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Research Article

Factors affecting bushmeat consumption in the Katavi-Rukwa ecosystem of Tanzania

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Abstract
Bushmeat consumption and trade are major problems for wildlife conservation in East Africa. To evaluate recognized drivers of bushmeat consumption, we used structured interviews of 435 households in 11 villages within an ethnically diverse division in rural western Tanzania; the study included both indigenous people and an immigrant population that has moved into the area over the last 40 years. We found that the number of wild animal carcasses reported to be entering villages was greater in villages situated nearer to nationally protected areas. In the indigenous sample, bushmeat consumption was more common in richer than in poorer households, challenging ideas that increasing the availability of alternative protein would necessarily reduce consumption of bushmeat. In the immigrant sample, we found the opposite pattern. We recommend that outreach programs be targeted at both hunters and consumers living near protected area boundaries; that careful evaluations be made of whether wealthy or poor are eating bushmeat; and that protein supplementation be considered more cautiously in solving the problem of bushmeat demand. Our findings highlight complexities of implementing practical solutions to bushmeat consumption in Africa.

Key words: hunting, Katavi-Rukwa, wildlife management, wildlife utilization

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Introduction

Consumption of bushmeat – defined as wildlife hunted for human consumption [1] – is a pervasive threat to wildlife not only in Africa but worldwide [2]. Until recently, most studies and concern about bushmeat consumption in Africa were centered on the west and center of the continent because bushmeat is often considered a forest activity and there is a perception that East African savannah reserves are well protected; nevertheless, it is now regarded as a serious problem in East Africa too [3], with Tanzania in particular receiving a good deal of study [4-10]. Our current understanding of this form of wildlife exploitation in Africa is centered on two distinct issues – what levels of protection are appropriate to limit bushmeat hunting? And can availability of alternative sources of protein affect bushmeat consumption? With respect to protection, there is some evidence that law enforcement does reduce offtake [11] and this has led to recommendations in the academic literature that governments should take on-ground law enforcement more seriously [12]. With respect to alternative sources of protein, there is considerable evidence that illegal bushmeat offtake is closely associated with economic factors [13], although this may vary according to urbanization and economic strata. At a broad level, then, it is generally agreed that increased patrols, arrests and fines in conjunction with much greater attention to social and economic problems may together have a chance of reducing bushmeat consumption on some parts of the continent [see 14].

Moving from the general to the specific, however, it is difficult to know how to change people's behavior without clear knowledge of the factors affecting bushmeat consumption [see 15]. For example, if bushmeat consumption is associated with low income, or lack of alternative protein sources, providing additional economic opportunities or new sources of protein might help alleviate the pressures on wildlife. If interest in bushmeat is linked to particular ethnic affiliations, education targeted at specific groups, and with appropriate cultural nuances, might be warranted. If bushmeat consumption is negatively associated with distance to protected areas, then focusing attention on villages closest to protected areas might be the most effective way of ensuring that conservation goals are met. All these implementation proposals must be evaluated in light of the fact that animal source protein is often a critical source of nutrition and health of residents in parts of rural Africa, and that hunting may carry cultural significance [16].

There is considerable agreement among studies over of the factors shown to affect bushmeat consumption in various parts of Africa, namely ethnicity, household size, household wealth, education, and distance from a protected area, but less consensus over the precise nature of these effects. For example, household size has positive effects on bushmeat consumption on Bioko Island, West Africa [17, see also 6] but negative effects in Gabon [18]. Household wealth is also typically associated with bushmeat consumption, with richer households consuming more in urban households in Rio Muni [19] although poorer households consume more in rural Equatorial Guinea [13]. Education is negatively associated with consumption of certain wild mammals in rural Gabon [18]. Bushmeat hunters enter protected areas from outside but to a decreasing extent with distance from their settlements [20-22]. Finally, ethnicity is strongly associated with bushmeat consumption in parts of Rio Muni [23]. To refine our understanding of household correlates of bushmeat consumption in western Tanzania where bushmeat activities are prevalent [7, 10] we chose the Katavi-Rukwa ecosystem where declines in mammal populations are in evidence [24-27]. We focused on Mpimbwe Division in particular, a rapidly growing area occupied by several ethnic groups and for which there is solid ethnographic background [28-30].

We hypothesized that bushmeat consumption would be less common among the Sukuma, an agro-pastoralist ethnic community that has recently migrated to the area, as opposed to the more sedentary indigenous hunter-fisher-cultivators of mixed ethnic origins (primarily Pimbwe, Fipa and Rungwa), in part for cultural traditions (see below) and in part because of the availability of alternate sources of protein in livestock-keeping households. Additionally, we predicted that bushmeat consumption would be more common in poorer households, and in households headed by less educated men, and in larger households, due to greater need and fewer economic alternatives. Because preliminary analyses showed that the explanatory factors varied by ethnicity [9] we present ethnic-specific models which can potentially capture the different dynamics of immigrant and indigenous ethnic groups.

