Research Article

Bushmeat Consumption in the Tarangire-Manyara Ecosystem, Tanzania

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Abstract

Illegal hunting, driven by demand for bushmeat, threatens animal populations throughout Africa. While bushmeat consumption is thought to be common in the Tarangire-Manyara ecosystem (TME) of Northern Tanzania, its magnitude and drivers are not well understood. This lack of knowledge may inhibit effective mitigation policies. We conducted 394 household interviews in the TME in 2013 and 2014 to assess both the scale and the possible drivers of bushmeat availability and consumption in the ecosystem. Using generalized linear mixed models, information theoretic model selection, and accounting for spatial clustering of the interviews, we tested multiple hypotheses that underlie bushmeat consumption. Bushmeat consumption in the TME was found to be widespread among the local population. Surprisingly, we found little differences in reported bushmeat consumption between survey years (2013: 38%; 2014: 33% of interviewees). Pastoral Maasai admitted to consuming bushmeat significantly less often (2013: 29%; 2014: 26%) than non-Maasai (2013: 38%; 2014: 34%). Interestingly, none of the hypothesized spatial- or household-level factors consistently correlated with reported bushmeat consumption. Neither alternative sources of available animal protein, nor relative wealth affected bushmeat consumption. In conjunction with the relatively low price of bushmeat (half the price of domestic meat), these results suggest that bushmeat consumption is largely driven by its availability and low cost, and only to a small degree by cultural differences. Thus, conservation interventions will likely be most successful if they holistically manage to increase the cost of bushmeat relative to alternative protein sources.

Keywords: bushmeat, ecosystem services, law enforcement

Résumé

La chasse illégale de gibier induit par la demande de viande de brousse menace les populations d'animaux sauvages à travers toute l'Afrique. Si la consommation de viande de brousse est admise comme un usage courant dans l'écosystème de Tarangire-Manyara (TME), son importance et ses mobiles ne sont pas bien compris. En 2013 et 2014, nous avons conduit 394 interviews dans des ménages du TME, dans le but d'évaluer aussi bien l'étendue que de possibles explications concernant la disponibilité et la consommation de viande de brousse dans cet écosystème. En utilisant des modèles linéaires mixtes généralisés avec une sélection de modèles basée sur la théorie de l'information et prenant en compte le regroupement géographique pour l'échantillonnage, nous avons testé plusieurs hypothèses pour expliquer la consommation de viande de brousse. La consommation de viande de brousse était répandue parmi la population locale. A notre surprise, nous n'avons trouvé que peu de différences dans les consommations rapportées au cours des années étudiées (2013 : 38% ; 2014 : 33%). Des Massaïs éleveurs, de manière significative, ont moins admis de consommer de la viande de brousse (2013 : 29% ; 2014 : 26%) comparés à des non-Massaï (2013 : 38% ; 2014 : 34%). Aucune des variables hypothétiques au niveau géographique ou des ménages n'était liée de manière cohérente à la consommation rapportée de viande de brousse. Ni des sources alternatives de protéines animales disponibles, ni la richesse relative des ménages n'influait sur la consommation de viande de brousse. Dans le contexte d'un prix relativement bas de la viande de brousse, ces résultats suggèrent que la consommation de viande de brousse est largement déterminée par sa disponibilité et son bas prix et seulement dans une faible mesure par des différences culturelles. En conséquence, des interventions visant à renforcer la préservation des animaux sauvages auront le plus de chances de succès si elles réussissent globalement à faire augmenter le prix de la viande de brousse par rapport à des sources alternatives de protéines.

Mots clés : la viande de brousse, les services écosystémiques, application de la loi

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Introduction

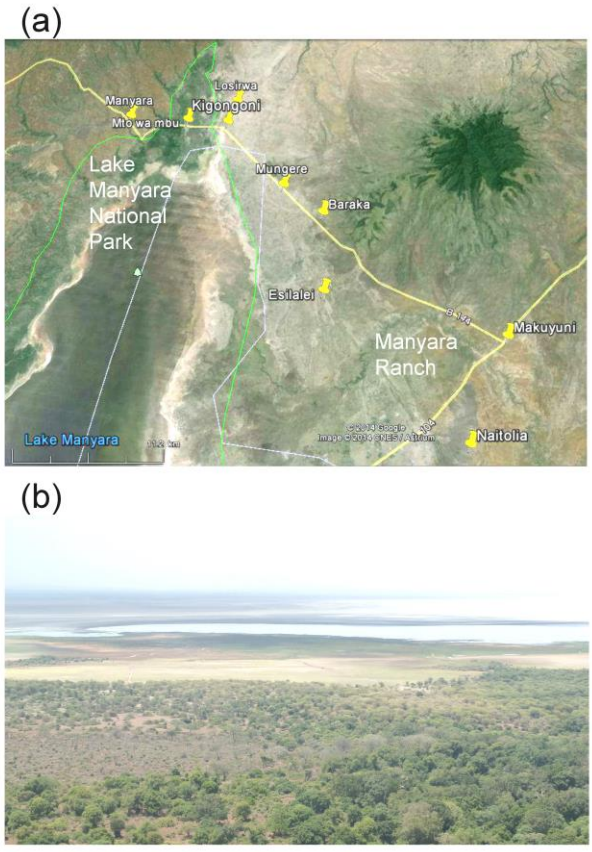
The consumption of meat from wild animals, known as bushmeat, is a common practice in many parts of Africa and presents a major threat to the conservation of wildlife [1]. Bushmeat consumption appears to be particularly prevalent in poorer areas where people rely on it as a primary and inexpensive source of protein in their diets [2-4]. However, bushmeat and animal products are also frequently consumed by wealthy people and are considered to be symbols of status in certain communities [5]. Bushmeat is associated with considerable risks of acquiring zoonotic pathogens which may cause severe symptoms in humans [6-8]. Ecologically, bushmeat hunting is rarely sustainable. In many countries throughout Africa, populations of large mammals have been dramatically reduced by unsustainable hunting [9-12], and subsequently, important ecosystem services, such as seed dispersal, have been impaired [13,14].

