



Influence of social status and industrial development on poaching acceptability

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ABSTRACT

Subsistence poaching threatens the persistence of wildlife populations worldwide and the well-being of people who participate in poaching. We conducted interviews around Murchison Falls National Park, Uganda to assess the acceptability of poaching. Conflict with wildlife was the most important factor determining attitudes towards poaching and the tools of the trade. More than 80 % of the respondents living within 5 km of the park boundary had never been inside the park. Additionally, the provision of goats as incentives to people did not influence attitudes but increased human-wildlife conflict. This implies that acceptability of poaching among people living in close proximity to wildlife is influenced by the nature of the interaction between people and protected areas, but more importantly, limiting positive interaction can create negative consequences. Our results emphasize the importance of providing remedies compatible with local livelihoods and conditions and show that negative experience with wildlife builds intolerance.

1. Introduction

Subsistence poaching occurs mostly in expanses of wooded savannah or forest patches inhabited by people groups that consider common wildlife species palatable (Fischer et al., 2014; Tumusiime et al., 2010; Watson et al., 2013). Rates of subsistence poaching tend to be elevated in poverty-stricken communities that lack sufficient sources of protein (Eliason, 1999). Subsistence poaching is a high risk - low yield activity which lends credence to the idea that it could be practiced mostly by people with limited alternative livelihood (Eliason, 1999). Subsistence poaching can undermine conservation efforts (Lindsey et al., 2013; Watson et al., 2013). For example, unsustainable harvesting of wildlife in the form of subsistence poaching can lead to local extinction of species which can also reduce the asset base for communities who seek to benefit from developing products from wildlife (Becker et al., 2013; Kimanzi et al., 2015). Moreover, because subsistence poaching is minimally structured and widespread where it occurs, it is more difficult to mitigate than specialist poachers (e.g., poachers engaged in international wildlife trade) (Hitchcock, 2000; Kahler and Gore, 2012; Lindsey

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et al., 2013). Unmitigated subsistence poaching could result in commercialized poaching (Baldus, 2002; Harrison et al., 2015; Lindsey et al., 2013). Furthermore, subsistence poaching exacerbates numerous conservation problems, including mammal population declines, receding wildlife habits, and less resilient wildlife populations due to impacts of climate change (Briggs, 2017; Wake and Vredenburg, 2008).

Historically, Murchison Falls National Park (MFNP) in northwestern Uganda has experienced high rates of subsistence poaching and the highest density of recorded snares in the world (Mudumba et al., 2020; Oneka, 1996). Although, this unsanctioned removal of wildlife remains largely undocumented, it is thought to have led to the local extinction of white rhinoceros (*Ceratotherium simum*) and the decline of local wildlife populations (MacKenzie et al., 2012). The area within and surrounding MFNP has been developed for oil mining since 2007, which has increased human activity and infrastructure inside the park (Uganda Wildlife Authority, 2014; Watkins, 2010). In MFNP, preliminary research found that the exploration of oil caused indirect habitat loss due to avoidance behavior in the common mammal species (Ayebare, 2011). In addition, the differences in productivity between the interior and exterior have remarkably isolated the park (Gray et al., 2018).

Wildlife conservation on human dominated landscapes such as MFNP depends heavily on how locals perceive their relationship with wildlife and wildlife managers (Becker et al., 2013; Watson et al., 2013). Understanding the drivers and demographic profiles of communities that partake in subsistence poaching is a crucial first step to addressing the problem (Lewis and Phiri, 1998; Tumusiime et al., 2010; Watson et al., 2013). We know very little of the coupled human-wildlife system around MFNP or how it will be affected by the 25-year oil mining in the park and surrounding areas (Harter et al., 2016; Kukiela et al., 2016; MacKenzie et al., 2017; Salerno et al., 2017). The objectives of our study were to: (i) define the social demographics of the community around MFNP (ii) determine the attitude of the local community towards wildlife managers, (iii) ascertain the acceptability of using common hunting tools to hunt or kill wildlife, and (iv) determine the influence of oil developments on acceptability of using illegal tools to hunt or kill wildlife. We aimed to establish a baseline understanding of these factors for the area.