Methods

Study site

This study was carried out in Mpanda District, Rukwa (now Katavi) Region in western Tanzania in villages bordering two protected areas, Katavi National Park (KNP) and Rukwa Game Reserve (RGR). Situated in the Rukwa Valley at latitude 6°45' to 7°05' S, longitude 30°45' to 31°25' E, KNP is the third largest national park in the country [29], being 4,471 km² in area [31]; it is managed by the Tanzania National Parks Authority (TANAPA); only photographic tourism is permitted within the Park. KNP is patrolled regularly and informants in villages report law infringements to TANAPA authorities. TANAPA outreach activities have made small investments in the area, building school houses and upgrading dispensaries. Other small community-based projects are being implemented (see http://mpimbweproject.ocom). The RGR (4194 km^2) borders KNP to the south east (Fig. 1) and is managed by the Wildlife Division; tourist hunting is allowed there from July to December. This area is patrolled less frequently than KNP due to shortage of staff. Both areas consist of miombo woodland – dry forest habitat characterized by *Markamia, Grewia, Terminalia, Syzygium, Acacia* and *Combretum* tree genera [32] but the national park additionally has four large floodplains that attract high concentrations of wildlife in the dry season [24,33]. The Katavi-Rukwa ecosystem receives approximately 900 mm of rain per year.

The study took place in 11 villages in Mpimbwe Division (with its estimated population of 100,000, E. Carabine and M. Borgerhoff Mulder, unpublished data), which lies to the south of KNP and west of RGR (Fig. 1). It is occupied by Pimbwe, Fipa, Rungwa, and Sukuma ethnic groups, who conduct a wide range of economic activities including subsistence hoe farming, commercial agriculture, cattle herding for cash and subsistence, fishing and hunting [28].

Background information

Katavi National Park (Fig. 2a) was established first as a game reserve in 1956, and as a national park in 1974; it was extended in size in 1998. Each of these land planning changes entailed population displacements in the Rukwa Valley – the indigenous Pimbwe (Fig. 2b) and Rungwa were evicted from their original villages at various periods starting in 1927, and later the immigrant Sukuma were forcibly removed from their dry season grazing areas at various times starting in 1998. The Pimbwe and Rungwa are renowned for being both hunters and fishers, economic activities that are part of their cultural heritage [34]. They originally occupied and hunted in much of the area now gazetted as KNP and, in the case of the Rungwa, in the RGR [35]. It is worth noting that their legal access to areas formally used for hunting and fishing is now much reduced as a result of protectionist conservation policies. The Fipa, original inhabitants of the Ufipa Plateau lying to the west of the Rukwa Valley, also consume bushmeat and are known for eating rodents [34]. Only the immigrant Sukuma have no strong reputation for being hunters, as they depend on an agropastoral production system. Therefore, there are good ethnographic justifications for separating Sukuma and non-Sukuma ethnic groups when examining patterns of bushmeat hunting in this area of Tanzania.

Our reference to Pimbwe, Fipa, and Rungwa as indigenous is for clarity, to differentiate them from the immigrant Sukuma, and does not suggest they have greater rights to the land in Mpimbwe. Note also that the area is typically associated with high levels of seasonal food insecurity [30], which are associated with high incidences of maternal anxiety and depression in both the indigenous and the Sukuma populations [36], although disproportionately so in the indigenous sample [37].

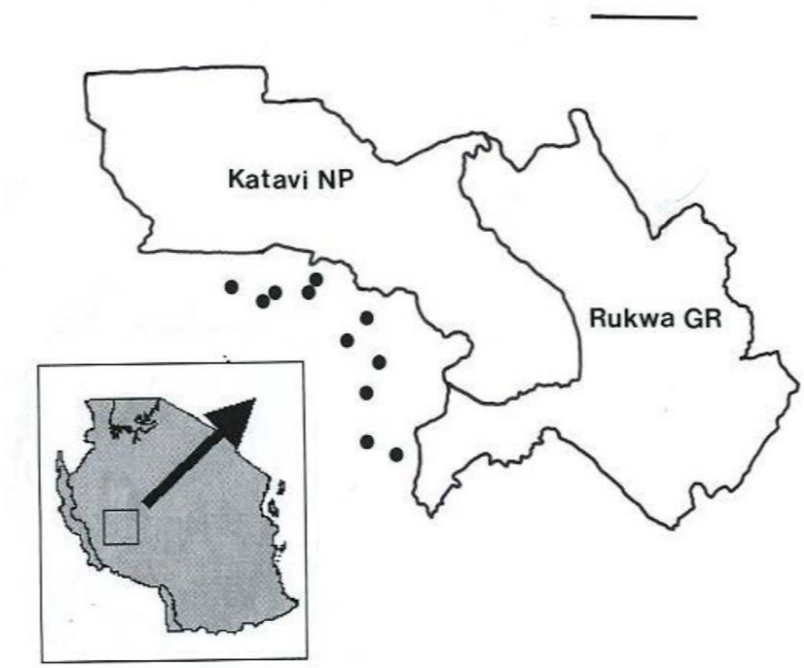

Fig. 1. Study area showing Katavi National Park (NP) and Rukwa Game Reserve (GR) in western Tanzania (see inset). Black dots show location of the eleven villages in Mpimbwe Division at the time of the study, all of which are included in the sample. Villages lie between 5.7 and 19.1 kms from the border of one of the two protected areas. Bar at top right denotes 25 kms.

