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Assessing disease risk perceptions of wild meat in savanna borderland settlements in Kenya and Tanzania

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Wild meat hunting and trade across African savannas is widespread. We interviewed 299 people in rural settlements along the Kenya-Tanzania border to examine impacts of COVID-19 on wild meat consumption and perceptions about wild meat activities associated with zoonotic disease risks. Education level played a key part in understanding COVID-19 transmission. Information about the pandemic was mostly acquired from the media. Nearly all respondents recognized that COVID-19 originated in China. As many as 70% reported no impact of COVID-19 on wild meat consumption; some believed that there was an increase. Over half of the respondents believed that consumption of wild meat leads to food-borne illnesses. Respondents recognized disease risks such as anthrax and brucellosis and accepted that people slaughtering and handling wild meat with open cuts were at greater risk. Ungulates were the most consumed animals, followed by birds, rodents, and shrews. Respondents perceived that hyenas, monkeys, donkeys, and snakes were riskier to eat. More than 90% of the respondents understood that handwashing with soap reduces risks of disease transmission. Country level (11 answers), education and gender (three answers each) and household economy (158 answers) were significant. Country differences were linked to differences in nature legislation; 50% of Kenyan respondents believed that wild meat should not be sold because of conservation concerns. Men were more worried about getting COVID-19 from live animals and perceived that wildlife should not be sold because of conservation reasons. Overall, there was a very strong inclination to stop buying wild meat if other meats were less expensive. Our results allow us to better understand the impact of the COVID-19 pandemic on wild meat-related activities. Differences between countries can frame the attitudes to wild meat since wild meat trade and consumption were found to be country specific.

KEYWORDS

wild meat, Bushmeat, disease risk, conservation, COVID-19, Kenya, Tanzania, Zoonoses

1. Introduction

Since the 1940s, zoonotic disease outbreaks have been increasing steadily with over 70% of zoonotic emerging infectious disease originating in wildlife (Jones et al., 2008). There is strong evidence that these zoonotic diseases are linked to human activities and close and frequent contacts with wildlife (Muehlenbein, 2013). Local people in Kenya and Tanzania, can gain

income from operating tourist lodges and wildlife safaris, and from associated spinoff activities. Regrettably, the COVID-19 pandemic, a global zoonotic disease, in East Africa (Ezra et al., 2021) has had significant negative impacts on national and local economies which has resulted in falling employment (McNamara et al., 2020). In Kenya alone, COVID-19 rendered more than three million people jobless and affected thousands of households that previously depended on direct and indirect revenues from tourism and related streams (Republic of Kenya, Ministry of Tourism and Wildlife, 2020). Growing evidence indicates that the collapse of the tourism sector caused by COVID-19 impact has pushed park-adjacent communities to turn to illegal wildlife hunting, with more local wild meat consumption as well as trade to supply urban markets (UNODC, 2020). Although quantitative data are still unavailable, the perception is that the COVID-19 pandemic and increased hunting have purportedly led to more wild meat being available in Kenya and Tanzania (Obi, 2021). In Kenya, poaching, clandestine selling or buying wild meat is heavily penalized by law (Republic of Kenya, 2013). By contrast, the Tanzanian Ministry of Natural Resources and Tourism established regulations in February 2020 that provide for the selling of game meat through licensed facilities or butcheries to enable Tanzanian citizens to have access to and consume wild meat. Tanzanians who wish to open such butcheries are given special licences to run their businesses while the harvesting of wild meat to supply these butcheries may be done by resident or tourist hunters or in instances of problem animal control. It should be noted that poaching of wild animals for meat or other purposes in Tanzania carries a penalty of up to 30 years in prison. However, Ochieng (2021) voices the concern that legalized wild meat sales in Tanzania will result in increased poaching not only within the country but also from neighboring countries where meat smuggled into Tanzania can be sold in its new legal markets.

The full impact of COVID-19 has been much greater than indicated by reported deaths due to the pandemic alone. Excess mortality from the disease in Kenya and Tanzania is likely to have been grossly underreported, with overall numbers likely to have been high (Wang et al., 2022). In these two countries, research of the perceptions on the impact of COVID-19 on wild meat hunting, trading and consumption is lacking as well as understanding the zoonotic disease risk perceptions associated with hunting and trading. The few studies that have been undertaken in other parts of Sub-Saharan Africa, generally highlight some undefined link between wild animals and zoonotic diseases such as COVID-19. In southern Cameroon (Kamogne Tagne et al., 2022), for example, the results of a survey of the impact of COVID-19 outbreak on wild meat hunting and consumption indicated that most respondents agreed that COVID-19 can be caught from wild meat. In most cases, interviewees learnt of a presumed wild meat-disease link from information disseminated in the media (radio and television) and from discussions with non-government organizations. Results of the Cameroon study suggested that most respondents were severely impacted by government restrictions in response to COVID-19, particularly loss of access to education, and travel restrictions, which led to loss of access to customers and loss of incomes. The decline in trade and consumption of animals associated with zoonotic diseases such as Ebola, have been documented in Nigerian markets (Funk et al., 2021), Guinea (Duonamou et al., 2020) and Liberia (Ordaz-Németh et al., 2017) though not in Togo (Seytre, 2016). Similarly, COVID-19 impacted wild meat sales in Nigeria (Funk et al., 2022) but seems not to have had any effect on consumers in Sierra Leone (Sainge et al., 2022). Such differences between countries may relate to contrasting social-psychological and economic drivers which shape consumption of wild meat due to a combination of historical and educational factors.