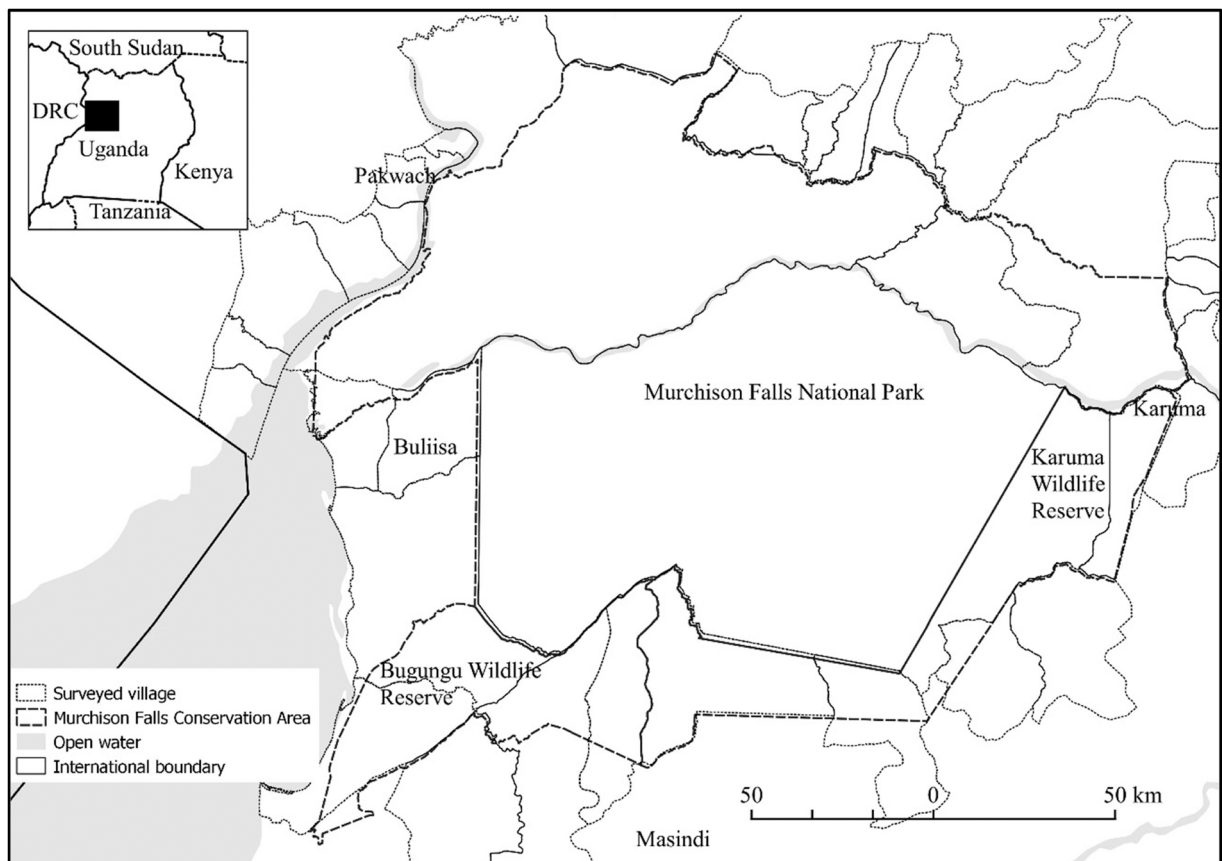


Fig. 1. Study area showing Murchison Falls National Park and surrounding parishes for a social survey conducted in July and August 2017.

2. Materials and methods

2.1. Study area

Murchison Falls National Park (Fig. 1) was established first as a wildlife reserve in 1926 and became a national park in 1952. This park is located in northwestern Uganda (02°15'N 31°48'E). Karuma Wildlife Reserve (820 km², gazetted in 1964) and Bugungu Wildlife Reserve (473 km, gazetted in 1964) are contiguous with MFNP (3,893 km²) and together make the largest conservation area in Uganda, the Murchison Falls Conservation Area (5,308 km²).

Murchison Falls National Park and surrounding reserves contain 76 mammal species (Plumptre et al., 2007). Mudumba et al., (2020) describes the social structure, vegetation, and wildlife of study area. Before our study, between 2009 and 2010, Uganda Wildlife Authority (UWA) had donated goats to homesteads living near the park as part of community conservation initiative to provide alternative source of protein (Becker et al., 2013). The donation of goats to some residents by UWA spurred other residents who had not previously owned goats to buy and rear their own goats. Anecdotal reports indicated that goats around MFNP are depredated by predators and rank high as cause of human-wildlife conflict (per. comm.).