Data collection

Data were collected in Kiswahili from Mpimbwe between July and September 2008 during the dry season; every one of the 11 principal villages was visited (Fig. 2c). In each village approximately 20 households were selected randomly (by use of village lists) from the center of the village to capture the indigenous population, and 20 households from a randomly selected subvillage in order to ensure coverage of Sukuma households that are typically situated outside the central village area (Fig. 2d). A total of 435 households out of an estimated 5,895 in the Division were studied, of which 245 were indigenous and 190 were Sukuma. Villages lie approximately 6 to 19 kms from the border of one of the two protected areas (KNP and RGR, Fig. 1).

Prior to interviewing households, meetings were held with village officials to solicit consent and obtain household lists from which households were picked at random. Because bushmeat consumption is an illegal activity, and interviewees might be expected to see a cost (either real or perceived) in providing honest answers, we developed a questionnaire that started with general questions about land under cultivation, crop harvests, education level, household members, livestock and other material assets owned, and food items consumed within the last month. Only later in the interview were households asked to answer voluntarily questions about bushmeat use in the village, and household bushmeat consumption (see Response Variables, below). By avoiding questions specifically focused on hunting activity, interviewees were never asked about an illegal activity directly; moreover, availability of bushmeat in the village is public knowledge, as meat is generally openly available. Interviews were conducted with heads of the household, or, in rare cases when household heads were absent, with other permanent family members. There were no cases where interviewees chose to discontinue the interview when asked about bushmeat even though withdrawal was always an option; we did not ask where bushmeat came from.