Policy and practical responses to the role that animals, especially wild animals, play as potential sources of pathogens to humans require information at various levels. In particular, interventions aimed at changing hunter and consumer behavior must be based on targeting intrinsic stimuli such as social norms or external influences, e.g., incentives/disincentives (Petrovan et al., 2021). Most effective examples of interventions to change hunter/harvester behavior typically combine several intrinsic and extrinsic approaches and are based on a sound comprehension of local context and culture (Salazar et al., 2019). Thus, understanding how people perceive the linkages between disease and wild meat, especially in situations where food security and livelihoods rely on this source of nutrition, is a fundamental first step to enable public health programs diminish zoonotic disease outbreaks and reduce infections. Perceptions of zoonotic disease transmission at different points of the wild meat value chain are crucial to change the behavior of those people engaged in hunting, butchering, and consuming wild meat (LeBreton et al., 2006).

Any intervention to reduce illegal wild meat trade and consumption must consider the context in which demand for wild meat is greatest. As has been reported in West and central Africa but also in Kenya and Tanzania, this points directly to urban centers, where the massive flow of wild meat from source habitats to these urban centers not only exacerbates wildlife overexploitation in rural areas but can also escalate zoonotic disease risk in consumer populations (Coad et al., 2019). Encouraging behavior change among all consumers can increase their awareness of hazards posed by high-risk species (including various types of animal farming), alongside promoting a greater concern of current environmental challenges, including biodiversity loss (Petrovan et al., 2021). These more informed ways of dealing with the potential zoonotic disease-wild meat issue will nullify any suggestion for bans on hunting, wildlife trade, closing of wet markets or prohibiting the consumption of wild animals. Such policies ignore essential elements of the problem that alienate and intensify hardship of local communities that depend on wildlife resources across the world for their food security (Fa et al., 2015, 2022; Booth et al., 2021).

Around the vicinity of Mount Kilimanjaro, along the border settlements in the Kenya and Tanzania, concerns have been raised by the Kenya Wildlife Service enforcement officials and those in the Kilimanjaro National Park (KINAPA) and the Rombo district Game Offices about the extent of wild meat consumption and the transboundary trade of wild meat. Various species of wildlife killed for their meat in the savanna areas are taken to the local communities and transported to markets nearby where it is then sold. In this paper, we interviewed inhabitants living in border settlements in both countries around the vicinity of Mount Kilimanjaro. From their responses, all the information collected concerns perception: (1) to wild meat and disease risks; (2) impacts of COVID-19 on wild meat consumption and (3) factors limiting or encouraging wild meat consumption. We also investigated whether there were differences by age, sex and country. Such face-to-face interviews can be useful to understand perceptions and the social influences underpinning wild meat consumption.

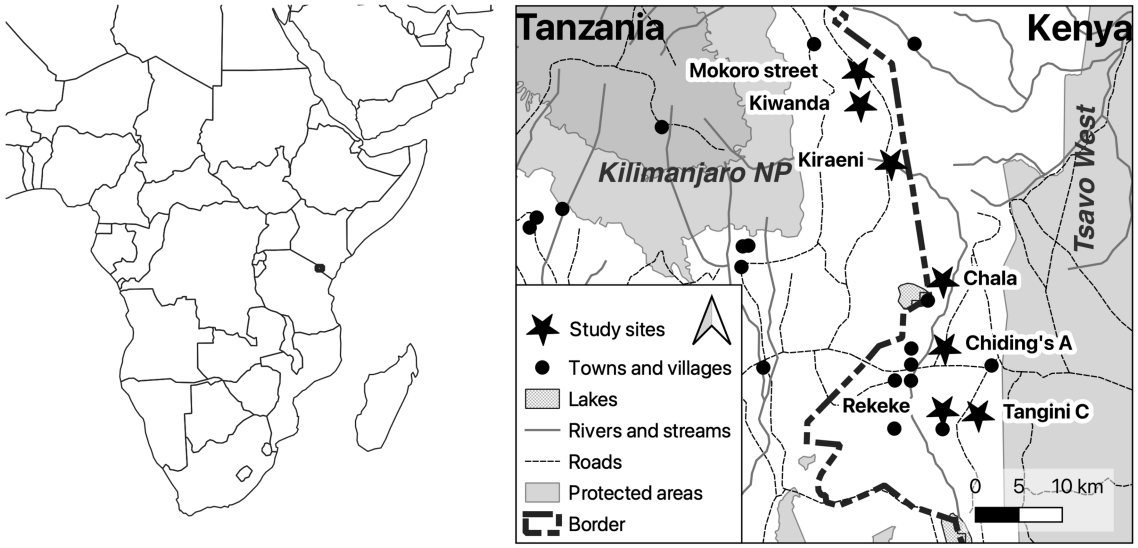

FIGURE 1
Study area on the border between Kenya and Tanzania. The map was created using QGIS version 3.22.9 'Białowieża' (qgis.org) from public domain map datasets from Open Street Map (www.openstreetmap.org), diva-gis (diva-gis.org) and the World Database on Protected Areas WDPA (www.protectedplanet.net/).

2. Methods

2.1. Study area

The study was carried out in six villages, three in the Taita Taveta county in Kenya (Chala, Kedong, Rekkeke/Tangiri), and three in Rombo district in Tanzania. The villages in Rombo district included Kiwanda, Makoro, and Kirawa Keni (Figure 1).