2.2. Data collection

We conducted face-to-face interviews during July and August of 2017. Eight locally sourced and trained research assistants fluent in local languages administered these interviews. Prior to the study, we developed the survey instrument and obtained the required approvals for field use (Michigan State University Institutional Review Board approval number x17–593e). We also obtained clearance to conduct interviews from local councils around MFNP. We initially piloted the questionnaire on individuals from 30 households to ensure the clarity of questions before the main study. We excluded households that were part of the trial in the main study. Interviews lasted on average 25 min.

In each parish (a territorial division smaller than a sub-county and composed of more than two villages), we restricted the interviews to those villages that bordered MFNP (24), Bugungu WR (4), or Karuma WR (7) (Rochlitz, 2010). We randomly selected households from a list of all village households generated by the local council leader ($n = 5653$, average = 161.5 per village, min = 71, and max = 309). Once a household was selected, we randomly determined whether to interview the head-of-household or the spouse by tossing a coin. Where there was no spouse, we interviewed the oldest household member instead. All participants signed a consent form and were allowed to opt out of the study at any time during the interview. This voluntary consent was important because the interviewees knew beforehand the objectives of our study which has been shown to improve the accuracy of responses (Duffy and St John, 2013; Lindsey et al., 2013; Watson et al., 2013).

The questionnaire had 4 sections (see Appendix C of the supplementary materials): (i) wildlife-related activities and interactions; this section sought to identify the types of interactions that the people had with wildlife in the area, (ii) general attitudes towards wildlife; this section required the respondents to respond to questions that showed their attitude towards wildlife, (iii) wildlife interaction in the village; which was to understand the human-wildlife interactions at village-level, and (iv) oil extraction and interviewee demographics; specifically asked personal information of the respondent and that of their immediate family. In this last section, we included questions on benefits from oil and oil infrastructure on the respondents land as well as questions regarding local people's attitudes towards nine common species of wildlife around MFNP (Becker et al., 2013; Kimanzi et al., 2015). The survey instrument is included in the supplementary materials.

2.3. Data analysis

To assess the acceptability to use one of the common illegal tools to hunt or kill wildlife, we scored the respondents' attitude towards five poaching instruments (nets, wire snares, spear, wheel traps, and guns) used to hunt nine species of common wildlife included in the study (see Appendix A). For each species and each poaching instrument, we scored answers of *Not acceptable* as a 0 and answers of *Somewhat acceptable*, *Acceptable*, and *Very acceptable* as a 1, 2, and 3, respectively. We excluded all responses of *No opinion* from our analysis. We then calculated *acceptability to use illegal tool* index for each respondent based upon these answers. This index ranged from 0 (all poaching instruments unacceptable for all species) to 135 (all poaching instruments very acceptable for all species). Hereafter we refer to this index as "poaching acceptability". We examined the distribution of these data by visually inspecting the central tendency, dispersion, and form to guide secondary data analysis (Vake et al., 2006). The resultant data were zero-inflated, with 250 respondents (86.2 %) indicating that all poaching instruments were unacceptable (i.e., a poaching acceptability of zero). The non-zero poaching acceptability data were widely dispersed (mean = 37.6, sd = 16.8, range 6–135). Given these data, we analyzed poaching acceptability using a hurdle model, which is specifically designed to analyze count response data that are zero-inflated (Balakrishnan and Ndhlovu, 1992; Duffy, 1999; Forsyth and Forsyth, 2012). Hurdle models are composed of two sub-models, each of which analyzes a distinct process. The first sub-model assumes data arise from a binomial distribution and evaluates the probability of a given outcome occurring or not. The second sub-model assumes data arise from a positive-definite distribution (e.g., counts) and evaluates the value of an outcome, given it occurred (Zuur et al., 2010). In our context, the binomial sub-model assessed whether a respondent found poaching unacceptable (i.e., a value of zero) or at least partly acceptable (i.e., a poaching acceptability of greater than zero). The count sub-model assessed the degree to which a respondent found poaching acceptable, given that it was at least partly acceptable. Due to the dispersion in our data, we used a negative binomial distribution for the count sub-model (Greene, 2008).