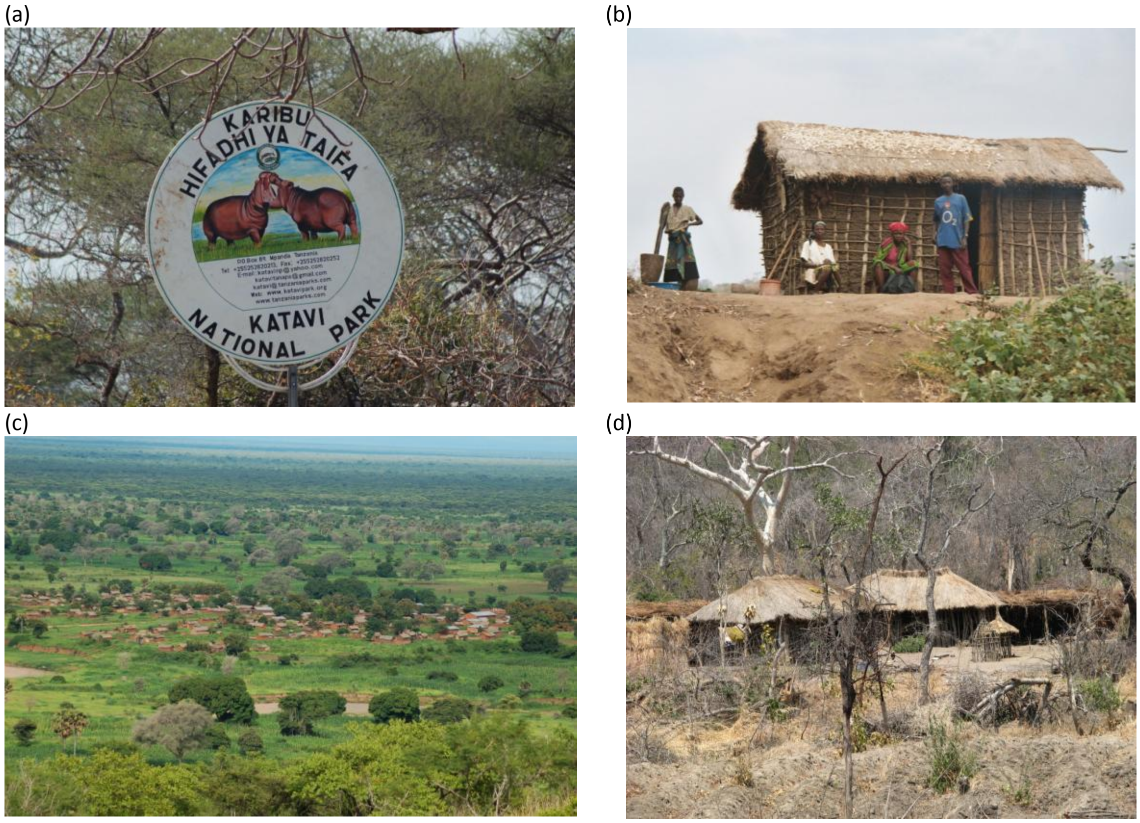

Fig. 2. (a) Entrance sign to Katavi National Park from Mpimbwe Division; (b) A Pimbwe household; (c) Mirumba village, the most westerly of the 11 villages sampled. Katavi National Park is the background; (d)) A Sukuma dwelling away from the village center. Photo credits: (a) and (c) Tim Caro; (b) and (d) Monique Borgerhoff Mulder.

Response variables

We used two different response variables to identify the extent of bushmeat consumption in our study area: carcass availability in the village and household consumption. To identify carcass availability we simply asked our interviewee to estimate how many wild animals were brought into each village per year (a long time frame designed to obtain annual rather than dry season offtake and also designed to anonymize any recent poaching activities). Bushmeat, in the form of an animal carcass, arrives at a village infrequently, but word spreads very rapidly through this close knit society and soon most people know meat is available whether they hunt or not. The time frame is appropriate given the number of carcasses entering a village per annum. As Tanzanians, and/or long term researchers in African villages, we are convinced this non-invasive means of gauging bushmeat prevalence at the village level, designed to obtain what is effectively public knowledge, exceeds the value of asking whether or not the interviewee hunts, even though we recognize that some error must emerge from this long time interval. Our second question, to identify consumption, was more direct: "How many times did you eat bushmeat during the last month," a shorter period designed to maximize recall. Since the response to the bushmeat consumption had a highly skewed distribution, we only looked at whether or not bushmeat had been consumed (*yes* or *no*).

Explanatory variables

Candidate explanatory variables consisted of (a) household size (b) education (primary or secondary with none as the reference group), (c) distance of village to the nearest protected area (a good indicator of access in this relatively open, roadless habitat) and (d) household wealth. Past research in Mpimbwe on food security, child growth and survival [e.g., 30, 38] reveals land (legally in public ownership but increasingly cultivated, inherited and sold by individuals), livestock and accumulation of material assets to constitute key dimensions of wealth differentiation. Accordingly we use four different wealth measures: area under cultivation (hectares), livestock ownership (tropical livestock units, TLU [one cow = 0.71 TLU, one sheep or goat = 0.17 TLU]), poultry ownership (chickens and ducks), and an index of assets owned (based on a principal components analysis of ten variables – tin -roofed house, hoe, radio, cell phone, wooden bed, beer drum, watch, plough and oxcart each of which was coded dichotomously as *yes* or *no*). In such assets indices, owning a particular asset increases the value of the index (scaled to a minimum of zero) by the amount determined by household's score on the first principal component [39].

Statistical analyses

For our first outcome variable (number of reported carcasses brought to the village per year), we fitted mixed effects models, defining 'village' as a random factor. Since the response variable consisted of over-dispersed counts, we used a negative binomial error structure, employing mixed models to accommodate our nested sampling design [40]. For our second dependent variable, our transformation of the very low frequency of reported bushmeat consumption into a binary response necessitated use of logistic regression. In a heterogeneous cultural context the drivers of bushmeat are likely to vary [9], so we used a multiple village design and a mixed effect modeling approach to explore measured and unmeasured village level effects on bushmeat availability and consumption. Because respondents from one village reported no consumption of bushmeat, a mixed model approach could not be applied to the logistic regression, and accordingly unmeasured village level effects were not controlled for. Models were fitted in the statistical package *R 2.10.0* [41] using the standard 'glm' function (for logistic regression) and the 'gamlssNB' function of the 'gamlss.mx' package for the mixed effects model [42].

Model selection

We first tested for co-linearity among the different measures of wealth. In the indigenous sample the four different measures of wealth were significantly ($p < .001$) correlated with each other; however, correlation coefficients were < .5 and we therefore tested all four measures of wealth independently. For the Sukuma sample, the four measures of wealth were strongly ($r > .6$) and significantly ($p < .001$) correlated with livestock ownership. We thus only used livestock ownership as a measure of wealth. Prior to analyses, we log+1 transformed variables to meet assumptions of normality. We then built a set of candidate models (including intercept only models and models including all variables) and used the sample size corrected Akaike's information criterion (AICc) and corresponding AICc weights to select the most parsimonious model(s). Given that the several models received similar model selection support, we used model averaging to estimate coefficients for the explanatory models [43].