Illegal hunting for bushmeat has been of particular interest in the rainforests of Western and Central Africa [15-22]; however, this practice is increasingly being documented in Southern [23, 24] and Eastern Africa as well [1, 25]. In East Africa, animals are often poached within or adjacent to protected areas [26-28], with migratory and relatively large species representing the majority of animals hunted [29-31]. In Tanzania, socio-economic and ecological aspects of illegal hunting have largely been focused on the Serengeti [25, 29, 32-36] and Katavi ecosystems [30, 31, 37, 38], and areas around the Udzungwa mountains [39-42]. However, a recent survey on bushmeat consumption suggested that bushmeat consumption is not limited to these selected areas, but indeed frequently occurs in multiple ecoregions of Tanzania [43].

The likelihood of consuming bushmeat has been hypothesized to be linked to multiple factors, including socio-economic status, availability of alternative sources of protein, ethnicity, and availability of bushmeat. Empirical evidence suggests that bushmeat consumption varies considerably among Tanzanian ecoregions and ethnicities [38, 43]. Moreover, socio-economic variables appeared to affect bushmeat consumption differently within distinct ethnicities inhabiting the same ecoregion [38]. For instance, studies in Western Tanzania found wealth to be positively associated with bushmeat consumption for indigenous people, but negatively associated with wealth for immigrant agro-pastoralists [38].

In order to assess the prevalence and drivers of bushmeat consumption in the Tarangire-Manyara ecosystem (TME), we estimated the prevalence of bushmeat consumption and associated correlates at the household level. Because Maasai people are generally considered not to consume bushmeat [43],

and have different lifestyles (predominantly pastoralists) and values from most other dominant ethnicities in the region, we assessed correlates for bushmeat consumption separately for Maasai and non-Maasai [38]. From the findings of previous studies [38, 43], we hypothesized that bushmeat consumption would be less prevalent among Maasai people, increase with the availability of bushmeat, decrease with the availability of alternative protein sources, and be higher in both poorer- and larger households. Beyond exploring ethnic-specific patterns and correlates of bushmeat consumption, we also assessed the effectiveness of top-down law enforcement. Responding to high levels of poaching (primarily elephant poaching), the Tanzanian government launched "Operation Tokomeza", a joint-forces, nation-wide law-enforcement operation to curb illegal wildlife utilization in late 2013 [44]. By conducting household interviews before and after these increased law-enforcement activities, we were able to assess the effect of elevated law-enforcement on bushmeat consumption.



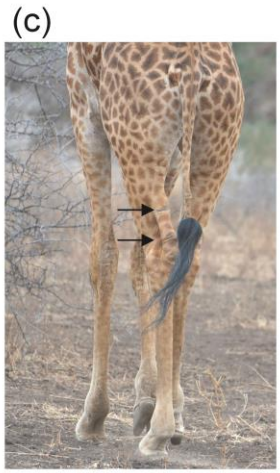


Fig. 1. (a) Location of the villages in the study area; household surveys were also conducted in several subvillages of Mto wa mbu. Manyara Ranch is a 182 km² protected area in between Lake Manyara National Park and Tarangire National Park (south of Naitolia, not on map). (b) View from the escarpment over Lake Manyara. (c) A giraffe (*Giraffa camelopardalis*) on Manyara Ranch that has survived an attack by a poacher (arrows indicate scars on left rear leg). Poachers often approach giraffes at night and try to cut their tendons with a machete. (d) Zebra (*Equus quagga*) skull in Esilalei. Zebras are one of the most frequently hunted species for bushmeat in the ecosystem [28].

Methods

Study Area

This study was conducted in the Tarangire-Manyara ecosystem (TME) of Northern Tanzania, stretching from the lower section of the Ngorongoro highlands on top of the rift valley escarpment (Karatu district) to the Manyara plains around Mto wa Mbu and adjacent Maasai land (Babati district). Several protected areas are situated within the study area: Lake Manyara National Park (LMNP), Mto wa Mbu game controlled area (CA), Manyara Ranch (MR) and Tarangire National Park (TNP) (Fig. 1). TME is rich in wildlife density and species diversity, and is famous for the migration of large herbivores, in particular wildebeest (*Connochaetes taurinus*) and zebra (*Equus quagga*) [45, 46]. Migration and wet season

dispersal bring wildlife outside of fully protected areas, particularly to MR and the CA. The proximity of human settlements to protected areas and to wildlife corridors, coupled with infrequent law enforcement in partially protected areas, make wildlife susceptible to illegal hunting in this area [28, 47]. The Maasai, known for their pastoralist lifestyles, represent the major ethnic group in the area, although many other ethnic groups are present as well. In particular, the town of Mto wa Mbu receives substantial immigration from different Tanzanian ethnicities. Pastoralism, small-scale agriculture, and business are the most widely practiced livelihoods in the area [48].

Household interviews

Interviews were conducted in mid-end April, 2013 and 2014 in the (sub-) villages of: Jangwani (sub-village of Mto wa Mbu), Baraka, Magadini Juu (sub-village of Mto wa Mbu), Naitolia, Mungere, Makuyuni, Mnada wa Zamani (sub-village of Mto wa Mbu), Kigongoni, Losirwa, Esilalei (Monduli district), and Manyara (Karatu district) (Fig.1). In each of these villages, twenty to fifty households were chosen at random along pre-determined transects. People were asked if they would be willing to participate in an interview: participation was voluntary, anonymity was guaranteed, and individuals had the right to discontinue the interview at any time. We interviewed slightly more males than females (2013: f=75; m=110; 2014: f=87; m=122), however, the gender ratio was similar between years (f/m: 0.65 in 2013 and 0.71 in 2014). The structured interviews were translated into Swahili and were performed by one trained local research assistant and two students from the School For Field Studies (SFS). Each interview took between 20 and 60 minutes.