Studies have shown that socio-economic dynamics (Noss, 2008), presence of extractive industry such as oil (Knapp et al., 2017),

and the nature of human-wildlife interaction (Engel et al., 2017; Loker et al., 1998) govern attitudes towards wildlife. Therefore, we used the hurdle model to evaluate respondents' poaching acceptability as a function of nine explanatory variables that encompassed respondent's socio-economic status, demographics, relationship with the oil industry, and interactions with wildlife (Table 1). These

Table 1

Names, descriptions, and value summaries of explanatory variables used in models predicting poaching acceptability in Murchison Falls National Park, Uganda. These data were collected via 691 face-to-face interviews with local people inhabiting villages adjacent to the park in July and August of 2017.

Variable	Description	Value Type and Summary
Attitude	Respondent's attitude towards MFNP park authority including how they managed wildlife and responded to wildlife conflict	<i>Likert scale</i> (3) Strongly disagree (A): $N = 284$, 41.1 % Agree (B): $N = 107$, 15.5 % Strongly agree (C): $N = 288$, 41.7 % No response (NR): $N = 12$, 1.7 %
Duration_Village	Number of years respondent has lived in the current village	<i>Numerical</i> Mean = 25.1, SD = 16.1, Range = 1–86
Occupation	The income-generating activity that the respondent spent the most time on	<i>Categorical</i> Business: $N = 60$, 8.7 % Fisherman: $N = 50$, 7.2 % Pastoralist: $N = 25$, 3.6 % Peasant: $N = 493$, 71.3 % Other: $N = 34$, 4.9 % NR ($N = 29$), 4.2 %
Income	Annual household income	<i>Categorical</i> <270,000*: $N = 109$, 15.8 % 275,000–936,000: $N = 236$, 34.2 % > 936,000: $N = 314$, 45.4 % NR: $N = 32$, 4.6 %
Own_Livestock	Whether a respondent's household owned livestock	<i>Binary</i> No: $N = 229$, 32.1 % Yes: $N = 449$, 65.0 % NR: $N = 20$, 2.9 %
Benefit_Park	Whether any household income comes from MFNP	<i>Binary</i> No: $N = 612$, 88.6 % Yes: $N = 55$, 8.0 % NR: $N = 24$, 3.5 %
Conflict_Wildlife	Number of experiences that a household member had been threatened, lost crops or livestock, or been injured or killed by wildlife	<i>Numerical</i> Mean = 4.0, SD = 3.7, Range = 0–27
Employed_Oil	Whether the household member was formally employed by the oil company	<i>Binary</i> No: $N = 591$, 85.5 % Yes: $N = 90$, 13.0 % NR: $N = 10$, 1.4 %
Duration house	Number of years a household had lived in the house	<i>Numerical</i> Mean = 10.6 SD = 10.3 Range = 49.0
Seen wildlife	Number of times of various interactions had with wildlife	<i>Numerical</i> a = 31 b = 29 c = 22 d = 2 e = 18 f = 20 g = 10 h = 18
Number below18	Number of household members below 18 years	<i>Numerical</i> Mean = 4 Min = 1 n = 573
Number above18	Number of household members below 18 years	<i>Numerical</i> Mean = 4 Max = 40 n = 642
Oil_Land	Whether there was oil infrastructure on household-owned land	<i>Binary</i> No: $N = 651$, 94.2 % Yes: $N = 40$, 5.8 % NR: $N = 0$, 0 %

* Income in Ugandan shillings (3800 shillings $\approx$ \$1USD)

variables were calculated from survey responses (see complementary materials for survey questions) and are described in detail in Table 1.

All the above variables could influence both processes evaluated by the hurdle model, namely, overall acceptance of poaching (i.e., unacceptable or partly acceptable, a binomial response), and the degree to which poaching was acceptable (i.e., a count response, given a respondent was at least partly accepting of poaching). Therefore, we included all variables in both sub-models of the hurdle model. Prior to modeling, we checked for collinearity among explanatory variables using variance inflation factors, which were all well below acceptable levels (i.e., < 2.0 ; Zuur et al., 2010). Our interviews were spatially clustered around villages and so we checked for spatial autocorrelation in model residuals using a spline correlogram (see Figure 2, Appendix B) (Rhodes et al., 2009). No spatial autocorrelation was evident in the model residuals (see complementary materials), suggesting that any spatial dependence that might have been present in the data was adequately captured by the model's explanatory variables (Kéry and Royle, 2015). We interpreted model results using a cutoff of $P < 0.05$ for statistical significance. We conducted all analyses using the R environment (Version 3.4.1) in RStudio (RStudio Team 2015; R Core Team 2017) and the packages *car* (Hartter et al., 2016; Kukiela et al., 2016; MacKenzie et al., 2017; Salerno et al., 2017), and *pscl* (Jackman et al., 2017).