Results

Patterns of bushmeat extraction and consumption

Respondents reported that hunters principally used guns (56.3% of 167 respondents who answered), and less commonly dogs and spears (36.5%), rather than snares as is common around Serengeti, for example. Hunters were reported as being principally active in protected areas (KNP: 31.9% of 263 respondents who answered, and RGR: 16.3%) but also around villages (24.7%). With respect to preferred animal source protein, respondents reported goat meat (34.7% of 435 respondents who answered) and beef (24.4%) but also mentioned buffalo *Syncerus caffer* (11.3%). There was no significant difference in preferred animal source proteins with respect to ethnicity (X^2 = 17.96, df = 12, p = .12). Bushmeat was principally used for both food and for generating income locally by the hunters (71.2% of 267 respondents who answered).

Factors affecting reported number of carcasses

On average, the number of wildlife carcasses reportedly available in the village was significantly higher in the indigenous subsample than in the Sukuma subsample (Wilcoxon rank sum test: W = 25778, p = .03).

For the indigenous sample, six models were similarly supported by the data, whereas the model with highest support contained only "Distance to nearest protected area" as explanatory variable (Appendix 1A). Models with similar support (ΔAICc < 2) always included “Distance to nearest protected area” and additionally either "Area under cultivation", "Assets rank", "Tropical livestock units (TLU)", or "Household size", or "Number of poultry owned". The model averaged estimates of the coefficients for these variables are (± SE): Intercept 2.05 (± 0.66) - 0.14 (± 0.06) Distance to nearest protected area + 0.03 (± 0.04) log (Area under cultivation+1) – 0.03 (± 0.02) Assets rank + 0.02 (± 0.04) log (TLU+1) + 0.01 (± 0.01) Household size – 0.01 (± 0.03) log (Number of poultry+1). The model averaged standard deviation of the mixing distribution was 2.16. Thus larger households (small effect size), and households with more land under cultivation (large standard error associated with estimate) and more livestock (large standard error associated with estimate) reported a greater number of carcasses brought to the village, whereas households in villages distant from a protected area (large effect size) and households with a high asset score (relatively small effect size) or owning larger numbers of poultry (large standard error associated with estimate) reported fewer wildlife carcasses.

In the Sukuma sample, the two most supported models contained "Household size" and "Distance to nearest protected area" (Appendix 1B). The averaged coefficient estimates were: Intercept 1.89 (± 0.47) – 0.07 (± 0.03) Distance to nearest protected area – 0.07 (± 0.03) Household size. The model averaged standard deviation of the mixing distribution was 2.38. Again, in the Sukuma sample, households distant from protected areas reported fewer carcasses but in contrast to the indigenous sample, household size was negative. Relationships between number of reported carcasses and distance to protected area and reported number of carcasses and household size were similar in strength.

Factors affecting bushmeat consumption

Likelihood of bushmeat consumption did not differ significantly between the indigenous and the Sukuma sample (Logistic regression, Sukuma vs indigenous: z = -1.41, df = 433, p = .16) in contrast to what we found for reported carcasses entering villages.

For the indigenous sample, several models had similar (ΔAICc < 2) support for explaining the likelihood of bushmeat consumption (Appendix 2A). The model averaged coefficients of these variables are: Intercept -2.24 (± 0.57) + 0.19 (± 0.12) log (Area under cultivation+1) + 0.25 (± 0.13) log (TLU+1) - 0.05 (± 0.04) Assets rank – 0.01 (± 0.01) Distance to nearest protected area + 0.29 (± 0.15) log (Number of poultry+1). Thus households with more land under cultivation (large effect size), more livestock (large effect size) and more poultry (large effect size) were more likely to report consuming bushmeat, whereas ownership of material assets (small effect size) and living farther away from protected areas (small effect size) were associated with reduced consumption. For the Sukuma sample, the likelihood of bushmeat consumption was best explained by the intercept only model (Appendix 2B).

Discussion

The principal species hunted in Mpimbwe were impala (*Aepyceros melampus*), common duiker (*Sylvicapra grimmia*), warthog (*Phacocherus africanus*), buffalo (*Syncerus caffer*) and bushbuck (*Tragelaphus scriptus*) [44]. Our first main finding concerns bushmeat activity in relation to distance from the protected area boundaries. Unsurprisingly, we find that households nearer to protected area borders report more carcasses entering their villages regardless of ethnicity, although other factors for which we have no information are also responsible for inter-village variation, as seen from the relatively high standard deviations of the mixing distributions. With respect to bushmeat consumption, the same pattern is seen for the indigenous sample (but not for the Sukuma sample), insofar as greater use of bushmeat was reported in villages close to protected area boundaries. Similar findings regarding greater bushmeat consumption in villages close to protected areas have been made on other parts of the continent [e.g., 45], and point to the need for anti-poaching and outreach activities being focused on villages close to protected area boundaries.