The Taita Taveta County is located approximately 360 km southeast of Nairobi and 200 km northwest of Mombasa and is a port and major gateway to Tanzania through Taveta town. The county, whose headquarters are situated in Mwatate sub-county, is one of the six counties in the Jumuiya ya Kaunti za Pwani regional economic bloc. Major towns include Voi, Taveta, Mwatate and Wundanyi. The county includes Tsavo East and Tsavo West National Parks, which are major tourism destinations. The rest of the area is occupied by ranches and includes Lakes Jipe and Chala in Taveta. Rombo district is in Northern Tanzania (3°09′ 37° 33′). The district is also located in the Eastern slope of Mount Kilimanjaro and contains a large portion of Mount Kilimanjaro. Rombo district is classified as Tropical Savanna area but due to the influence of Mount Kilimanjaro, has a varied climate. In this area, permanent crops such as coffee and banana are grown, but seasonal crops such as maize, round potatoes, fruits and vegetables, sorghum, groundnut, cassava, banana, and finger millet are also grown. The study villages (Kiwanda, Makoro and Kirawa Keni) are found along the border line between Tanzania and Kenya in the north and east side of the district. These villages are found in the highlands where mountain vegetation interspersed by scrubs is the typical vegetation. The main ethnic group in the district is the Chagga, others are Kamba and Kikuyu who reside in Kenya. Most of these ethnic groups predominantly rely on small agriculture and business. Conservation areas around these sites are Kilimanjaro National Park (KINAPA), Mt. Lotima Forest Reserve and Lake Chala Forest Reserve.

2.2. Survey design

Surveys were carried out in December 2021. We interviewed 299 people, 189 in the Kenyan villages and 110 on the Tanzanian side. Respondents were chosen by their availability and willingness to participate. We targeted both male and female respondents as well as those under the age of 18 who are living with a guardian who was present during the time of addressing the survey. We applied a structured questionnaire (see Table 1) for the full questionnaire using a Kobo Collect form[1] to enable responses to be directly recorded on a tablet computer during interviews. Questions were formulated to span a wide net to assess awareness and perceptions of diseases that are or maybe transmitted from wild meat. Questionnaires also adopted questions from similar investigations in West Africa (Funk et al., 2021). We refer to wild meat as bushmeat since the latter term is more commonly used to denote the meat from wild animals in Africa, but the former is the more generic, worldwide term which we use in the text (see Coad et al., 2019). All interviews were carried out in pairs to ensure that the flow of conversations continued while the other recorded responses. No voice recorders were used during this survey.

2.3. Ethics and data collection

Ethical approval for this study was given through ILRI's Institutional Research Ethics Committee (IREC2021-58). Research permits (Tanzanian permit # HWR.G.10/1/VII/63) were obtained to perform our work in both countries; in Tanzania, permits were also provided in the form of introduction letters to the village authorities.

1 https://kc.humanitarianresponse.info

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TABLE 1 Summary statistics for all 23 questions.

Questions grouped in question types (binary, ordinal and Likert)	Independent variable	Test statistics	*p*	*p'*	Supplementary Figures
BINARY		Df, Deviance, residuals, Df residials, Dev			
Do you like eating bushmeat?	Country	1, 10.2243, 296, 402.41	0.0014	0.0233	Supplementary Figure S1A
Did you hear of COVID-19 from the media?	–				
Did COVID-19 originate in China?	Country	1, 26.9898, 240, 154.39	<0.0001	<0.0001	Supplementary Figure S1B
Did COVID-19 originate in wild animals?	Education	2, 12.5977, 212, 266.33	0.0018	0.0286	Supplementary Figure S1C
Are you worried about disease transmission from bushmeat?	–	–	–	–	–
Have you reduced your bushmeat consumption because of diseases like COVID or Ebola	Economy	3, 13.5893, 143, 139.00	0.0035	0.0418	Supplementary Figure S1D
Do you think some animal species are risky to eat?	Education	2, 12.3205, 289, 286.08	0.0021	0.0305	Supplementary Figure S1E
Is it riskier to have bushmeat than red meat, poultry, fish?	Country	1, 28.4679, 296, 339.91	<0.0001	<0.0001	Supplementary Figure S1F
Would you stop buying bushmeat if other meat was cheap or cheaper than bushmeat?	–	–	–	–	–
ORDINAL EXCEPT LIKERT SCALE		Chisquare, Df			
What has been the impact of COVID-19 on bushmeat trade and consumption?	–	–	–	–	–
Worried about COVID-19 in general?	Country	11.6249 1	0.0007	0.0121	Supplementary Figure S1G
Concerned about COVID-19 in bushmeat in your market?	Country	22.3960 1	<0.0001	<0.0001	Supplementary Figure S1H
Concerned about COVID-19 in live animals in your market?	Country	15.1614 1	0.0001	0.0025	Supplementary Figure S1I
ditto	Gender	11.6076 1	0.0007	0.0121	Supplementary Figure S1J
LIKERT		Chisquare, Df			
Can bushmeat transmit COVID-19?	-				
Can bushmeat transmit Ebola?	-				
Can bushmeat transmit Malaria?	Country	58.633 1	<0.0001	<0.0001	Supplementary Figure S1K
Can bushmeat transmit Food Poisoning	Country	12.012 1	0.0005	0.0119	Supplementary Figure S1L
Risks through slaughter with open wound?	-	-	-	-	-
Risks through handling with open wound?	-	-	-	-	-
Hand washing reduces risk of disease transmission?	Education	11.663 2	0.0029	0.0395	Supplementary Figure S1M
Do not sell- ethical/religious considerations	Country	20.757 1	<0.0001	0.0002	Supplementary Figure S1N
Do not sell- Animal conservation	Country	35.411 1	<0.0001	<0.0001	Supplementary Figure S1O
ditto	Gender	8.567 1	0.0034	0.0418	Supplementary Figure S1P
Do not sell- Disease transmission	Country	34.648 1	<0.0001	<0.0001	Supplementary Figure S1Q
ditto	Gender	8.340 1	0.0039	0.0435	Supplementary Figure S1R

The test statistics is shown only for those questions with at least one significant variable ($p' < 0.05$). Shown are observed *p*-values (*p*) and Benjamini and Hochberg (1995) corrected *p*-values (*p'*) across all questions for false discovery rates.

