type (GLM test, χ^2_3 = 4.76, p = 0.314). The distribution of the stages of growth at which incidents generally occur did not differ between the subdivisions (χ^2_4 = 7.07, p = 0.132). Within subdivisions however, mature crops were more affected than both intermediate (χ^2_1 = 35.64, p < 0.001) and young (χ^2_1 = 40.95, p < 0.001) stages (Figure 3). Overall, 71% of damages reported happened at a mature stage, 16% at the intermediate stage, and 13% at the young stage of crops within subdivisions. Figure 3 displays the percent distribution of crop raiding incidents by growth stages of the crops in three subdivisions of the Campo Ma'an region, southern Cameroon, while Table 1 shows the distribution of the percentage of reported wildlife incidents by crop type. Table 2 displays the distribution of the crop raiders by subdivision, from which, five were reported more often reported [Cane rat (28%), elephant (19%), talapoin (14%), porcupine (11%) and rat (9%)]. Overall, although the model fit was not high (R^2=0.13), the distribution of crop raiding incidents was significantly different with respect to wildlife species (GLM test, χ^2_{17} = 58.44, p = 0.021) and the involvement of various species in crop damage differed among subdivisions (GLM test, χ^2_2 = 131.13, p < 0.001). Elephants were more destructive to crops in Niete (28%) and Campo (20%) as compared to Ma'an with only 1% (Chi-square test, χ^2_2 = 23.99, p < 0.001).

Factors influencing crop damage occurrence and mitigation measures used

The severity of crop damage did not vary according to the average distance of households from the park border (ANOVA test, $F_{3, 119}$ = 0.62, p = 0.603). Although not significant (ANOVA test, $F_{2, 119}$ = 2.17, p = 0.119), households in Ma'an seemed on average closer to the park (Mean ± SD = 4.5 ± 3.6 km) than those in Campo (7.25 ± 4.2 km) and Niete (6.3 ± 4.5 km). Most respondents (97%, n = 123) were settled on national domain and only 3% (n = 4) owned their land. Most farm plots (72%, n = 74) were at least 5 km from the nearest border of the National Park, but still were victims of wildlife damages regardless of subdivisions. The average distance of households from FMU did not vary with the severity of crop damage (p = 0.321) but was significantly