Our second general finding relates to the role of various forms of wealth on perception of carcass availability and bushmeat consumption. In short, we did not support our hypothesis that poorer households would rely more heavily on bushmeat, but instead found an interesting ethnic effect. Among the indigenous sample, larger households, and households with more land under cultivation and more livestock reported greater carcass availability, and households with more land under cultivation, more livestock and more poultry reported greater bushmeat consumption. This may provide evidence that Pimbwe, Fipa and other indigenous populations of the Rukwa valley use their traditional sources of wealth to generate cash to purchase and consume bushmeat. The fact that assets holdings among the indigenous sample were negatively associated with perceptions about carcass availability and bushmeat consumption requires further explanation. Recall that assets include watches, mobile telephones, radios, tin roofs and pieces of non-traditional furniture (wooden beds), as well as items of capital value such as oxcarts, ploughs and beer drums. The asset-holding scale therefore differentiates households according to their “modern," development-oriented, or pro-economic diversification stance. Conceivably such households may be less interested in bushmeat because they are more modernized. We are nevertheless wary of this interpretation because education level of household head, a likely indicator of less traditional leanings, did not enter into the best models. Rather, we speculate that among traditionally wealthy households bushmeat and external goods may be substitutes for each other.

The situation among Sukuma households is quite different. Whereas larger indigenous households reported more carcasses entering villages, larger Sukuma households reported fewer carcasses. Because Sukuma household size is strongly correlated with land, livestock and poultry wealth, this suggests that the wealthy Sukuma households are generally less aware of carcasses in the village and possibly less engaged in bushmeat consumption, quite contrary to the findings for the indigenous sample.

In other studies, the association between measures of wealth and involvement with bushmeat is similarly conflicting: some studies report positive associations [e.g., 23], some report no association [e.g., 13] and others report urban-rural-dependent associations [e.g., 19]. In Mpimbwe, bushmeat is a third of the price of domestic meat [10], and therefore land-poor households would be expected to avail themselves of this cheaper animal source protein. Yet this is not the case. Poorer indigenous households eat only maize meal or cassava, supplementing this with vegetables such as domestically or wild harvested greens, or beans, and much more rarely meat, fish or eggs [30]. While bushmeat is a cheaper option than domestic meat, it is still largely a luxury. In short, it is the wealthier indigenous householders who are supplementing their vegetable diet with the cheapest available animal protein, bushmeat, a pattern previously only seen in urban environments. Among the Sukuma, however, this pattern is not observed; among these immigrants both perception of carcass availability and possibly bushmeat consumption are greater among the smaller and less wealthy households. If this is a general result throughout the country, Tanzanian rural indigenous communities that experience economic growth may be having a negative impact on the nation's wildlife, an effect potentially exacerbated by the arrival of Sukuma immigrant families.

There are other interesting aspects of our findings that relate to protein availability, ethnicity, education, and multilevel analyses. Bushmeat consumption for the Pimbwe and Fipa appears to be a luxury for households already relatively rich in livestock and poultry protein, although this is not the case for the Sukuma. This suggests that supplementing protein intake may not be an effective intervention for lowering reliance on bushmeat within indigenous communities, unless the price can be brought below that of bushmeat. Our results for the Sukuma, however, are comparable to those of Loibooki and colleagues [5], who showed that livestock rich households around Serengeti are significantly less involved in illegal hunting than livestock poor households.

With regard to ethnicity, it is noteworthy that, in contrast to a number of other studies, we did not find support for the hypothesis that ethnicity affects bushmeat consumption (although it did affect perceptions of carcasses entering the villages, probably because indigenous households tend to form the core of the village, and hence the commercial hub where bushmeat is typically sold). Rather more interestingly, the precipitating factors for bushmeat consumption differ markedly between groups. Within Tanzania, these results can be compared with only one other study where ethnic differences in hunting preferences were explored: around Serengeti, ethnic groups differed in the reported size of animals killed, and the reasons for killing them [9]. Both studies indicate that a single ethnic group study of bushmeat consumption is inadequate to provide a full picture of the drivers of bushmeat offtake.

We found no evidence that level of schooling affects either the perception of bushmeat availability or its consumption. Education was measured only for the household head, suggesting that at least in the past primary and secondary school curricula provided little material to influence bushmeat consumption. The effects of primary and secondary school education, and park visits, on the present cohort of school children are current topics of investigation [46].

Finally we emphasize the need for studies of bushmeat drivers, particularly in ethnically and economically heterogeneous contexts, to use mixed effects model designs so that village-specific dynamics can be accounted for and made available for implementation activities. While we recognize that the large geographic spread required for such studies necessarily reduces the amount of time that can be spent with interviewees, we suspect (and have to some extent shown) that these behaviours are likely to be strongly spatially and ethnically structured.