The interview protocol was reviewed and approved to meet the conditions for exemption from Institutional Review Board (IRB) review, under Type B, Category 2 of the U.S. federal code 45 Part 46 on human subjects protections in research (IRB: TZ-02-13-14). All research was carried out under TAWIRI-research permits 2012-241-NA-2012-57 to 2014-324-ER-2013-191. The interviewees were asked for general information on ethnicity, education level (no formal education, primary school, secondary school, and higher levels of education combined), number of household members, ownership of livestock, poultry and key assets, and approximate frequency of consumption of various food items during the past year. Among the food items, bushmeat was one option. Availability of bushmeat was assessed by asking participants how frequently they see bushmeat for sale. We also asked interviewees whether they had been involved in hunting activities in the previous year. Appendix 1 contains the complete questionnaire. The market prices of legal domestic- and illegal bushmeat meat were collected through interviews with poachers in 2013 (poachers were identified through informants). Prices for domestic meat were also confirmed by local consumers.

Data analysis

We tested how reported bushmeat availability during the past year was affected by distance to Kigongoni (a village reported to be a major marketplace for bushmeat) using a logistic regression. Previous studies have tested distance to protected areas as a possible correlate for bushmeat consumption, but this did not appear straightforward in our case because the dispersion of wild animals during the wet season, coupled with little law enforcement outside protected areas, makes illegal hunting more frequent in community areas than in protected areas [28]. Therefore, we hypothesized that bushmeat consumption may be related more to proximity of local bushmeat markets than to distance from protected areas. Distance to Kigongoni was measured from Global positioning system (GPS) waypoints displayed in Google Earth, with one measurement taken for each (sub-) village visited (Fig. 1). Village was entered as a random factor and binary coding was used for reported bushmeat availability during the past year (yes=1, no=0). The same analytical approach was used for the target

variable 'reported involvement in hunting'. As explanatory variables, we considered ethnicity and year and their interaction.

In order to gauge bushmeat consumption, we first generated descriptive data including percentage of the population consuming bushmeat. To test for differences in reported bushmeat consumption among years and ethnic groups we used a logistic regression, with village entered as a random factor and ethnicity and year as explanatory variables (considered as an interaction to account for independent effects of ethnicity and year).

A general linear mixed model with binomial error structure was used to analyze socio-economic and spatial variables that may affect bushmeat consumption. We tested whether admitted bushmeat consumption (1= reported consumption during the past year; 0=no reported consumption during past year; in line with Mgawe et al. [38]) were related to the following hypothesized variables: household size, ownership of either chickens (*Gallus gallus domesticus*), shoats (sheep *Ovis aries* and goats *Capra aegagrus hircus* combined), and/or cattle *Bos taurus* (all coded as either yes or no because interviewees were occasionally not able to state the exact number of livestock), education level (no formal education, primary school, secondary school), wealth (measured with an index), distance to Kigongoni. Wealth was assessed using an index based on ownership of certain key possessions, including bicycles, motorbikes, vehicles, radios and a television. The index scores were derived from the first component of a principal component analysis on the suite of assets [38]. The index is inversely scaled with low (high) values indicating households with many (few) assets. The (sub-) village in which data were collected was entered as a random effect in order to account for potential non-independence between households in the same village. For each year (2013 and 2014) and ethnicity (Maasai and other ethnicities) we fitted separate models to account for possible confounding effects of ethnicity and law enforcement [38]. For each ethnicity-year combination, we fitted all possible models and ranked the models according to the sample size corrected Akaike's information criterion (AICc) and corresponding model weights [49]. Since several models received similar model support, we averaged the parameter estimates from those models that were within 4 AICc scores from the model with the lowest AICc score using the natural average method [50].

In order to predict model outcomes, we estimated odds ratios (exponent of regression coefficient) for relevant explanatory variables. Odds ratios provide information on how the likelihood for the target variable changes if the explanatory variable changes by one unit. All data analyses were performed in *R* [51].

Results

Bushmeat availability

In total, we conducted 394 interviews over the two study years (2013: 185; 2014: 209). Bushmeat was reported to be available for purchase at some point during the last year by 48% of respondents in 2013 and by 41% of respondents in 2014. In 2013, reported bushmeat availability did not change with respondent's distance from Kigongoni (P = 0.541). However, in 2014, the likelihood of reported bushmeat availability declined marginally significantly (P = 0.091) by 0.941 for each km from Kigongoni. According to interviews with local poachers in 2013, bushmeat was sold for around TSH 3000 per kilogram (approximately US $ 2). In contrast, beef or goat meat was sold for around TSH 6000 (approximately US $ 4) per kilogram in local markets.

Involvement in hunting

Overall, involvement in illegal subsistence hunting activities was admitted by 10 % of respondents (Maasai: 16%; other ethnicities: 4%) in 2013 and by 2 % of the interviewees in 2014 (Maasai: 4%; other ethnicities: 2%). Most interviewees explained that such hunting was generally opportunistic killing of smaller species – such as Kirk's dik dik (*Madoqua kirkii*) – and utilized to augment household meals. Interviewees belonging to other ethnicities were significantly (P = 0.019) less likely to report being involved in hunting than Maasai (odds ratio: 0.25). Reported involvement in hunting did not differ between years (P = 0.286) and the interaction 'year x ethnicity' was also not statistically significant (P = 0.861).

Bushmeat Consumption

In 2013, 38% of the surveyed population admitted to bushmeat consumption compared to 33% of all interviewees in 2014. Overall, bushmeat consumption was less frequently admitted by Maasai compared to members of other ethnicities (Fig. 2). A logistic regression suggested that the likelihood of reporting bushmeat consumption during the past year was significantly higher (P = 0.035; odds ratio: 2.243) for members of other ethnicities compared to Maasai. Bushmeat consumption was not significantly different between 2013 and 2014 (P = 0.659) and the interaction between ethnicity and year was also not significant (P =0.374). Among those who admitted bushmeat consumption, the reported frequency of consumption was relatively evenly distributed (Fig. 3).