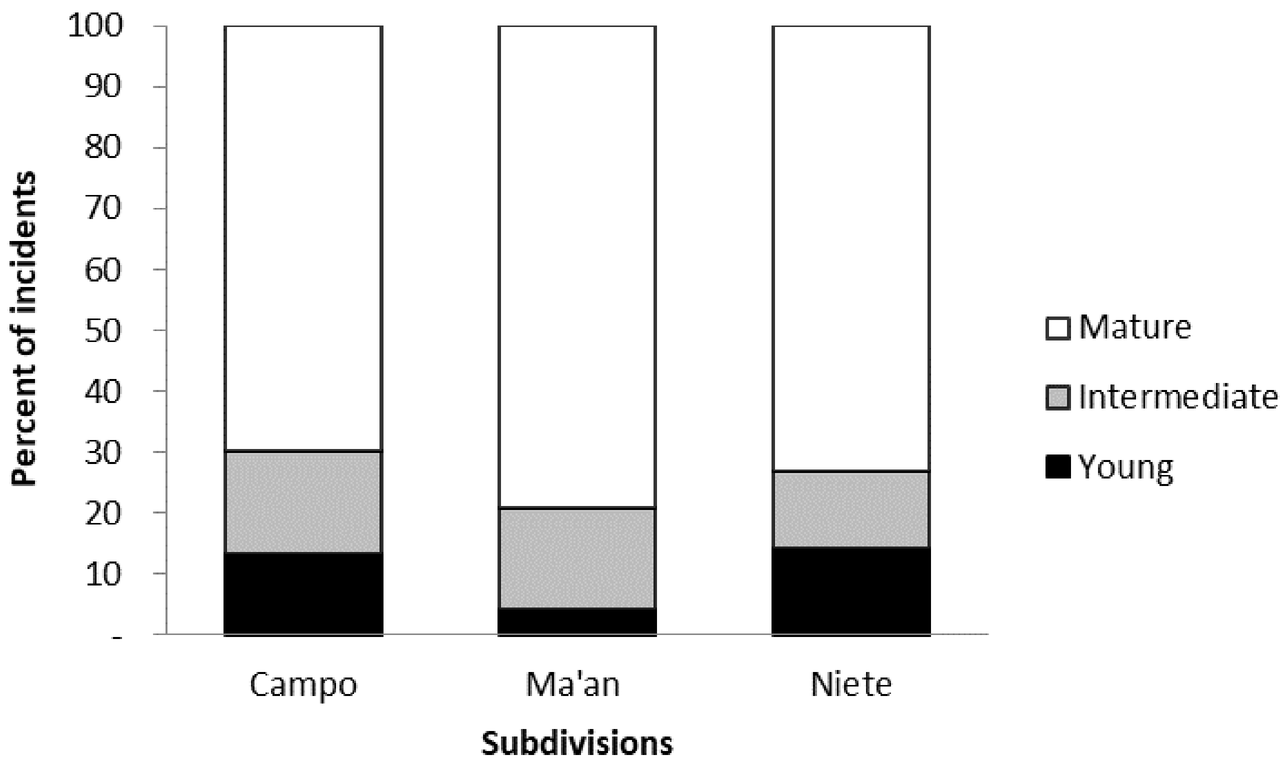

Figure 3. Percent distribution of crop raiding incidents by growth stages of the crops in three subdivisions of the Campo Ma'an region, southern Cameroon.
Source: Authors

Table 2. Distribution of crop raiding incidents reported per animal taxon in Campo (N = 450), Ma'an (N = 131) and Niete (N = 219).

Animal species	Total	Campo		Ma'an		Niete	
		n	%	n	%	n	%
Cane rat: *Thryonomys swinderianus*	225	120	27	33	25	72	33
Elephant: *Loxodonta cyclotis*	151	89	20	1	1	61	28
Talapoin: *Miopithecus talapoin*	113	71	16	14	11	28	13
Porcupine: *Atherurus africanus*	86	37	8	27	21	22	10
Rat: *Cricetomys gambianus*	75	24	5	27	21	24	11
Bush pig: *Potamochoerus porcus*	41	36	8	5	4	0	0
Sitatunga: *Tragelaphus spekei*	22	19	4	3	2	0	0
Gorilla: *Gorilla gorilla*	24	17	4	7	5	0	0
African buffalo: *Syncerus caffer*	18	13	3	2	2	3	1
Mandrill: *Mandrillus sphinx*	11	11	2	0	0	0	0
Snakes	7	3	1	2	2	2	1
African small-grain lizard: *Varanus sp*	4	3	1	1	1	0	0
Chimpanzee: *Pan troglodytes*	5	3	1	2	2	0	0
Squirrel: *Xerus erythopus*	9		0	6	5	3	1
Pangolin: *Uromanis tetradactyla*	2	2	0	0	0	0	0
Birds*	4	1	0	0	0	3	1
African civet: *Vivera civetta*	2	1	0	0	0	1	1
Daman tree*: Dendrohyrax arboreus*	1	0	0	1	1	0	0

*Birds refer to Grey parrot (Psitacus eritacus) and Village Weaver (Ploceus cucullatus).
Source: Authors

Table 3. Frequency and percentage distribution of mitigation techniques per subdivision.