Questions inevitably arise regarding the reliability of reported behaviour. First, an undetermined amount of underreporting may have occurred because bushmeat consumption is illegal. Subsequent interviews with hunters (not reported here) suggest this may have been the case (AM unpublished data) but it is unlikely to affect the relative contributions of causal drivers of consumption. Second, there is the false consensus effect, in this case the possibility that those who hunt overestimate the prevalence of hunting in the village, and those who do not hunt underestimate prevalence [47, 48]. Such effects may well bias overall estimates of offtake – downwards, for example if only a few individuals hunt heavily, upwards if the majority hunt even sparsely – but it should not affect analyses of variability within and between villages. Third, women were typically not interviewed unless there was no adult male household member available; it is possible that estimates would have been higher (women cook) or lower (women generally interact less with outsiders) if women been systematically surveyed. Fourth, responses could have been anonymized through randomized response techniques (RRT) [47, 48], but in our view the complexities of this approach would have exacerbated the potential sensitivity of questions regarding the eating of bushmeat, the illegality of which is not uniformly recognized by all villagers. Finally, an independent measure of illegal hunting activity per village based on focused interviews *with hunters* in the same village (AM, unpublished data) was correlated with the measure of number of carcasses reported here, (*Kendall's tau* = 0.50, *p* = .04) but not with bushmeat consumption (*Kendall's tau* = 0.38, *p* = .12). This suggests that the indirect question (number of carcasses) is a more reliable indicator of village bushmeat activity than the direct question regarding household consumption (which measures household-specific preferences).

Implications for conservation

Our study extends understanding of bushmeat consumption to a rapidly growing area of western Tanzania [29] known for its considerable wildlife offtake from protected areas [44]. We conclude that bushmeat activities are higher nearer to protected areas; that, contrary to our predictions, bushmeat consumption was less common in poorer indigenous households, challenging the idea that increasing the availability of alternative protein would necessarily reduce consumption of bushmeat unless its price became lower than that of bushmeat. We recommend that outreach programs designed to reduce bushmeat offtake in Mpimbwe be targeted at both hunters near the boundaries of protected areas and consumers located throughout the Division; that land-rich households should be a particular focus of attention; and that protein supplementation be given cautious consideration in solving the problem of bushmeat offtake.

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Appendix 1. Sample size corrected Akaike's information criterion (AICc), difference in AICc scores (Δ AICc) and AICc weights for candidate mixed effects models (with village ID as blocking variable) explaining the number of carcasses reported by A) indigenous and B) Sukuma respondents in Mpimbwe For analyses, area under cultivation, tropical livestock units and number of poultry owned were log (1+x) transformed to meet assumptions of normality.

A. Indigenous sample	AICc	Δ AICc	AICc weights
Distance to nearest protected area	1193.39	0.00	0.27
Distance to nearest protected area+Assets rank	1194.29	0.90	0.17
Distance to nearest protected area+Area under cultivation	1195.12	1.73	0.12
Household size+Distance to nearest protected area	1195.16	1.77	0.11
TROPICAL LIVESTOCK UNITS+Distance to nearest protected area	1195.25	1.86	0.11
Number of poultry owned+Distance to nearest protected area	1195.27	1.88	0.11
Education level+Distance to nearest protected area	1196.77	3.37	0.05
Intercept	1200.80	7.41	0.01
Assets rank	1201.20	7.81	0.01
Area under cultivation	1201.26	7.87	0.01
Household size+Education level+TROPICAL LIVESTOCK UNITS+Distance to nearest protected area+Assets rank+Area under cultivation+Number of poultry owned	1201.32	7.93	0.01
Assets rank+Area under cultivation	1202.12	8.73	0.00
TROPICAL LIVESTOCK UNITS	1202.19	8.79	0.00
Number of poultry owned+Area under cultivation	1202.75	9.36	0.00
Number of poultry owned	1202.83	9.44	0.00
Household size	1202.83	9.44	0.00
TROPICAL LIVESTOCK UNITS+Assets rank	1202.94	9.55	0.00
Number of poultry owned+Assets rank	1202.99	9.60	0.00
Household size+Assets rank	1203.20	9.81	0.00
Household size+Area under cultivation	1203.24	9.85	0.00
TROPICAL LIVESTOCK UNITS+Area under cultivation	1203.25	9.86	0.00
Education level	1203.49	10.10	0.00
Education level+Assets rank	1203.94	10.55	0.00
Number of poultry owned+TROPICAL LIVESTOCK UNITS	1204.06	10.67	0.00
Household size+TROPICAL LIVESTOCK UNITS	1204.23	10.84	0.00
Education level+Area under cultivation	1204.54	11.15	0.00
Number of poultry owned+Household size	1204.88	11.49	0.00
Education level+TROPICAL LIVESTOCK UNITS	1205.00	11.61	0.00
Number of poultry owned+Education level	1205.56	12.17	0.00
Household size+Education level	1205.59	12.20	0.00