3. Results

3.1. Demographic and socio-economic characteristics

We conducted 691 interviews (42.7 % female respondents) in 36 parishes (mean = 19.41, sd = 9.24, range = 2–38). Nearly half of respondents (48.1 %) reported household income in the highest category ($> 936,000$ Ugandan shillings), with lower proportions reporting incomes in the middle (35.3 %; 275,000 – 936,000 shillings) and lowest categories (16.6 %; $< 270,000$ shillings). Over half (65.0 %) of respondents said they owned livestock, the strong majority of which were goats (86.4 % of all owned livestock). Finally, most (71.3 %) of the respondents were peasants. Other occupations were relatively uncommon, with the second-most common being those related to business (8.7 %). Few respondents (13.0 %) were formally employed by the oil industry. Eight percent of the respondents had received income from MFNP. A small proportion (10.9 %) of respondents' or their household members had ever been inside MFNP. For those individuals who had been inside MFNP, park visits had occurred on average 3.0 years prior to the interview (sd = 6.9 years, range: 1 – 40 years).

3.2. Park and wildlife related responses

Baboon (*Papio anubis*), buffalo (*Syncerus caffer*), elephant (*Loxodonta africana*), and kob (*Kobus kobus*) were the most observed species since the respondents moved into their village (Table 2). The interviewees categorized 13.3 % ($N = 886$) of their interaction with wildlife as threatening. Buffalo were reported as the most threatening species accounting for 27.7 % ($N = 245$) of animal threats while waterbuck were the least threatening species contributing 1.5 % ($N = 13$). Additionally, Buffalo injured or killed most (33.4 %, $N = 238$) amongst wildlife that killed or injured, and elephants ranked second (27.4 %, $N = 195$). Baboon and lion were reported to injure and kill about the same number of people.

Livestock and crop destruction occurred 17.97 % of the time when wildlife moved onto community land. Baboon (29.1 %, $n = 349$), elephant (22.5 %, $n = 270$), and buffalo (19.0 %, $n = 227$) were disproportionately mentioned as cause of crop and livestock destruction (Fig. 3).

3.3. Attitudes towards use of hunting tools

Of the 691 interviews, 290 (42.0 %) included complete answers for the 15 survey questions that were used to create explanatory

Table 2

The experiences that the respondents had with wildlife since they moved into their village. %spp is the ratio of experience such as observed the species over the total number of experiences for that species given by the respondent. %all spp is the ratio of the species experience over the total for that experience over all other species.

	Baboon		Buffalo		Elephant		Hartebeest		Hyaena	
	%spp	% all spp	%spp	% all spp	%spp	% all spp	%spp	% all spp	%spp	% all spp
Observed	41.1	17.7	37.8	15.9	35.3	14.88	73.2	11.0	57.5	5.6
Seen tracks or signs	13.3	29.3	10.1	21.8	12.4	26.2	4.8	3.5	3.8	1.9
Threatened	14.5	22.8	18.0	27.7	17.2	26.0	3.7	1.9	10.5	3.7
Crops / livestock destroyed	25.0	29.1	16.6	18.9	20.1	22.5	11.5	4.3	18.2	4.8
Person injured / killed	6.0	11.8	17.4	33.4	14.6	27.4	1.5	1.0	9.6	4.2
	Kob		Leopard		Lion		Waterbuck			
	%spp	% all spp	%spp	% all spp	%spp	% all spp	%spp	% all spp		
Observed	76.4	14.8	50.4	6.0	45.5	6.3	73.2	7.9		
Seen tracks or signs	7.8	7.7	3.9	2.4	3.9	3.9	6.0	3.3		
Threatened	3.5	2.5	14.5	6.3	15.2	7.7	3.7	1.5		
Crops / livestock destroyed	10.5	5.5	15.3	4.9	15.2	5.7	14.8	4.3		
Person injured / killed	1.4	1.3	15.6	8.4	18.3	11.5	2.0	1.0		