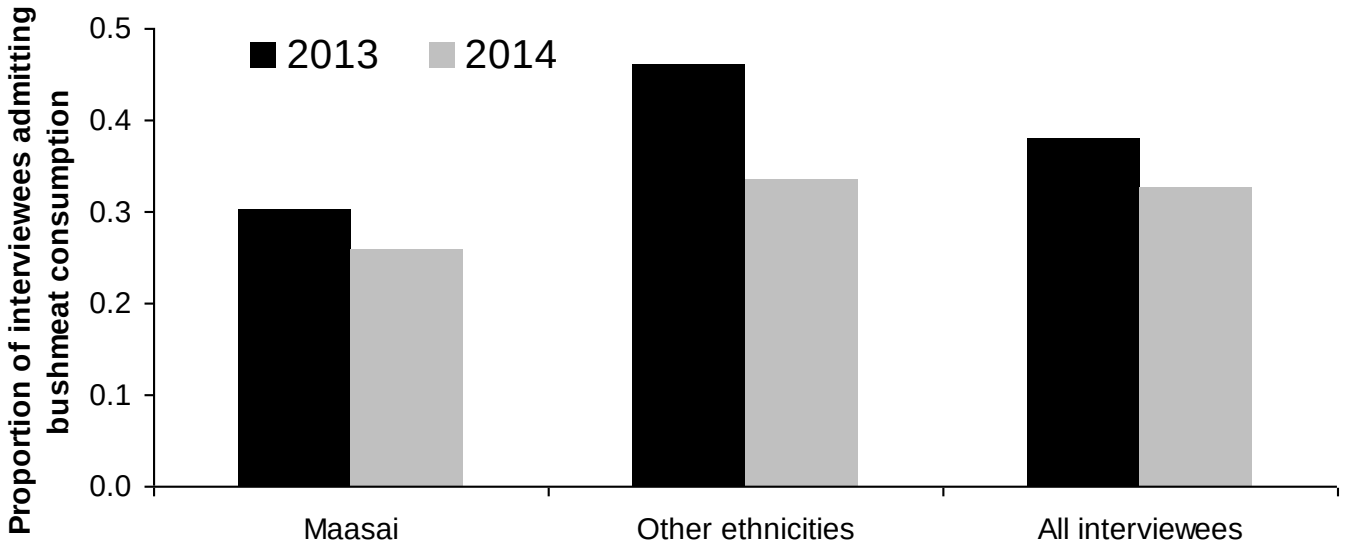


Fig. 2. Proportion of interviewed Maasai (sample size=123) and members of other ethnicities (sample size=271) admitting to eating bushmeat in 2013 and 2014 in the Tarangire-Manyara ecosystem, Tanzania.

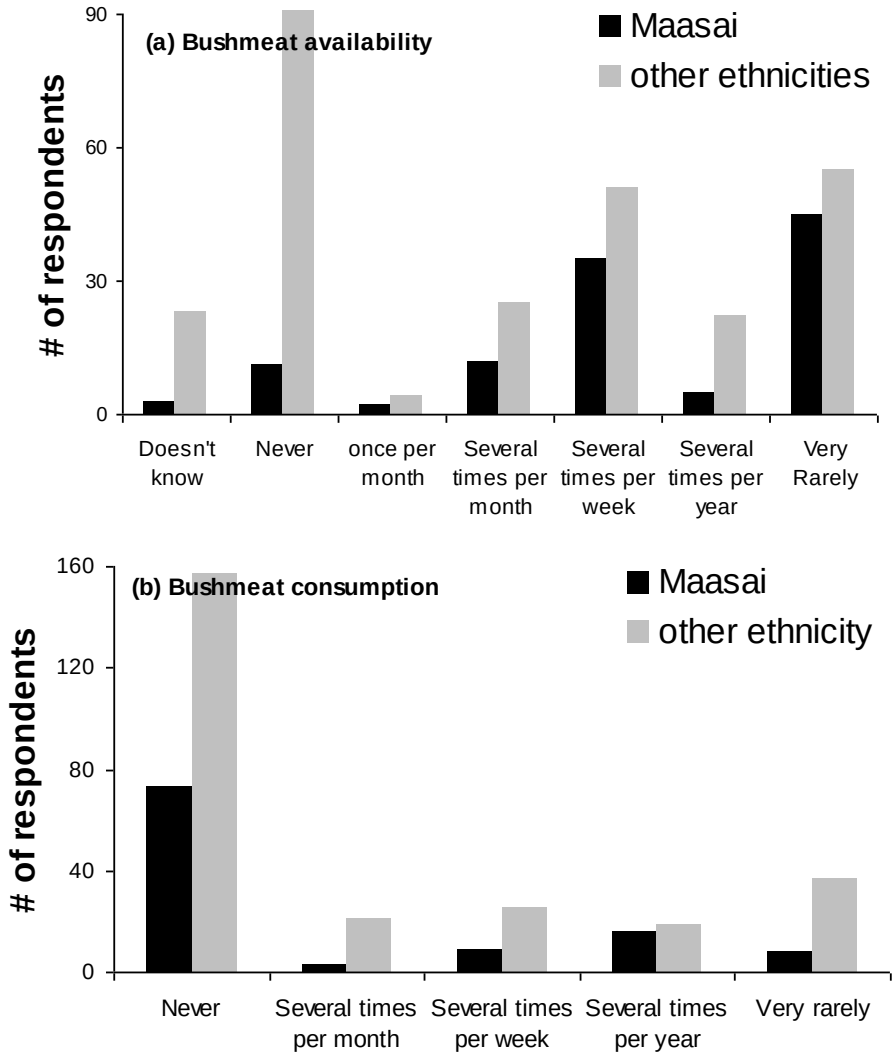


Fig. 3. Reported frequencies of (a) bushmeat availability and (b) bushmeat consumption among Maasai and other ethnicities in 2013 and 2014 in the Tarangire-Manyara ecosystem, Tanzania.

Correlates of bushmeat consumption – Maasai

In 2013, the likelihood of Maasai admitting to bushmeat consumption increased significantly, 1.1 times per additional km distance to the main bushmeat market of Kigongoni (Table 1). Maasai who owned chickens had a 3.7 times higher likelihood of self-reporting bushmeat consumption than Maasai who did not own poultry. Other variables (wealth index, household size, shoat and cattle ownership) were present among the top models but did not reach statistical significance. Education level was not present among the top models.

Table 1. Average model coefficient estimates (β), adjusted standard errors (SE), z- and P-values for variables explaining the likelihood of reported bushmeat consumption for interviewed Maasai in the Tarangire-Manyara ecosystem in 2013 and 2014. Estimates were averaged from the top (ΔAICc ≤ 4) generalized linear mixed models with binomial error structure and logit-link function. Wealth was assessed on an index based on ownership of key possessions. Statistically significant results (p ≤0.05) are bolded, while marginally significant results (0.10 ≥p>0.05) are italicized. For both years, the standard deviation of the random intercepts was 0.