B. Sukuma sample	AICc	Δ AICc	AICc weights
Household size	723.54	0.00	0.29
Household size+Distance to nearest protected Area	724.19	0.66	0.21
Household size+TROPICAL LIVESTOCK UNITS	725.59	2.05	0.10
Distance to nearest protected area	725.91	2.37	0.09
Household size+Education level	726.64	3.10	0.06
Intercept	726.83	3.29	0.06

Household size+Education level+Distance to nearest protected area	727.40	3.87	0.04
TROPICAL LIVESTOCK UNITS+Distance to nearest protected area	727.52	3.98	0.04
TROPICAL LIVESTOCK UNITS	728.11	4.57	0.03
Household size+Education level+TROPICAL LIVESTOCK UNITS	728.71	5.17	0.02
Education level+Distance to nearest protected Area	728.91	5.37	0.02
Household size+Education level+TROPICAL LIVESTOCK UNITS+Distance to nearest protected area	729.56	6.03	0.01
Education level	729.88	6.35	0.01
Education level+TROPICAL LIVESTOCK UNITS+Distance to nearest protected area	730.63	7.09	0.01
Education level+TROPICAL LIVESTOCK UNITS	731.13	7.59	0.01

Appendix 2. Sample size corrected Akaike's information criterion (AICc), difference in AICc scores (Δ AICc) and AICc weights for candidate logistic regression models explaining the likelihood of bushmeat consumption by (A) indigenous and (B) Sukuma respondents in Mpimbwe (see Appendix 1)

A. Indigenous sample	AICc	Δ AICc	AICc weights
Number of poultry owned+TROPICAL LIVESTOCK UNITS	172.81	0.00	0.09
Number of poultry owned	173.01	0.20	0.08
TROPICAL LIVESTOCK UNITS	173.29	0.48	0.07
Number of poultry owned+Area under cultivation	173.58	0.77	0.06
Area under cultivation	173.66	0.85	0.06
Number of poultry owned+Distance to nearest protected area	173.75	0.94	0.06
TROPICAL LIVESTOCK UNITS+Assets rank	173.75	0.94	0.06
Number of poultry owned+Assets rank	173.79	0.98	0.06
TROPICAL LIVESTOCK UNITS+Area under cultivation	173.79	0.98	0.06
Assets rank+Area under cultivation	174.00	1.19	0.05
TROPICAL LIVESTOCK UNITS+Distance to nearest protected area	174.39	1.58	0.04
Distance to nearest protected area+Area under cultivation	174.43	1.62	0.04
Assets rank	174.66	1.85	0.04
Number of poultry owned+Household size	175.03	2.22	0.03
Household size+TROPICAL LIVESTOCK UNITS	175.30	2.49	0.03
Distance to nearest protected area+Assets rank	175.36	2.55	0.03
Household size+Area under cultivation	175.64	2.83	0.02
Intercept	176.16	3.35	0.02
Household size+Assets rank	176.55	3.74	0.01
Education level+TROPICAL LIVESTOCK UNITS	176.57	3.76	0.01
Number of poultry owned+Education level	176.60	3.79	0.01
Distance to nearest protected area	176.77	3.96	0.01
Education level+Area under cultivation	177.02	4.21	0.01
Household size	177.54	4.73	0.01
Household size+Distance to nearest protected area	178.00	5.19	0.01
Education level+Assets rank	178.27	5.46	0.01
Education level	179.36	6.55	0.00
Education level+Distance to nearest protected area	179.97	7.16	0.00
Household size+Education level	180.74	7.93	0.00
Household size+Education level+TROPICAL LIVESTOCK UNITS+Distance to nearest protected area+Assets rank+Area under cultivation+Number of poultry owned	182.82	10.01	0.00

B. Sukuma sample	AICc	Δ AICc	AICc weights
Intercept	101.99	0.00	0.25
Distance to nearest protected area	103.01	1.02	0.15
Household size	103.42	1.43	0.12
TROPICAL LIVESTOCK UNITS	103.63	1.64	0.11
Household size+Distance to nearest protected area	104.07	2.08	0.09
TROPICAL LIVESTOCK UNITS+Distance to nearest protected area	104.18	2.19	0.09
Household size+TROPICAL LIVESTOCK UNITS	105.37	3.38	0.05
Education level	105.78	3.79	0.04
Education level+Distance to nearest protected area	106.89	4.90	0.02

Household size+Education level	107.24	5.25	0.02
Education level+TROPICAL LIVESTOCK UNITS	107.38	5.39	0.02
Household size+Education level+Distance to nearest protected area	107.99	6.00	0.01
Education level+TROPICAL LIVESTOCK UNITS+Distance to nearest protected area	108.05	6.06	0.01
Household size+Education level+TROPICAL LIVESTOCK UNITS	109.19	7.20	0.01
Household size+Education level+TROPICAL LIVESTOCK UNITS+Distance to nearest protected area	109.76	7.77	0.01