Our study was undertaken using a Free Prior Informed Consent (FPIC) approach. We first explained the aims of the research to the village leader from whom we obtained permission to work and stay in the area. Following this, interviewers were free to approach any household in each village to carry out the interviews. The objective of our project was explained to potential interviewees as well as the

nature of our questions. Those who were under the age of 18 were interviewed in the presence of a guardian as we believe that it provides insight into the role they may play in the wild meat value chain which could include helping parents clean meat, hunt or sell. We explained that participation was voluntary, that data would be anonymized and that persons approached by us could stop the interview process at any point. Interviews were conducted in Swahili or vernacular language, spoken fluently by all respondents and the research team. We applied care to remain neutral and avoid leading questions and biassing interviews. Follow-up questions were asked during interviews to explore emerging avenues of discussion. Given the on-going COVID-19 pandemic in December, interviews were carried out in compliance with COVID measures that included maintaining a distance of at least 1.50 m between the research team and respondents during the interview, using masks if interviews were carried out in-doors and using handwashing sanitizing gel before each interview.

TABLE 2 Independent variables used.

Independent variable	Scores
Country	Tanzania, Kenya
Age	Up to 25, 26–35, 36–45, 46–55, more than 55
Gender	Male, female
Education	No formal education, primary school, secondary school, higher education
Livelihood	Agriculture, blue collar, none, retired, hunting, housewife, fishing, white collar
Economy	Okay, bad, good, very bad
Sheep Goats	Keeps sheep or goats (yes/no)
Cattle	Keeps cattle (yes/no)
Poultry	Keeps poultry (yes/no)

2.4. Statistical analysis

All statistical analyses and visualizations were conducted in R (R Foundation for Statistical Computing, 2021). Demographic data were described and differences between study sites were evaluated by χ^2 test of contingency tables. Two types of answers to questionnaire questions were possible: ordered ordinal responses of three or more categories (including four categories such as "not worried at all," "somewhat worried," "strongly worried," and five Likert-type categories of levels of agreements "strongly agree," "agree," "neutral," "disagree," "strongly disagree") and binary yes/no responses. Ordered ordinal answers were analyzed by fitting ordered logistic regression, also called cumulative link models with the R function *clm* from the R package 'ordinal' (Bojesen Christensen, 2019). Cumulative link models are an extension of logistic regression to account for the ordered, categorical nature of the response variable (Christensen and Brockhoff, 2013). Response categories represent an ordered sequence, e.g., from "acceptance" to "neutral" to "rejection." We made no assumption about the distance between adjacent categories. An analysis of deviance (ANODE) was conducted to identify statistically significant independent variables. ANODE is the appropriate alternative for ANOVA for categorical variables (Mangiafico, 2016). It uses "deviance" instead of sum of squares and chi-squared tests instead of the F-tests in ANOVA. ANODE was implemented using the function *Anova.clm* from the R package 'RVAideMemoire' with type II χ^2 testing (Hervé, 2021). Type II assumes no significant interaction effect between independent variables (Country, Age, Gender, Education, Livelihood, Economy, Sheep/Goats, Cattle, Poultry). Binary answers were analyzed by fitting binomial general linear models with the R function *glm* and by conducting an ANODE with the basic R function *anova* with χ^2 testing using the *glm* fitted model as input. Fitting the *clm* and *glm* models included all independent variables (Table 2), e.g., for the first question:

'Do you like eating bushmeat' ~ country + Age + Gender + Education + Livelihood + Economy + SheepGoats + Cattle + Poultry.

Only those which were significant in the ANODE analysis were reported in Table 1 and Figure 2. In rare cases, one of the independent variables was not informative as indicated by the *clm* and *glm* outputs and were removed from the modelling. Because questions probed related attitudes and knowledge (e.g., "Concerned about COVID-19 in live animals in your market?" and "Concerned about COVID-19 in bushmeat in your market?") answers of each interviewee were not independent from each other. All the dependent variables are the questions. To account for multiple statistical testing of the same data body we applied the Benjamini and Hochberg (1995) correction for false discovery rates to calculate a corrected p value, p', using the function *p.adjust* in R. We choose the Benjamini and Hochberg (1995) correction over other corrections such as the Bonferroni procedure because it is less conservative (White, 2019). Except where otherwise stated, the sample size n was 299, the number of completed questionnaires.

3. Results

3.1. Socio-demographic information

A total of 63% of the 299 completed questionnaires were in the three Kenyan villages and 37% in the Tanzanian villages. Overall age distribution of interviewees was balanced except for those in the 18–25 years (12%) and younger group (1%) (14%, 26–35: 21%, 36–45: 22%, 46–55: 21%, 55 and older: 23%). The two country samples differed significantly from each other with more 56-year-old and older persons interviewed in Tanzania (Figure 2A). The gender ratio was 53%:47% men: women with significantly different ratios in the two countries (Figure 2B). Education levels included no formal education (13%), primary education (64%) and secondary and advanced education (23%); no differences between country samples were observed (Figure 2C). Livelihoods were dominated by agriculture (66%) over blue collar employment (10%), white collar employment (8%), fishing or hunting (2%), household work (4%) as well as no work (11%). The two country samples were significantly different from each other with more agriculture among respondents in Tanzania (Figure 2D). No significant differences were found in cattle (47%, Figure 2E), goat and sheep (75%, Figure 2F) and poultry ownership (77%, Figure 2G). We also inquired about ownership of camels, horses and donkeys, and pigs, but these were not included in the analysis because these animals are rarely kept (0.3, 2, 7%, respectively).