Methods	Total	Campo		Ma'an		Niete	
	N	n	%	n	%	n	%
Fencing	54	35	52	8	57	11	24
Trapping	45	30	44	8	57	7	16
Noise making	22	15	22	2	14	5	11
Fire around the farm	20	15	22	1	7	4	9
Camping in the farm	13	12	18	0	0	1	2
Abandon the plot	6	2	3	0	0	4	9
Killing problem animal	4	2	3	1	7	1	2
Lighting farm at night	1	1	2	0	0	0	0
Raising bees	1	1	2	0	0	0	0
Scarecrows	4	1	2	1	7	2	4
Pepper crops	1	1	2	0	0	0	0
Clearing farms' edge	4	0	0	1	7	3	7
Shifting land	2	0	0	0	0	2	4
Growing sweet potatoes	1	0	0	0	0	1	2
Early harvest	1	0	0	0	0	1	2
Selecting crop	1	0	0	0	0	1	2
None	14	5	7	1	7	8	18

A total of 127 respondents were surveyed in Campo, Ma'an and Niete from May through August 2018.
Source: Authors

different between subdivisions (ANOVA test, $F_{2,\ 119}$ = 21.35, $p < 0.001$), with model R^2 = 0.28. On average farms from Ma'an (3.3 ± 2.1 km) were farther to FMU border than those from Campo (2.2 ± 0.8 km; Estimated difference 1.17, [0.17, 2.18]); while farms from Ma'an were on average farther than those from Niete (3.95 ± 1.9 km; Estimated difference 1.79, [1.12, 2.45]). Sixteen methods were identified as commonly used by locals to protect their crops from wildlife damage (Table 3). Overall, mitigation techniques used by respondents differed significantly in proportion for the five most used methods (Table 3) regardless of the subdivisions (χ^2_4 = 39.81, $p < 0.001$). While noise making was equally used among subdivisions (χ^2_2 = 2.77, p = 0.251), use of traps (16%, χ^2_2 = 23.23, $p < 0.001$) and fencing (24%, χ^2_2 = 13.77, p = 0.001) were less used in Niete as compared to Campo and Ma'an (Table 3).

Economic impact of human wildlife conflict

Average agricultural income losses did not vary between the subdivisions (ANOVA test, $F_{2,\ 90}$ = .05, p = 0.950), but varied significantly with severity level (ANOVA test, $F_{3,\ 90}$ = 3.39, p = 0.021), with model R^2 = 0.10). The average losses of agricultural income were estimated for Campo, Ma'an and Niete (Table 4). The average loss of income for households experiencing moderate losses (Mean ± SD = 189,080 ± 248,615 FCFA or US$ 315 ± 415, n = 14) were lower (Estimated difference with 95% CI = -1174180.2, [-2,266,542.61, -81,817.84]) compared to the average income loss of those with extremely severe crop losses (1,462,763 ± 2,686,825 FCFA or US $2,437 ± 4,478, n = 25). Households with more severe income losses (522,840 ± 870 FCFA or US $ 871 ± 1,096, n = 21) and those with severe losses (376,910 ± 390,015 FCFA or US $ 628 ± 650, n = 19) were comparable (All p > 0.05). The average agricultural incomes were estimated respectively for Campo, Ma'an and Niete (Table 4). All calculations are done at a rate of US $ 1 = 600 FCFA.

Human influence on wildlife

Data were presented from the anti-poaching unit for the period 2014-2017 from the CMTOU in Table 5. It appears that a variety of evidence exists confirming the real impact of humans on wildlife including actual gun seized to poachers. Between May and December 2019, 19 cameras deployed in the conservation area took 20,325 photos. From these images, 10,681 humans were seen on 4,376 photos (22%) and included 428 (4%) hunters, 9,531 (89%) loggers, 28 (1%) antipoaching patrols staff and 694 (6%) research assistants. Human occurrence differed between land use types (n= 9,959, χ^2_2 = 18,64, $p < 0.001$; Figure 4). The majority were filmed in the community area as compared to the park (χ^2_1 = 9721, $p < 0.001$) and the FMU (χ^2_1 = 9,129.70, $p < 0.001$). In addition, more persons were filmed in the FMU compared to the park (χ^2_1 = 189.90, $p < 0.001$). The distribution of

Table 4. Summary (mean ± standard deviation) of the average agricultural income and average agricultural income losses by farmers in Campo, Ma'an and Niete subdivisions.