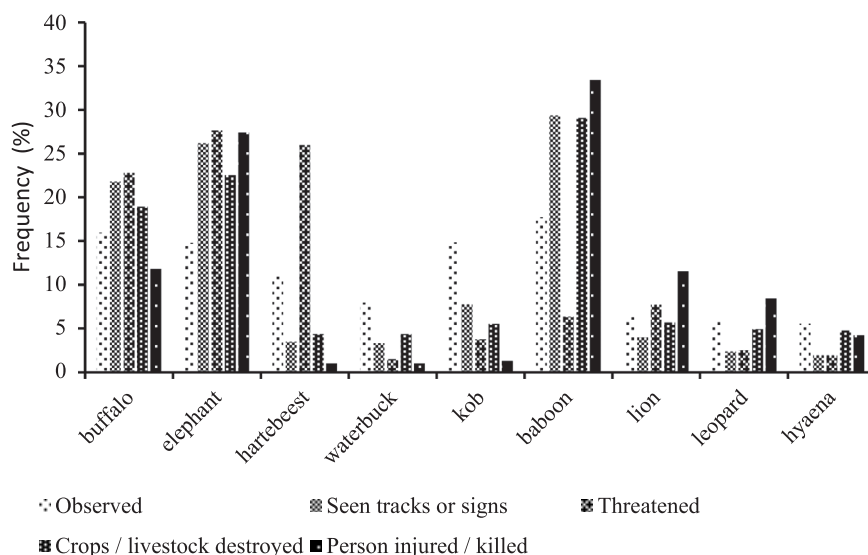


Fig. 3. Frequency of experiences by species reported by respondents of the study for a social survey conducted in July and August 2017 in and around Murchison Falls National Park, Uganda.

variables to model poaching acceptability. No spatial autocorrelation was evident in the model residuals (Appendix B), suggesting spatial dependence was adequately captured by the model's explanatory variables. The data were zero-inflated, with 86.2 % ($n = 250$ of 290) of respondents indicating that all poaching instruments were unacceptable (i.e., a poaching acceptability of zero). The non-zero poaching acceptability data were widely dispersed (mean = 37.6, $sd = 16.8$, range 6–135). In the binomial sub-model, three variables had a statistically significant ($P < 0.05$) relationship with poaching acceptability (Table 3). The probability that a respondent found poaching at least partly acceptable increased with increasing wildlife conflict and duration lived in the village and decreased if respondents owned livestock (Table 3). The count sub-model also found three significant relationships between variables and poaching acceptability (Table 3). The degree to which respondents found poaching acceptable increased with increasing wildlife conflict, decreased with when respondents' attitude toward MFNP was more positive, and increased when a respondent owned livestock (Table 3).

Table 3

Model parameter estimates, standard errors, and statistical significance from a hurdle model predicting poaching acceptability. The model was fit to data from surveys administered in Murchison Falls National Park, Uganda in July and August 2017.

Parameter	Binomial sub-model		Count sub-model	
	Estimate	SE	Estimate	SE
Intercept	-3.12***	0.69	3.07***	0.39
Conflict_Wildlife	0.10*	0.04	0.04*	0.02
Duration_Village	0.03**	0.01	0.00	0.01
Annual_Income_M ^A	1.15	0.62	0.11	0.37
Annual_Income_H ^A	0.80	0.61	0.64	0.36
Benefit_Park ^Y	-0.90	0.84	-0.49	0.71
Attitude_Pos ^B	-0.98	0.62	-0.84*	0.35
Attitude_V_Pos ^B	-0.27	0.39	-0.80***	0.23
Visit_Park ^Y	0.93	0.59	0.24	0.44
Own_Livestock ^Y	-0.97*	0.39	0.45*	0.22
Oil_Land ^Y	0.54	0.65	-0.11	0.43
Employed_Oil ^Y	-0.80	0.63	0.16	0.52

* P -values: < 0.05 .