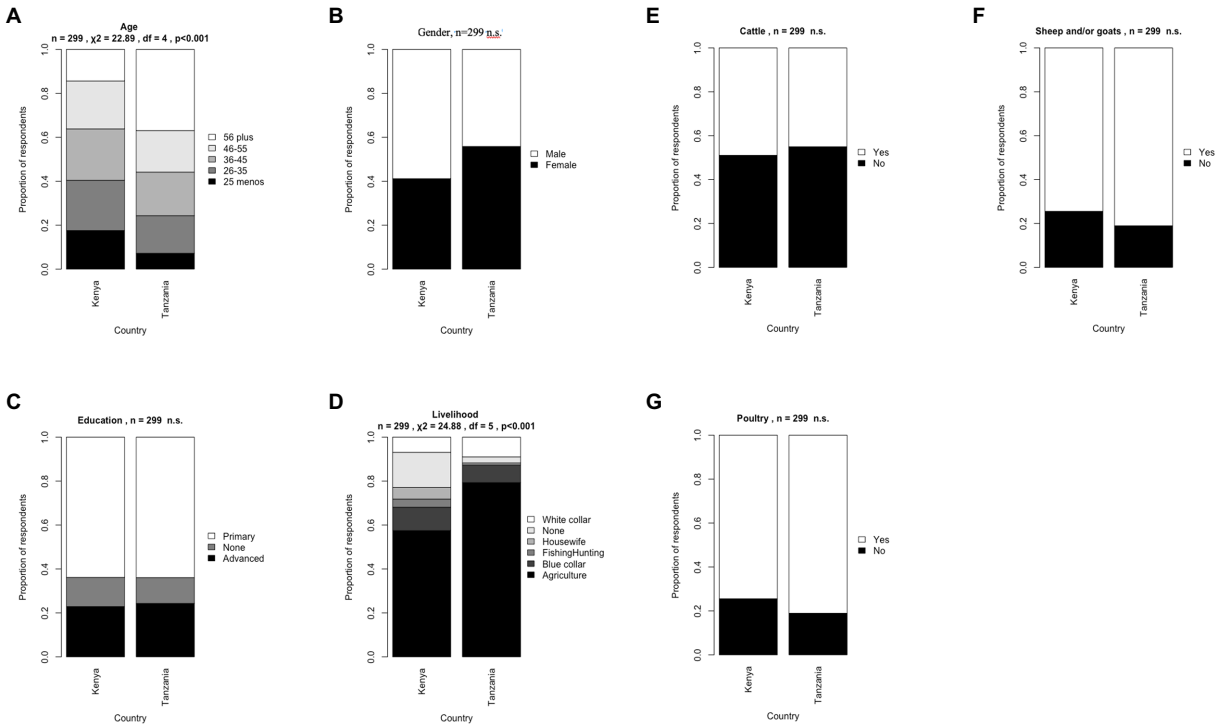

FIGURE 2
Demographic characteristics of respondents regarding age **(A)**, gender **(B)**, education **(C)**, livelihoods **(D)**, and ownership of cattle **(E)**, goat and sheep **(F)** and poultry **(G)**.

3.2. Country, gender, education, and economy specific variations

General answer frequencies for all with 23 probed questions are shown in Figure 3. The 299 conducted interviews resulted in 179 statistical ANODE tests. A total of 51 tests resulted in $p < 0.05$ without correction for multiple testing and 18 resulted in $p' < 0.05$ after Benjamini and Hochberg (1995) correction. Supplementary Table S1 indicates which questions resulted in significant differentiation. The frequency distributions stratified according to independent variables are shown in Supplementary Figure S1 for those questions with significantly differing answers for independent variables where 11 answers at the country level, three answers each for education and gender and one answer for economy demonstrate significant differentiations.

Country differences: Tanzanian respondents liked eating wild meat significantly more (>60%) than respondents in the Kenyan border villages (>40%) (Supplementary Figure S1A). Tanzanian respondents also agreed less that COVID-19 originated in China (Supplementary Figure S1B) and that it is less risky to eat wild meat than other meat (Supplementary Figure S1F). Respondents in Tanzania were more worried about COVID-19 in general (Supplementary Figure S1G) but were less strongly concerned about COVID-19 in wild meat and live animals in markets (Supplementary Figures S1H,I). They disagreed less strongly that wild meat can transmit malaria and food poisoning (Supplementary Figures S1K,L). Tanzanian respondents also agree less than Kenyan respondents that wild meat ought not to be sold for ethical and/or religious considerations, animal conservation and disease transmission (Supplementary Figures S1N,O,Q).

Gender differences: Men were significantly more concerned about COVID-19 in live animals in markets than women (Supplementary Figure S1J) and more men agreed that wild meat ought not to be sold for animal conservation and disease transmission reasons than women (Supplementary Figures S1P,R).

Educational differences: More respondents with a formal education agreed compared to those without a formal education in response to the questions whether COVID-19 originated in wild animals, whether wild meat consumption was reduced because of zoonotic disease and whether hand washing reduces the risk of disease transmission (Supplementary Figures S1C,E,M).

Economic differences: Answers to only one question were significantly impacted by this variable. Economy was important for having reduced wild meat consumption because of diseases like COVID-19 or Ebola. However, the effect was not consistent across all categories; respondents with Bad and Good economy did not lessen their wild meat consumption as much as those in the Okay and Very bad economy (Supplementary Figure S1D).

3.3. COVID-19 concerns and wild meat consumption

Figure 3 shows the answer frequencies to all binary questions, which concern wild meat eating and transmission of diseases, in particular COVID-19. Seventy-six percent heard about COVID-19 from the media. The majority (88%) believed that COVID-19 originated from China as opposed to Europe or Africa and less than half of the respondents agreed that the disease originated in animals (35%).