Subdivisions	Average agricultural income (mean ± SD)		Average loss of agricultural income (mean ± SD)	
	CFA	USD	CFA	USD
Campo	945,235 ± 1,196,515	1,575.5 ± 1,994	644,480 ± 1,003,630 (68%)	1,075 ± 1672.7
Ma'an	1,794,135 ± 2,153,780	2,990 ± 3,590	420,265 ± 267,200 (23%)	700.5 ± 445.3
Niete	1,327,660 ± 3,051,700	2,212 ± 5,086	1,075,800 ± 2,801,530 (74%)	1,793 ± 4,667

The values are given in the local currency in Franc CFA (Communauté Financière Africaine) and in US$ (1 USD ~ 600 CFAF). The percentage of income losses are given in brackets.
Source: Authors

Table 5. Summary of the results from the antipoaching unit between 2014 and 2017 in the Campo-Ma'an Technical Operational Unit.

Poaching indices	2014	2015	2016	2017
Gun seized	19	11	15	23
Sockets	159	282	177	230
Traps destroyed	578	319	819	607
Ammunition seized	243	101	138	119
Camps destroyed	35	52	57	66
Animal remains	466	211	135	149
Earing report	6	7	20	14
Ivory seized	0	2	0	2
Elephant carcasses	0	1	3	4
Complaints against wildlife (elephants, gorilla, mandrill)	16	2	3	3

Gun seized, traps destroyed, firearms cartridges, ammunition seized, camps destroyed, animal remains seized, ivory seized, and elephant carcasses are all related to illegal actions of humans against wildlife. Hearing reports refer to humans suspected of conducting illegal activity related to wildlife and transferred to the court for prosecution. Complaints against wildlife refer to a limited number of farmers who reported their crop damages to the conservation office.
Source: Authors

the hunters differed significantly between land use types (χ^2_2 = 403.88, $p < 0.001$; Figure 4). Overall, more hunters (78%, n = 333) were observed in the community area as compared to the park (2%, n = 7, χ^2_1 = 312.58, $p < 0.001$ and FMU (21%, n = 88, χ^2_1 = 142.58, $p < 0.001$). There were also more hunters in the FMU than in the park (χ^2_1 = 69.06, $p < 0.001$). Of the 9,531 images of loggers, the majority (99%, n = 9,409) were filmed in community area as compared to the FMU (1%, n = 122, χ^2_1 = 9,049.20, $p < 0.001$; Figure 4). No tree logging activity was observed in the park.

DISCUSSION

The findings confirm the reportedly increasing HWC worldwide, with evidence of wildlife damaging crops and humans poaching and destroying wildlife habitat. We also show that level of conflict varies among subdivisions and therefore can be site-specific, causing the abandonment of farms and the dependence of the populations of Campo on the food crops that are no longer cultivated locally. Finally, the study provides evidence of humans' influence on wildlife using human photos from 19 camera traps. That 98% of the respondents reported being a victim of damage by wildlife is symptomatic of people living close to PAs and may be the result of the increase in population in this area; from 60,338 inhabitants in 2002 to 111,000 in 2011 (MINFOF, 2014). This result is consistent with several studies with more than 80% of households experiencing wildlife crop raiding (Weladji and Tchamba, 2003; Karanth et al., 2013b; Gontse et al., 2018). Many wildlife species from various taxa were identified as responsible for crop damage, including elephants and rodents (King, 2010; Ole, 2011; Conover et al., 2018). We found the level of damage to differ between the subdivisions, being less severe in Ma'an where elephant density is lowest (Matthews and Matthews, 2006; Nzooh-Dongmo et al., 2015). The observed pattern matched elephant's distribution in the CMTOU; as Ma'an was the less affected by elephant damages. In contrast, Niete, previously problem-free (Eyebe et al., 2012; MINFOF, 2014), became a new elephant conflict area since the start or major project in