** P -values: < 0.01 .

*** P -values: < 0.001 .

^A The reference category for Annual_Income was Low, thus model parameters represent the effect of Medium and High income compared to Low income

^B The reference category for Attitude_Park was Negative, thus model parameters represent the effect of Positive and Very Positive compared to a Negative attitude

^Y The reference category was No for all Yes/No variables, thus model parameters represent the effect of answering Yes compared to No

4. Discussion

We found that most people living in the neighborhood of MFNP had never been inside of the national park. Those respondents who had been inside were there last more than three years ago on average, which coincides with the time of oil exploration inside the park when many casual laborers were hired for seasonal jobs (Mudumba and Jingo, 2015; Plumptre et al., 2015). There is growing evidence that limiting the interaction of people and wildlife worsens the level of human-wildlife conflict (Weladji and Tchamba, 2003; Woodroffe et al., 2005). On the other hand, involving local communities via community conservation outreach projects promotes conservation (Muth and Bowe, 1998). Active participation of local people in conservation decision making can provide additional protection for wildlife by the community (Kato and Okumu, 2008), better working relationship with park management (Plumptre et al., 2007), and improved livelihoods due to increased access to ecotourism opportunities in the area (Archabald et al., 2001; Romanach et al., 2007).

The respondents were more acceptable to use an illegal tool to hunt or kill wildlife (i.e., found poaching acceptable) when they had experienced a negative interaction with wildlife, owned livestock and had lived longer in the village. The area around MFNP contains a high number of goats relative to cattle partly because Uganda Wildlife Authority donated goats to some community members. More than half of respondents owned livestock with goats being the predominant kind. Depredation of goats around MFNP was low with less than 10 cases confirmed since 2009 (Mudumba and Jingo, 2015). The low predation cases could be due to low livestock densities around the park which are at a lower risk of predation (Converse, 1976; Krosnick et al., 2001). However, our results show that livestock influenced poaching acceptability. People who owned livestock around MFNP were likely to accept poaching and to a higher degree than those who did not. It was likely that the livestock owners around MFNP perceived wildlife as a significant threat to their livestock. Uganda wildlife Authority had donated goats as a way of directly benefiting locals from the park. Programs that directly benefit the locals have been shown to increase the tolerance of wildlife by the beneficiaries especially if the benefits are directly linked with wildlife conservation (Browne-Nuñez, 2010). However, given that livestock is a known key driver of human-wildlife conflict (Ritchie et al., 2013), caution coupled with predator proof livestock husbandry should accompany projects that introduce domestic animals in close proximity with wildlife.

The human wildlife conflict was low with less than 20 % of human-wildlife interaction resulting into livestock or crop destruction. However, elephants were disproportionately reported by respondents to destroy crops or livestock and injure or kill people even though they accounted for about 28 % of the wildlife conflict. Even then, conflict with wildlife significantly increased the odds and magnitude of poaching acceptability around MFNP. People who perceive wildlife as a threat to their wellbeing typically have negativistic views towards wildlife (Treves and Naughton-Treves, 1999). This pattern points to a need to minimize negative interactions between people and wildlife through positive interactions guided by the human-heritage centered conservation approach (Montgomery et al., 2020).

We found no relationship between the oil industry (presence of oil infrastructure on one's land and employment in oil industry) and poaching acceptability. Few (13 % of interviewees) respondents were directly employed in oil industry and even fewer (5.8 %) leasing land to oil companies to put their infrastructure. The oil industry is a highly specialized industry with unskilled workers relegated to causal jobs (Figgis and Standen, 2005). It could be that the proceeds from the oil industry to the locals were inadequate to substantially change the few beneficiaries' lifestyle or attitudes. This is likely given that the level of human-wildlife conflict, a major cause of negative attitudes towards wildlife was low to obscure gains that might accrue from the oil industry.

Our study found that when the people living around MFNP supported the use of illegal tools to poach, the magnitude of acceptability declined when they perceived their relationship with the national park management to be positive. However, local people's attitudes had no influence on whether one found poaching acceptable or not. The relationship between the local people and park managers is important for the co-existence of people and wildlife on shared landscape (Ayebare, 2011; Omoya et al., 2014; Wanyama et al., 2014). Around MFNP, local community-park manager relations are addressed via the community conservation unit, and we recommend that this avenue should be strengthened for even greater impact. Our study supports the notion that positive beliefs for wildlife are developed over time (Vake et al., 2006). The longer one lived in the village, the less acceptable to poaching they became.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Tutilo Mudumba, Sophia Jingo, and Remington Moll. The first draft of the manuscript was written by Tutilo Mudumba, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Statements and Declarations

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.gecco.2022.e02271](https://doi.org/10.1016/j.gecco.2022.e02271).

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