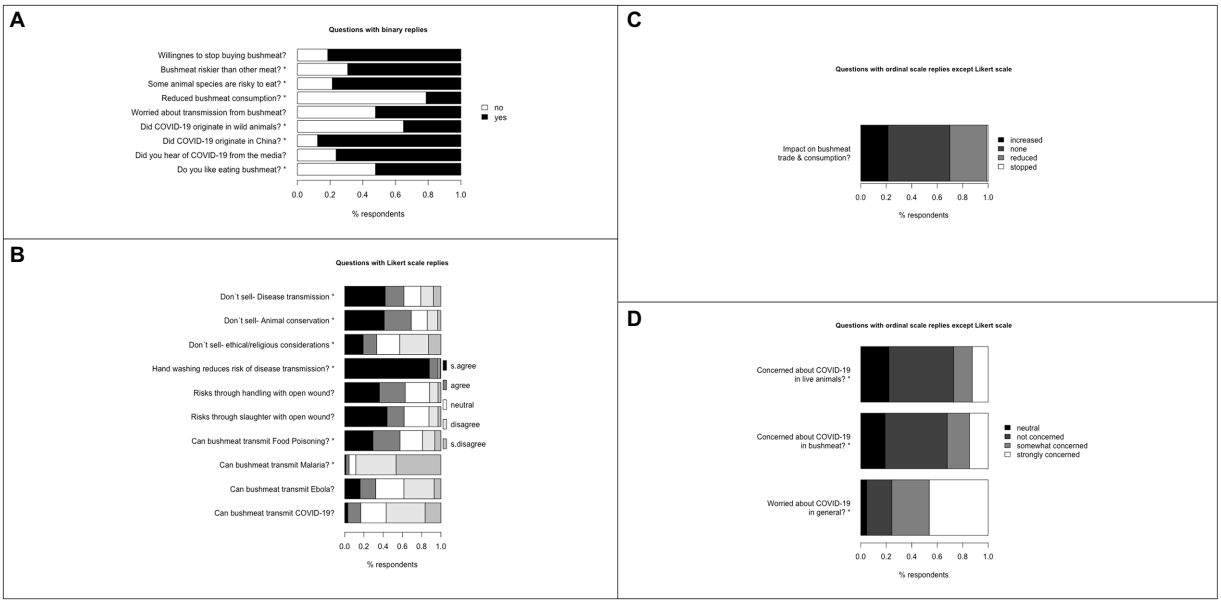

FIGURE 3
Reply characteristics to questions whose replies were in binary scale **(A)**, ordinary scale except Likert **(B)** and ordinary Likert scale **(C,D)**. Questions marked with * indicate those where replies significantly deviate for at least one independent variable after Benjamini and Hochberg (1995) correction for false discovery rate.

Answer frequencies to all ordinal, non-Likert scale questions are shown in Figures 3B,C. Only 30% of respondents believed that the impact of COVID-19 caused wild meat trade and consumption to stop or be reduced. Almost three quarters were strongly concerned or somewhat concerned (46 and 29%, respectively) about COVID-19 in general, but only a third strongly were concerned or somewhat concerned (15 and 17%, respectively) about COVID-19 in wild meat in the local markets. Similar percentages (12 and 15%, respectively) were observed for concern toward COVID-19 in live animals in local markets.

Responses to all ordinal, Likert-scale questions (Figure 3D) indicate that 16% of respondents strongly agreed or agreed that wild meat can transmit COVID-19. For Ebola disease, the percentage was higher and for malaria lower with 32 and 4%, respectively. Most support was reported for transmission of food poisoning from wild meat with 57% of respondents strongly agreeing or agreeing. Risks for disease transmission through slaughter or handling were agreed or strongly agreed by 62 and 63%, respectively. Almost all respondents (97%) agreed or strongly agreed that hand washing reduces the risk of COVID-19 transmission. Regarding whether wild meat should be sold, most respondents agreed or strongly agreed that wild meat should not be sold because of animal conservation (69%) or disease risk (62%) reasons while the minority (33%) agreed or strongly agreed that wild meat should not be sold for ethical or religious considerations.

3.4. High-risk species consumption and risks associated with disease transmission

Strong evidence exists that zoonotic disease outbreaks have been linked to human activities such as consumption of wild meat (Coad et al., 2021) and some species are more risker than others. In this study, half of the respondents (52%) were worried about the transmission of other diseases from wild meat but only 21% of them ($n = 156$) had reduced their wild meat consumption because of zoonotic disease such as Ebola and COVID-19. Out of 299 questionnaires, 112 (38%) cited worries about anthrax, but to a much lesser extend worms (2.7%), food poisoning (1.3%), viral disease other than COVID-19 (9.4%), bacterial disease including brucellosis (5.7%), protozoan (1%) and other, unspecified diseases (5.7%). A total of 79% of respondents believed that it is risky to eat some animal species and two thirds (69%) believed that it is riskier to have wild meat than red meat, poultry, or fish. The large majority (81%) would stop buying wild meat if other meat was cheap or cheaper than wild meat. Figures 4, 5 rank the perceived high-risk species and species that were bought the most in the last year, respectively. The majority (35%) of respondents believed that hyaenas were the riskiest animals to consume, followed by monkeys (20%), snakes (6%), zebras and lions (3.7 and 3% respectively). The most bought species were ungulates followed by birds and rodents or shrews. Most respondents who bought birds, rodents and shrews were from Kenyan settlements. Rodents and shrews were bought by 19% of the Kenyan settlements compared to 4.3% from Tanzania and 22% of the respondents from Kenyan settlements bought birds compared to 13% from Tanzania.

4. Discussion

Trade and consumption of wild meat in East African savannas is widespread and complex (Lindsey et al., 2013; van Velden et al., 2018). Our study demonstrates how rural peoples, primarily agriculturalists along a frontier region between Kenya and Tanzania, perceive zoonotic and other disease risk associated with wild meat activities. Individuals from these communities are in close and frequent contact with wildlife.