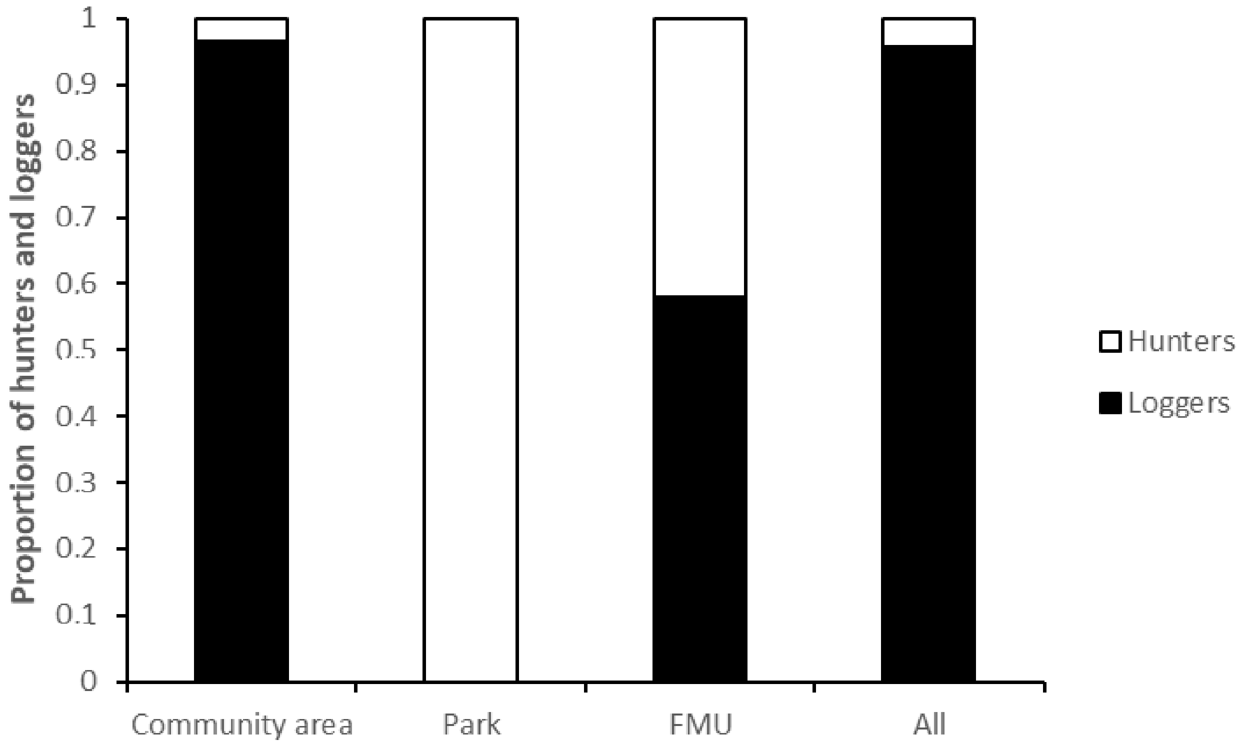

Figure 4. Proportion distribution of the number of images of hunters and loggers across Community Land, National Park, and Forest Management Unit (FMU). Hunters occurring in the National Park or FMU are considered poachers.
Source: Authors

the conservation area. Elephants were the animals causing the most losses in Campo and Niete with their single raiding event surpassing the cumulative raiding of all other crop raiders. This result is consistent with the broad idea of extreme severity associated with elephant damages (; Anand and Radhakrishna, 2017; Gontse et al., 2018; Ngama et al., 2018). Selective damage to staple food crops by wildlife lowers the yield (Eyebe et al., 2012; Nyirenda et al., 2018; Breuer and Ngama, 2020). Although crop damage occurs at all stages of plant growth, it worsens when crops mature and are ready for harvest by farmers. This result is consistent with other findings (Granados and Weladji, 2012; Mwakatobe et al., 2014; Pant et al., 2016; Breuer and Ngama, 2020). Forest elephants might consider farms with mature crops as part of their seasonal food. Indeed, mature crops are of high nutritional value providing necessary calories needed by wild animals while reducing their movement and feeding time**.** We observed in the field that the creation of plantations opens the canopy and creates attractive spots surrounded by fruit trees consumed by wildlife, including elephants. Such disturbed areas create secondary forests that are attractive to wildlife because it concentrates good quality food in a small area (Mwakatobe et al., 2014; Breuer and Ngama, 2020). Distance to the PA is an important predictor of the severity level of damages to crops (Naughton-Treves, 1997; Mwakatobe et al., 2014). Most damage occurred within 500 m of villages, far from the park border but often close to the logging concessions considered PAs, and, therefore, part of wildlife habitat (MINFOF, 2014; Nzooh-Dongmo et al., 2015). Contrary to observations elsewhere (Naughton-Treves, 1997; Mwakatobe et al., 2014; Pant et al., 2016), we found that proximity to park border did not explain the level of damage. Wildlife in the conservation area takes advantage of the contiguous forest cover despite a variety of land use systems being applied. Indeed, the 2015 inventory of wildlife shown that elephants as many other wildlife reside permanently in the FMU to which villages are closer than to the park (MINFOF, 2014; Nzooh-Dongmo et al., 2015).