	β	SE(β)	z-value	*P-value*	β	SE(β)	z-value	*P-value*
	2013				2014			
Intercept	**-2.366**	**1.079**	**2.193**	**0.028**	-2.601	3.437	0.757	0.449
Distance to Kigongoni	**0.105**	**0.049**	**2.159**	**0.031**	0.149	0.111	1.338	0.181
Wealth	0.023	0.209	0.108	0.914	*-0.967*	*0.562*	*1.722*	*0.085*
Chicken ownership	**1.316**	**0.589**	**2.235**	**0.025**	2.320	2.080	1.116	0.265
Shoat ownership	-0.675	0.798	0.846	0.398	-2.941	2.392	1.229	0.219
Cattle ownership	-0.034	1.419	0.024	0.981	4.448	3.259	1.365	0.172
Household size					0.087	0.068	1.271	0.204

In 2014, Maasai with more assets were marginally significantly more likely to self-report bushmeat consumption (odds ratio: 0.38 per index score). Other variables (distance to Kigongoni, chicken, shoat and cattle ownership, and household size) were present among the top models but did not produce a statistically significant signal (Table 1).

Correlates of bushmeat consumption – other ethnicities

In 2013, none of the variables hypothesized to correlate with bushmeat consumption were statistically significant (Table 2). In 2014, only household size was marginally significantly and negatively correlated with the likelihood of admitting bushmeat consumption. Per additional household member, the likelihood of self-reporting bushmeat consumption decreased by 0.88. Interestingly, we found substantial variation in bushmeat consumption depending on the village (indicated by the standard error of the random intercepts) in the model for other ethnicities but not in the models for Maasai (Tables 1, 2).

Table 2. Average model coefficient estimates (β), adjusted standard errors (SE), z- and P-values for variables explaining the likelihood of reported bushmeat consumption for interviewed non-Maasai in the Tarangire-Manyara ecosystem in 2013 and 2014. Estimates were averaged from the top (ΔAICc ≤ 4) generalized linear mixed models with binomial error structure and logit-link function. Wealth was assessed on an index based on ownership of key possessions. Statistically significant results ($p \leq 0.05$) are bolded, while marginally significant results ($0.10 \geq p > 0.05$) are italicized. The factors of the variable 'education' are relative to no formal education. The standard deviation of the random intercepts was 0.334 (2013) and 0.392 (2014).

	β	SE(β)	z-value	*P-value*	β	SE(β)	z-value	*P-value*
	2013				2014			
Intercept	-0.125	0.630	0.198	0.843	-0.043	0.572	0.076	0.940
Distance to Kigongoni	-0.033	0.034	0.982	0.326	-0.022	0.024	0.931	0.352
Wealth	0.117	0.185	0.633	0.526	-0.083	0.141	0.591	0.554
Chicken ownership	0.067	0.572	0.117	0.907	-0.501	0.340	1.474	0.141
Shoat ownership	0.722	0.648	1.114	0.265	-0.051	0.479	0.105	0.916
Cattle ownership	-0.354	0.745	0.475	0.635	-0.587	0.708	0.829	0.407
Household size	0.015	0.064	0.230	0.818	*-0.128*	*0.077*	*1.655*	*0.098*
Primary education	0.441	0.720	0.612	0.540	0.220	0.769	0.286	0.775
Secondary education	-0.034	0.836	0.040	0.968	0.373	0.807	0.463	0.644

Discussion

Our extensive household survey suggests that bushmeat consumption in the Tarangire-Manyara ecosystem is widespread among the local population. Surprisingly, we found little differences in reported bushmeat consumption between survey years and between Maasai and non-Maasai, and very few of the hypothesized factors correlated with reported bushmeat consumption.

Scale and patterns of bushmeat consumption

In both survey years, at least 41% and 33% of the interviewees reported that bushmeat was available and admitted to bushmeat consumption, respectively. Both availability and consumption were frequently reported to occur at high frequencies (Fig 3). Due to the illegal nature of bushmeat, these figures likely underestimate the actual magnitude of bushmeat availability and consumption [52, 53]. Clearly, more sophisticated, indirect social research techniques (e.g. randomized response technique, projective questioning, or the brief implicit association test) can be applied to gauge the actual scale of illegal bushmeat consumption (or hunting) in the ecosystem. However, by definition, these indirect methods do not allow associating attributes of interviewees with illegal activities [52, 53].

Surprisingly, Maasai frequently admitted to bushmeat consumption and even hunting. This is in stark contrast to Maasai in other parts of Northern Tanzania who had not reported consuming bushmeat at all [43]. We suspect that, due to the close co-existence of Maasai and other ethnicities in this part of Tanzania, Maasai are exposed to different lifestyles and habits (including bushmeat consumption) and partly give up their traditional behaviors.

Overall, this suggests that pastoralist ethnicities (such as Sukuma and Maasai), previously thought not to be involved in bushmeat activities, are now – at least in some areas of Tanzania - involved in bushmeat activities [38]. A small proportion of local people admitted to opportunistically hunting wild animals for their own consumption. However, most bushmeat is supplied by young men who hunt wildlife illegally and sell the meat at local markets. Most of these illegal hunters live in Kigongoni and Mto wa Mbu, where reported bushmeat availability was highly prevalent [28; unpublished data].

Correlates of bushmeat consumption

Unsurprisingly, a varied picture of variables influencing bushmeat consumption was revealed, with factors fluctuating substantially in magnitude and significance between years and ethnic groups. However, between Maasai and non-Maasai ethnicities, and between 2013 and 2014, household size, wealth, education level, cattle and shoat ownership had no significant impact on bushmeat consumption. The lack of correlation between livestock ownership and bushmeat consumption contrasts with other studies' finding, that livestock ownership reduces bushmeat consumption [36]. This suggests that bushmeat consumption in the studied area is not necessarily due to a lack of alternative protein sources. Similar to our study, livestock ownership among the people in the Pimbwe area of southwestern Tanzania was also not related to bushmeat consumption [38]. One reason for this unexpected result may be that many households sell livestock to augment other expenses and seldom slaughter livestock for their own meat consumption.