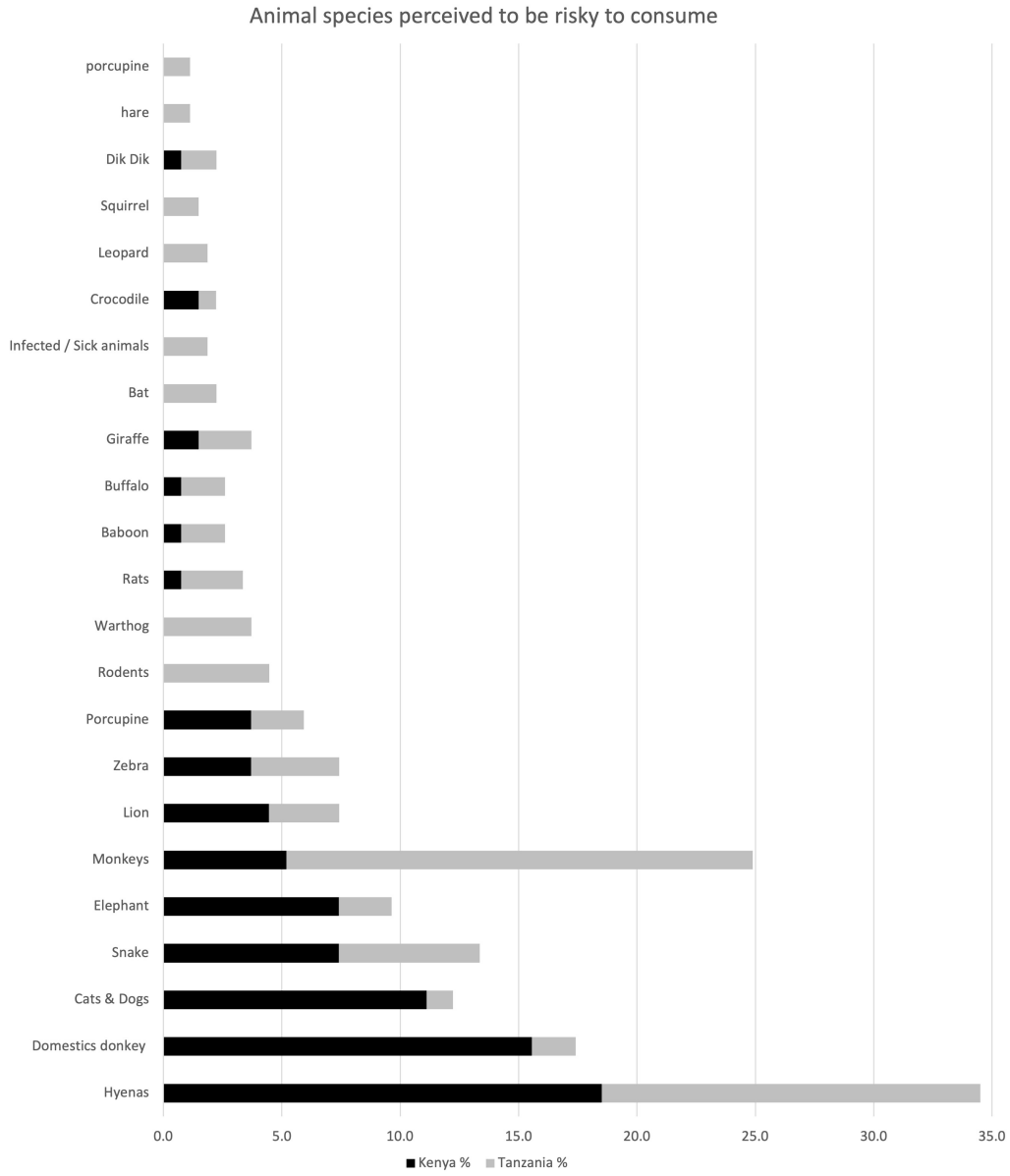

FIGURE 4
Species perceived by respondents as high risk.

In addition, our study has allowed us to better understand the impact of the COVID-19 pandemic on wild meat-related activities.

Having interviewed 299 people, we found significant statistical country differences in most responses. These differences may reflect the contrast between countries in how they regulate use of wildlife. In both Kenya and Tanzania, killing of wildlife without a license is subject to imprisonment. However, in 2020, Tanzania legalized the wild meat trade through special licenses to stop illegal hunting, boost the economy and provide employment to local communities. Anecdotal evidence from the respondents suggests that animals are killed and moved across the porous country borders suggesting the need for improved regulation on wildlife movement which can also contribute to evidence-based conservation guidance along human-wildlife interactions (Katzner and Arlettaz, 2020). Pressures on wildlife in Kenya and Tanzania are likely to have increased considerably because of deteriorating economic conditions brought about by the COVID pandemic. Solutions to this situation need to be manifold but primarily focused on generating work alternatives for those inhabitants that have relied on income from viewing wildlife. It is interesting to point out that respondents consumed wild meat instead of livestock due to the high costs of purchasing livestock. While more studies need to be carried out in Kenya to improve our understanding on the demand of wild meat, both in West Africa and in Asia, residents of large urban centers like Brazzaville/Kinshasa and Ho Chi Minh are known to consume wild meat due to socio-cultural aspects (Fa et al., 2019; Nguyen and Jones, 2022; Wright et al., 2022).