Farmers mostly make cash income from the sale of their crops. Crop destructions by wildlife influenced household economic stability as elsewhere (Weladji and Tchamba, 2003;; Mwakatobe et al., 2014; Gontse et al., 2018; Terada et al., 2021). The average agricultural income lost per year per household were lower in Ma'an (23%) than in Campo (68%) and Niete (74%), and this corroborates the distribution of the elephant populations likely to raid farms unfortunately with no direct aid from the conservation authorities. This indicates that despite the diversity of crop raiders, the imprint of the forest elephants on people's income is particularly noticeable (Nyirenda et al., 2018; Breuer and Ngama, 2020;

Compaore et al., 2020; Terada et al., 2021). Several studies have documented the detrimental effects of human activities on wildlife (Fa et al., 2015; Kouassi et al., 2017; Lata et al., 2018), which may well also be occurring in the CMTOU where we found evidence of poaching and logging attributed to local communities. Bushmeat is a staple food for people living in the vicinity of PAs (Fa et al., 2015; Kouassi et al., 2017; Martin et al., 2020). Because of the restrictions on hunting, poaching is often the only way people can have access to the much-needed bushmeat, although one can hunt in the community area as per the domestic use right. In fact, the hunting and consumption of species with high growth rate is tolerated to improve cohabitation between forest wardens and farmers, and to minimize the risk of human–human conflict (*sensu* Dickman, 2010; Breuer and Ngama, 2020; Martin et al., 2020). That local communities do not have access to the species causing them the more losses can trigger negative attitudes toward wildlife and conservation (Weladji and Tchamba, 2003; Granados and Weladji, 2012). Based on this, one may consider some of their actions as retaliations, justifying to some extent their resentment towards wildlife as seen by the many proofs reported by the law enforcement unit (amount of poachers' camps and traps destroyed, ammunitions collected, firearms and ivories seized, poachers arrested, etc. (Table 5) (Tiani et al., 2005). Local communities were also involved in "illegal" logging in the CMTOU. These activities impose the opening of roads and removal of trees some of which provide fruit food to forest elephants. Consistent to other findings, this will lead to the fragmentation and loss of wildlife habitat, the movement of animals to other sites where they may become vulnerable, and ease the access to the park for poachers (Lata et al., 2018; Breuer and Ngama, 2020). Even though our images displayed illegal hunters and loggers, we did not denunciate them to park authorities, fulfilling our obligation of respecting their privacy, a guarantee for the acceptance by the populations of the introduction of camera traps for research (Sandbrook et al., 2018, Sharma et al., 2020). Disturbances in the park's eastern side from dam construction (2012–2017) might have forced large mammals, including elephants, to move away (MINFOF, 2014; Nzooh-Dongmo et al., 2015).