Similarly, while wealth and household size have been found to be significant factors affecting bushmeat consumption in Gabon [2], their non-significant or marginally significant correlation in this study suggests that bushmeat is not necessarily associated with relative wealth of households. Similar to other areas of Tanzania, the cost of bushmeat in our study area was half the cost of meat from domestic animals [36, 38]. This low price, relative to domestic meat, may be a key driver for the widespread bushmeat consumption among the local population in the ecosystem [31].

Factors influencing bushmeat consumption also varied between Maasai and non-Maasai groups. For Maasai, chicken ownership was a significant predictor of bushmeat consumption in 2013 (but not in 2014). Traditionally, the Maasai do not keep chickens or consume bushmeat. Ownership of chickens may thus indicate a departure from the traditional purely pastoralist lifestyle, which appears to go hand in hand with an increased likelihood of consuming bushmeat.

Strategies for reducing bushmeat hunting and consumption

The widespread occurrence of bushmeat consumption suggests that conservation interventions need to holistically address bushmeat hunting, trade, and consumption in this ecosystem. Demand for cheap bushmeat (despite a large potential supply of livestock) is a serious threat to wildlife conservation in the ecosystem, and elsewhere in Tanzania, and is often overlooked in the media and policy agendas. The law enforcement operation 'Tokomeza' was particularly geared towards fighting elephant poaching, but also targeted bushmeat poachers. The 6 % decrease in reported bushmeat consumption between 2013 and 2014 – though insignificant - may reflect a slight decrease in bushmeat use prompted by the law enforcement operation. However, we can not determine whether this decrease in reported bushmeat consumption was an actual decrease or whether it resulted from elevated fear and subsequent under-

reporting. While our results suggest that bushmeat consumption is prevalent among the human population in this ecosystem, with minimal differences among ethnicities, spatial, or household-level attributes, conservation interventions are urgently required – particularly given the high human population growth rate (3.2%) in the study area [54]. The surveyed households were located in important wildlife corridors and dispersal areas of the ecosystem that are crucial for the functional connectivity of the ecosystem [46, 55]. The extent of illegal hunting is substantially impacting the behavior, population size and community structure of wildlife in the ecosystem [28, 47].

So far, the main conservation strategy to curb bushmeat poaching in the ecosystem has focused on improving law enforcement in the core protected areas and multiple-use areas that connect the two national parks [28]. Clearly, improved anti-poaching activities could reduce bushmeat supply and thus increase the cost of bushmeat, which may eventually reduce bushmeat demand and consumption [36]. In addition to field-based law enforcement, we strongly suggest law enforcement in villages, particularly in Mto wa Mbu and Kigongoni, where the bushmeat is almost openly available. Previous research has shown that providing alternatives to bushmeat hunters/traders appears to be a more cost-effective approach to reducing bushmeat supply than increased law-enforcement [42]. So far, conservation agencies have not implemented this approach in our study area. We, therefore, strongly suggest supplementing increased law enforcement with a program that provides bushmeat hunters with alternative forms of income [36, 42], so that poaching will be perceived as (a) more risky and thus (b) be less profitable compared to actual alternatives. Importantly, such programs need to be cooperative ventures between local communities and conservation agencies [56].

Implications for conservation

Our survey extends knowledge of bushmeat consumption to a fast-growing area of Northern Tanzania that is important for many wildlife populations and for the tourism sector of Tanzania. We found bushmeat consumption in the Tarangire-Manyara ecosystem to be widespread, and to occur in all major ethnic groups. In line with research from other areas of Tanzania, we found that the demand for bushmeat is not closely related to household-level attributes, but is rather steered by the availability and relatively low price of bushmeat. We therefore suggest that conservation implementations should focus on reducing the supply of bushmeat, which would increase the price of bushmeat relative to other (readily available) protein sources.

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References

[1] Lindsey, P. A., Balme, G., Becker, M., Begg, C., Bento, C., Bocchino, C., Dickman, A., Diggle, R. W., Eves, H., Henschel, P., Lewis, D., Marnewick, K., Mattheus, J., McNutt, J. W., McRobb, R., Midlane, N., Milanzi, J., Morley, R., Murphree, M., Opyene, V., Phadima, J., Purchase, G., Rentsch, D., Roche, C., Shaw, J., van der Westhuizen, H., van Vliet, N. and Zisadza-Gandiwa, P. 2013. The bushmeat trade in African savannas: Impacts, drivers, and possible solutions. *Biological Conservation* 160:80-96.

[2] Foerster, S., Wilkie, D.S., Morelli, G.A., Demmer, J., Starkey, M., Telfer, P., Steil, M. and Lwebel, A. 2011. Correlates of bushmeat hunting among remote rural households in Gabon, Central Africa. *Conservation Biology* 26**:** 335-344**.**

[3] Golden, C. D., Fernald, L. C. H., Brashares, J. S., Rasolofoniaina and Kremen, C. 2011. Benefits of wildlife consumption to child nutrition in a biodiversity hotspot. *Proceedings of the National Academy of Sciences of the United States of America* 108:19653-19656.

[4] Brashares, J.S., Golden, C.D., Weinbaum, K.Z., Barrett, C.B. and Okello, G.V. 2011. Economic and geographic drivers of wildlife consumption in rural Africa. *Proceedings of the National Academy of Sciences of the United States of America* 108:13931–13936.

[5] Fa, J., Peres, C., and Meeuwig, J. 2002. Bushmeat Exploitation in Tropical Forests: an Intercontinental Comparison. *Conservation Biology* 16:232-237.

[6] Wolfe, N. D., Daszak, P., Kilpatrick, A. M. and Burke, D. S. 2005. Bushemat hunting, deforestation, and prediction of zoonotic disease emergence. *Emerging Infectious Diseases* 11:1822-1827.

[7] Alexander, K. A., Blackburn, J. K., Vandewalle, M. E., Pesapane, R., Baipoledi, K. and Elzer, P. H. 2012. Buffalo, bush meat, and the zoonotic threat of brucellosis in Botswana. *PLoS ONE* 7(3): e32842. doi:10.1371/journal.pone.0032842.