In both of our study countries, there is recognition that wild meat overconsumption can become a major threat to wildlife including in

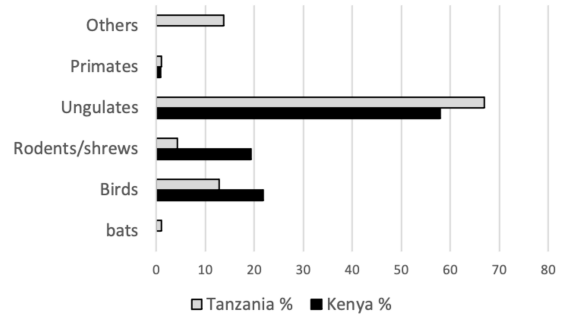

FIGURE 5
Animal groups that were bought most over the previous year.

protected areas (e.g., in Tanzania: Ndibalema and Songorwa, 2008; Martin et al., 2012). Mitigation programs are often difficult to implement successfully because demand for wild meat differ depending on the socioeconomic conditions rural communities live in, and on alternative protein resources available (e.g., Ceppi and Nielsen, 2014). Other motives include species availability, taste, health and culture (Nguyen et al., 2021) Ultimately, the regulation of wild meat use is essential for biodiversity conservation and to ensure rural communities' well-being. Differences in how this can be achieved is patently distinctive. We found that 50% of respondents mainly those in the Kenyan border believed that wild meat should not be sold due to conservation reasons. In Kenya, legislation for the protection of species may be the main conservation tool applied. In the case of Tanzania, although it also relies on the application of the law, effectiveness may have to rely on the implicit assumption that voluntary compliance will occur because wildlife use is somewhat liberalized. In both countries, ineffective regulations and weak enforcement will have significant negative effects on the wildlife that is being protected. Rowcliffe et al. (2004) have provided some proof that the protection of vulnerable species can only take place through adequate implementation, for example by wildlife authorities restricting access to protected areas, or by traditional authorities prohibiting the sale of protected species in local markets. Alongside this, behavior change interventions grounded in an understanding of the socio-cultural drivers underpinning consumer demand patterns are needed. Research on the cultural, social, and psychological dimensions of wild meat demand are essential. We show that qualitative research (Drury et al., 2011), as employed in our study, is a cost-effective tool to understand perceptions and social influences underpinning wild meat consumption, factors not easily captured through other survey approaches.

In both countries together we found that education level of the respondent played a key role in understanding disease risks associated with wild animals. This was demonstrated when asked if COVID-19 originated in wild animals and 60% responded negatively among the primary and advanced degree education, and 90% responded negatively among the group with no educational background. Furthermore, it was evident that media played a role in relaying information specific to COVID-19 and was observed as majority of respondents (80%) heard about COVID-19 from the media and 90% recognized that it originated from China. The impact of COVID-19 pandemic caused by the SARS-CoV-2 virus has affected supply and demand of wild meat by disrupting supply chains, and dramatically impacting international travel and tourism (McNamara et al., 2020). In our study, 30% of people were (strongly or somewhat) concerned about COVID-19 in live animals which may have led to reduced consumption due to concerns over health risks associated with wild meat. This is interesting because while wild animals may act as reservoirs for SARS-CoV-2 (Kuchipudi et al., 2021), there are no direct links of transmission from wild animals to humans for COVID-19. Recent findings have shown that the SARS-CoV-2 can infect other animals such as ferrets, cats and white-tailed deer (Kuchipudi et al., 2021; Hale et al., 2022) and nearly 75% of new diseases emerging are from animal reservoirs. Respondents interviewed (80% in Kenya and 50% in Tanzania) recognized that some wildlife species were ranked as high-risk to consume due to zoonotic disease, these included monkeys and snakes, and interestingly most respondents also perceived that hyaenas were high-risk animals. This perception is not clear and would require further investigations to determine if this perception is linked to cultural believes within these communities. Previous studies led by East et al. (2004) have shown coronavirus infections in Spotted Hyenas (*Crocuta crocuta*). Our research also showed that rodents and shrews were consumed, mainly from respondents in Kenyan settlements. This is of concern as recent studies in Kenya (Onyuok et al., 2019) have detected new paramyxoviruses from rodents which are a public health concern as they are considered important agents of diseases of humans and animals. Over half of the respondents believed that consumption of wild meat leads to food borne illnesses and recognized the high disease risks associated with slaughter and handling of wild meat with open wounds. The increased use and exploitation of wildlife has been listed as one of seven human-mediated factors that are most likely driving the emergence of zoonotic disease (UNEP and ILRI, 2020).

However, even high awareness of the zoonotic disease risks associated such as anthrax from certain wildlife species, and a willingness to stop buying wild meat is not a guarantee that it leads to behavioral change. First, people can underestimate the risk in cases even when they recognize that there is a risk (Gardner and Stern, 1996). Second, there is a trade-off between risky behavior and associated benefit from that risky behavior, in this case providing food. The threat must be large enough to result in a forfeiture of the benefit (Monroe and Willcox, 2006). For example, knowledge of zoonotic risk from anthrax is widespread among owners of cattle, herdsmen, butchers and consumers but this did not lead to behavioral change (Opare et al., 2000; Otupiri et al., 2000). The strong negative economic effect of the COVID pandemic in Tanzania and Kenya works against people sacrificing wild meat despite their knowledge of the risk.

Our study has shown how inhabitants of the Kenya/Tanzania borderlands perceive zoonotic disease and use of wild meat. Although a start, we are conscious that there is still a need to investigate further how complex dynamic processes determining perceptions of threats and risks from wildlife and zoonotic disease are dealt with by different people. Bayesian methods, such as Baysian Mindsponge Framework (Nguyen et al., 2022) or variations of this can allow researchers to incorporate how value systems, mindset, risk evaluation and processing available information by people can influence their decisions on why and how they consume wild meat. Such insights will allow researchers to propose more realistic and accurate disease prevention behavioral campaigns that must involve the participation

of communities to help reduce risks of zoonotic disease spillover, protecting the livelihoods of people, wildlife and the ecosystem.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by ILRI's Institutional Research Ethics Committee. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

EP, AM, SF, and JF: study design. EP, AM, and MY: fieldwork. SF: data analysis. EP, JF, SF, and CF: writing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fevo.2023.1033336/full#supplementary-material

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