Severe damages to different crop species threaten the food security of the populations. This may build resentment in them, as no alternative food source exist, making it challenging to resolve HWC (Dickman, 2010; Barua et al., 2013). Local resentment is often intensified by conservation regulations that impede local communities' capacity to cope with losses to wildlife (Dickman, 2010). Consequently, they turn to illegal activities in the conservation area, which put pressure on wildlife habitat and threatens biodiversity. This calls for an urgent need for a broad enough solution to accommodate both parties, which is not easy to achieve. Indeed, although several mitigation strategies have been proposed and even tested in several places, most have limitations suggesting that conflict requires original and comprehensive approaches for long-term resolution (Dickman, 2010; Anand and Radhakrishna, 2017; Karanth and Kudalkar, 2017). HWC is complex because of involvement of many factors (Dickman, 2010; Anand and Radhakrishna, 2017; Torres et al., 2018). Conflict situations in the CMTOU are all about crop damages by wildlife in search of nutritious and palatable foods, and poaching, making coexistence difficult for communities and conservationists (Torres et al., 2018; Breuer and Ngama, 2020; Terada et al., 2021). This situation induced direct costs for farmers in terms of time and money (Barua et al., 2013, Nyirenda et al., 2018). There are also indirect costs, such as the psychological effects associated with the risk of starvation, injury or even death (Barua et al., 2013; Hoare, 2015; Breuer and Ngama, 2020; Terada et al., 2021). HWC is shaped by actual and past interactions with wildlife. Considering such hidden aspects that shape conflict situations can be a significant step toward a lasting solution (Dickman, 2010; Barua et al., 2013; Hoare, 2015; IUCN, 2020).

The construction of fences and traps around fields was used against small fauna. In contrast, noise production by any means possible was used to repel problem animals such as elephants, great apes, and other animals considered dangerous (Ole, 2011; MINFOF, 2014). Fencing is often associated with camping in the forest near the farms around large fires, producing smoke that may keep animals away. These methods, taken individually or in combination, unfortunately, require a physical presence which has repercussions on the organization of the family, their livelihood, and the children's education, especially during the harvest period (King, 2010; Mwakatobe et al., 2014). Sometimes, farmers use scarecrows or call for culling from the wildlife authorities, which does not occur often. A compensation scheme existed in the early period of the creation of the CMNP, including setting up revolving funds with women's associations and a micro-credit system to help local people develop economic activities, but it has since disappeared because of the insolvency of the first beneficiaries (MINFOF 2014). Other less-widely used techniques have also been implemented, such as night lighting of fields with flares and cultivation of chili at the edge of the field, but as we know, smart elephants get habituated when repeatedly exposed to new methods (King 2010; Nelson et al. 2003). Compensation schemes have been also proposed elsewhere and used as mitigation strategies, but results are not always conclusive (Nelson et al., 2003; Karanth et al., 2013a).

Economic losses in agriculture (Table 4) could justify the intensity of alternative activities such as hunting, fishing, gathering or picking of non-wood forest products that provide financial support to households (Tiani et al., 2005). In addition, we noticed the lack of enthusiasm for the creation of new agricultural plots by some respondents in Campo, arguing that the presence of the elephant in their vicinity is forcing them to switch their feeding habits favoring imported products, to be purchased and for which they are not used to. At the subdivision level, the direct impacts of the conflict in the western side of the park (Campo and Niete, Table 4) could be the lack of locally produced foodstuffs, which would have helped to lower the cost of living. Unfortunately, almost all the products consumed are imported from areas less exposed to HWC including Ma'an. Such impacts have been described in northern Congo leading to an increased price of staple food products (Breuer and Ngama, 2020). Although we validated crop raiding data with those compiled for the conservation of large and medium size mammals, we acknowledge several limitations to the study. We used recall type questionnaires whereby the data are obtained based mainly on the declarations of farmers. Therefore, they present the risk that people may differ in their ability to recall and may not be accurate in their answers because of poor memory. Also, they may have overestimated the loss hoping to receive some sort of compensation at one point. The interview took place in private for some households. In contrast, some respondents were interviewed in the presence of their relatives who could have influenced their answers to questions, depending on how information was being shared within a household. Despite our efforts to validate the extent of damages reported by the respondents, we could only visit 12 farms from which recent elephant damages could still be visible in the field. Although signs may be less visible, we could have visited other farms damaged by other wildlife species as well.