[8] Daszak, P. 2006. Risky behaviour in the Ebola zone. *Animal Conservation* 9:366-367.

[9] Caro, T. M. 2008. Decline of large mammals in the Katavi-Rukwa ecosystem of western Tanzania. *African Zoology* 43:99–116.

[10] Craigie, I. D., Baillie, J. E. M., Balmford, A., Carbone, C., Collen, B., Green, R.E. and Hutton, J. M. 2010. Large mammal population declines in Africa's protected areas. *Biological Conservation* 143: 2221–2228.

[11] Henschel, P., Hunter, L. T. B., Coad, L., Abernethy, K. A. and Mühlenberg, M. 2011. Leopard prey choice in the Congo Basin suggests exploitative competition with human bushmeat hunters. *Journal of Zoology* 285:11-20.

[12] Western, D., Russell, S. and Cuthill, I. 2009. The status of wildlife in protected areas compared to non-protected areas of Kenya. *PLoS ONE* 4:e6140.

[13] Wang, B.C., Sork, V.L., Leong, M.T. and Smith, T.B. 2007. Hunting of mammals reduces seed removal and dispersal of the afrotropical tree *Antrocaryon klaineanum* (Anacardiaceae). *Biotropica* 39:340-347.

[14] Brodie, J. F., Helmy, O.E., Brockelman, W. Y. and Maron, J.L. 2009. Bushmeat poaching reduces the seed dispersal and population growth rate of mammal-dispersed tree. *Ecological Applications* 19:854-863.

[15] Anadu, P. A., Elamah, P. O. and Oates, J. F. 1988. The bushmeat trade in southwestern Nigeria: a case study. *Human Ecology* 16:199-208.

[16] Fa, J. F., Juste J., del Val, J. P. and Castroviejo, J. 1995. Impact of market hunting on mammal species in Equatorial Guinea. *Conservation Biology* 9:1107-1115.

[17] Wilkie, D. S. and Carpenter, J. F. 1999. Bushmeat hunting in the Congo Basin: an assessment of impacts and options for mitigation. *Biodiversity and Conservation* 8: 927-955.

[18] Barnes, R. F. W. 2002. The bushmeat boom and bust in West and Central Africa. *Oryx* 36:236-242.

[19] Brashares, J. S., Arcese, P., Sam, M. K., Coppolilo, P. B., Sinlair, A. R. E., and Balmford, A. 2004. Bushmeat hunting, wildlife declines and fish supply in West Africa. *Science* 306:1180-1183.

[20] Cowlishaw, G., Mendelson, S. and Rowcliffe, J.M. 2005. Evidence for postdepletion sustainability in a mature bushmeat market. *Journal of Applied Ecology* 42:460–468.

[21] Fa, J.E. Ryan, S.F. and Bell, D.J. 2005. Hunting vulnerability, ecological characteristics and harvest rates of bushmeat species in afrotropical forests. *Biological Conservation* 121:167–176.

[22] Fa, J.E. and Brown, D. 2009. Impacts of hunting on mammals in African tropical moist forests: a review and synthesis. *Mammal Review* 39:231-264.

[23] Hayward, M. W. 2009. Bushmeat hunting in Dwesa and Cwebe Nature Reserves, Eastern Cape, South Africa. *South African Journal of Wildlife Research* 39:70-84.

[24] Lindsey, P.A., Romanach, S.S., Tambling, C.J., Chartier, K. and Groom, R. 2011. Ecological and financial impacts of illegal bushmeat trade in Zimbabwe. *Oryx* 45**:**96-111.

[25] Loibooki, M., Hofer, H., Campbell, K.L.I., and East, M.L. 2002. Bushmeat hunting by communities adjacent to the Serengeti National Park, Tanzania: the importance of livestock ownership and alternative sources of protein and income. *Environmental Conservation* 29:391-398.

[26] Okello, M.M. and Kiringe, J.W. 2004. Threats to biodiversity and their implications in protected and adjacent dispersal areas of Kenya. *Journal of Sustainable Tourism* 12:55-69.

[27] Kiffner, C., Stoner, C. and Caro, T. 2013. Edge effects and large mammal distributions in a national park. *Animal Conservation* 16:97-107.

[28] Kiffner, C., Kioko, J., Kissui, B., Painter, C., Serota, M., White, C. and Yager, P. 2014. Inter-specific variation in large mammal responses to human observers along a conservation gradient with variable hunting pressure*. Animal Conservation* 17:603 – 612.

[29] Ndibalema, V.G. and Songorwa, A.N. 2008. Illegal meat hunting in Serengeti: dynamics in consumption and preferences. *African Journal of Ecology* 46:311-319.

[30] Martin, A. and Caro, T. 2013. Illegal hunting in the Katavi-Rukwa ecosystem. *African Journal of Ecology* 51:172-175.

[31] Martin, A., Caro, T. and Kiffner, C. 2013. Prey preferences of bushmeat hunters in an East African savannah ecosystem. *European Journal of Wildlife Research* 59:137-145.

[32] Kaltenborn, B. P., Nyahongo, J. W., Tingstad, K. M. 2005. The nature of hunting around the Western corridor of Serengeti National Park, Tanzania. *European Journal of Wildlife Research* 51:213-222.

[33] Holmern, T., Muya, J. and Røskaft, E. 2007. Local law enforcement and illegal bushmeat hunting outside the Serengeti National Park, Tanzania. *Environmental Conservation* 34:55-63.

[34] Setsaas,T. H., Holmern, T., Mwakalebe, G., Stokke, S., and Røskaft, E. 2007. How does human exploitation affect impala populations in protected and partially protected areas? – A case study from the Serengeti ecosystem, Tanzania. *Biological Conservation* 136:563-570.

[35] Mfunda, I.M. and Røskaft, E. 2010. Bushmeat hunting in Serengeti, Tanzania: an important economic activity to local people. *International Journal of Biodiversity Conservation* 2:263-272.

[36] Rentsch, D. and Damon, A. 2013. Prices, poaching, and protein alternatives: an analysis of bushmeat consumption around Serengeti national Park, Tanzania. *Ecological Economics* 91:1-9.