Conclusion

We reported evidence of HWC in the CMTOU, the subdivisions with higher elephant density suffering higher economic losses. As agriculture is the main source of food and income for these populations, we need to understand elephant movement patterns better to inform the development of appropriate mitigation measures. It is imperative that we rethink conservation policies for large mammals in this densely populated area. This will imply revisiting land use planning and the choice of sites allocated for the creation of large-scale plantations in this landscape. We acknowledge that HWC is complex in nature and that mitigation strategies do not always work. Therefore, we recommend using holistic and adaptive solutions, which consider direct and indirect costs while satisfying wildlife and human needs. This will require setting up adaptive land use systems, modifying and empowering wildlife legislation. For example, the creation of a community hunting area on the FMU as proposed by the management plan of the CMNP (MINFOF, 2014), and the facilitation of the use rights by allowing locals more access to natural resources from the CMTOU to favor tolerance and coexistence of both protagonists. Also, it may be important to set up a permanent crop damage monitoring process in different villages close to farmers to estimate the actual level of loss.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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SUPPLEMENTARY MATERIALS

Supplementary material 1: Consent form

Human-wildlife conflict in the Campo-Ma'an Technical Operational Unit, southern Cameroon

By:______________, PhD student,___________ University. Contact:__________
Preamble:

This questionnaire is designed for research on "the human-wildlife conflicts" in your community, carried out by me, ________________________. The research aims are to: (1) assess the socio-economic impact of the human-wildlife interactions around CMNP; (2) study the relationship between different stakeholders that is park staff, local people, the private organizations as well as the non governmental organizations operating in the area; (3) Assess people's attitudes and perceptions towards wildlife, the park and the wildlife legislation; (4) Study some ecological aspects of the elephants including testing some mitigation measures; and finally (5) Propose plans to mitigate conflicts and promote ecosystem-based management for the park.

If you accept to participate, you will be asked several questions (see questionnaire), and eventually we will visit your farm to assess the level of damage caused by elephants to your crops. The answers that you will provide us on the following questionnaire, which lasts approximately 45 minutes, will remain confidential and will be used exclusively by the researchers for the study.

There is no risk in participating in this study. However, by providing your name, we may use this information in the events of a compensation program that is retroactive. There is no guaranty for this, however. You are free to decline or accept that your name be disclosed for this purpose.

It remains at your discretion to determine whether you wish to answer the questionnaire in whole or in part, or if you do not wish to participate at all. If this study is published, the anonymity and confidentiality of this questionnaire will always apply. You must also be at least 18 years old to participate.
If you have any questions, please do not hesitate to ask me during the interview or later by email at "
_____________________"or by phone at"_______________________".

Do you agree to participate in the study under the conditions described above?
If yes, say YES
If no, say NO

Thank you!"

Supplementary material 2: Subset of the Household questionnaire

Name: _______________________ Age _______________ Sex____________

Education level:

Primary:	Lower secondary:	Upper secondary:	Higher education:

(1) Did you experience crop damage by wildlife anytime the last 3 years? Y___ N___
(2) If yes, list crop types by area cultivated and the expected income/sale from each.

	Area	Crop types	Total output (tons/bags)	Sale (in Franc CFA)
1				
2				
3				
4				

(3) How far is your farm from the village?

01 : 0-500 m	02 : 0.5-1 km	03 : more than 1 km	04: Estimate (from the village)

(4) How far is your farm from the CMNP?

01: 0-2 km	02: 2-5 km	03: > 5 km (give an estimate)

(5) What proportion of your field was damaged?

01: a little bit (0 - 25%) moderate	03: more than half (50% - 75%) more severe
02: just under half (25% - 50%) Severe	04: the whole field (75% - 100%) extremely severe

(6) What animals are responsible for the damage (by crop type and by crop stage of growth)

		Stage of growth		
Species	Type of crop damaged	Young	Intermediate	Mature
1				
2				
3				
4				
5				
…				

(7) What are the methods you have used to deter wildlife from causing crop damage? Name and describe each, including to what extent it was effective.

1:_____________________________________

2: _____________________________________

3:_____________________________________

4:_____________________________________