[37] Martin, A., Caro, T. and Borgerhoff Mulder, M. 2012. Bushmeat consumption in western Tanzania: A comparative analysis from the same ecosystem. *Tropical Conservation Science* 5:352-364.

[38] Mgawe, P., Mulder, M.B., Caro, T., Martin, A. and Kiffner, C. 2012. Factors affecting bushmeat consumption in the Katavi-Rukwa ecosystem of Tanzania. *Tropical Conservation Science* 5:446-462.

[39] Nielsen, M. R. 2006. Importance, cause and effect of bushmeat hunting in the Udzungwa Mountains, Tanzania: Implications for community based wildlife management. *Biological Conservation* 128:509-516.

[40] Nielsen, M. R. and Treue, T. 2012. Hunting for the benefits of joint forest management in the Eastern Afromontane Biodiversity Hotspot: Effects on bushmeat hunters and wildlife in the Udzungwa Mountains. *World Development* 40: 1224-1239.

[41] Rovero, F., Mtui, A. S., Kitegile, A. S. and Nielsen, M. R. 2012. Hunting or habitat degradation? Decline of primate populations in Udzungwa Mountains, Tanzania: An analysis of threats. *Biological Conservation* 146:89-96.

[42] Nielsen, M. R., Jacobsen, J. B. and Thorsen, B. J. 2014. Factors determining the choice of hunting and trading bushmeat in the Kilombero Valley, Tanzania. *Conservation Biology* 28:382-391.

[43] Ceppi, S. L. and Nielsen, M. R. 2014. A comparative study on bushmeat consumption patterns in ten tribes in Tanzania. *Tropical Conservation Science* 7:272-287.

[44] Tanzania Daily News 2013. Tanzania: Putting 'Operation Tokomeza' in Its Perspective. URL http://allafrica.com/stories/201312230129.html.

[45] Morrison, T.A. and Bolger, D.T 2012. Wet season range fidelity in a tropical migratory ungulate. *Journal of Animal Ecology* 81:543-552.

[46] Morrison, T.A. and Bolger, D.T 2014. Connectivity and bottlenecks in a migratory wildebeest *Connochaetes taurinus* population. *Oryx* 48:613-621.

[47] Kiffner C., Wenner C., LaViolet A., Yeh K. and Kioko J. 2015. From savannah to farmland: effects of land use on mammal communities in the Tarangire-Manyara Ecosystem, Tanzania. Afric*an Journal of Ecology* 53:156-166.

[48] Msoffe, F.U., Said, M.Y., Ogutu, J.O., Kifugo, S.C., de Leeuw, J., van Gardingen, P. and Reid, R.S. 2011. Spatial correlates of land-use changes in the Maasai-Steppe of Tanzania: implications for conservation and environmental planning. *International Journal of Biodiversity and Conservation* 3:280-290.

[49] Burnham, K.P. and Anderson, D.R. 2002. Model selection and multi-model inference: a practical information theoretic approach. 2nd edn. New York: Springer-Verlag.

[50] Grueber, C.E., Nakagawa, S., Laws, R.J. and Jamieson, I.G. 2011. Multimodel inference in ecology and evolution: challenges and solutions. *Journal of Evolutionary Biology* 24:699–711.

[51] R Core Team 2014. *R: A language and environment for statistical computing. R Foundation for Statistical Computing*. Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

[52] Cross, P., St. John, F.A.V., Khan, S., and Petroczi, A. 2013. Innovative Techniques for Estimating Illegal Activities in a Human-Wildlife-Management Conflict. *PLoS ONE* 8, e53681

[53] Nuno, A. and St. John, F.A.V. in press. How to ask sensitive questions in conservation: A review of specialized questioning techniques. *Biological Conservation* DOI:10.1016/j.biocon.2014.09.047

[54] National Bureau of Statistics (NBS) and Office of Chief Government Statistician (OCGS), Zanzibar. 2013. 2012 Population and Housing Census: Population Distribution by Administrative Units; Key Findings. Dar es Salaam, Tanzania: NBS and OCGS. [available at: http://nbs.go.tz/nbs/sensa/PDF/2012%20PHC%20POPULAR%20VERSION.pdf]

[55] Mwalyosi, R.B.B. 1991. Ecological evaluation for wildlife corridors and buffer zones for Lake Manyara National Park, Tanzania and its immediate environment. *Biological Conservation* 57:171 – 186.

[56] Nyaki, A., Gray, S.A., Lepczyk, C.A., Skibins, J.C. and Rentsch D. 2014. Local-scale dynamics and local drivers of bushmeat trade. *Conservation Biology* 28, 1403-1414.

Appendix 1

1. Location name = _____ Easting _____, Southing _____
2. Gender of respondent's = _____(1 male, 2 female)
3. Land use=_____
4. Residency = _____ (lived all life here (4), spend half of life here (3), frequent visitor (2), rare visitor (1))
5. Formal education level = _____(University college (4), secondary school (3), Primary school (2), None (1))
6. Resident's major form of livelihood = _____(agriculture, livestock keeping, employed, business)
7. Tribe_____
8. Number people in the household_____
9. Livestock owned by respondents household cattle …….sheep …….. goats……., donkeys…….. chicken……
10. Do you or your family own the following _

Bicycle … …….. Motor cycle …… vehicle …….. radio…… ……. TV……water tank

11. How frequently do you or someone in your family participate in the following activities? Several times per week (1), several times a month (2), several times per year (3), very rarely (4), never (5)

Keeping livestock	
Crop Farming	
Fishing	
Trading	
Hunting	
Tourism	

12. How frequently do you or someone in your family eat the following food items? Several times per week (1), several times a month (2), several times per year (3), very rarely (4), never (5).

Ugali	
Rice	
Makande	
Chicken	
Beef	
Chips	
Meat from wild animals	

13. How frequently do you or someone in your family eat meat? Several times a week (1), several times a month (2), once per month (3), several times per year (4), never (5).

14. How frequently is meat from wild animals available for purchase in this area? Several times a week (1), several times a month (2), once per month (3), several times per year (4), very rarely (5), never (6).