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The Importance of Bushmeat in Household Income as a Function of Distance from Protected Areas in the Western Serengeti Ecosystem, Tanzania

Flora Felix Manyama[1], Martin Reinhardt Nielsen[2], Eivin Røskaft[3], & Julius William Nyahongo[1]

[1] Department of Conservation Biology, University of Dodoma, Dodoma, Tanzania

[2] Department of Food and Resource Economics, University of Copenhagen, Frederiksberg C, Denmark

[3] Norwegian University of Science and Technology (NTNU), Department of Biology, Realfagbygget, Trondheim, Norway

Correspondence: Flora Felix Manyama, Department of Conservation Biology, University of Dodoma, P.O. BOX 338, Dodoma, Tanzania. E-mail: modalflom@yahoo.com

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Abstract

Bushmeat hunting is widespread in villages adjacent to protected areas in Western Serengeti. However, little information is available about the role of bushmeat income in the household economy as a function of distance from the protected area boundary, preventing the formulation of informed policy for regulating this illegal trade. This study was conducted in three villages in Western Serengeti at distances of 3 (closest), 27 (intermediate) and 58km (furthest) from the boundary of Serengeti National Park to assess the contribution of bushmeat to household income. The sample consists of 246 households of which 96 hunted or traded bushmeat, identified using snowball sampling through the aid of local informers. The average income earned from bushmeat was significantly higher for bushmeat traders than hunters. The contribution of bushmeat to household income was significantly higher in Robanda the village closest to the protected area boundary compared to Rwamkoma and Kowak, the more distant villages. A Heckman sample-selection model reveals that household participation in hunting and trading bushmeat was negatively associated with distance to the protected area boundary and with the household head being female. Household reliance on bushmeat income was negatively associated with age and gender of the household head and distance to the protected area boundary. Hence, efforts to reduce involvement in hunting, and trading bushmeat should target male-headed households close to the protected area boundary.

Keywords: Bushmeat Income, Bushmeat Reliance, Hunter and Bushmeat Trader Households, Regular Households and Other Household Income Sources

1. Introduction

Bushmeat contributes significantly to household income and food security in many locations across Sub-Saharan Africa (Lindsey et al., 2013; Nielsen et al., 2017; Ahmadi et al., 2018). However, bushmeat hunting can deplete wildlife populations compromising conservation objectives (Wilkie et al., 2011; Ripple et al., 2016). Most remaining wildlife resources are found in protected areas where hunting is prohibited (Costello et al., 2008). The fact that hunting is illegal in many locations makes obtaining information about the revenue generated from this resource difficult. However, the design of effective policies to reduce illegal bushmeat hunting require information about the importance of bushmeat in household economies (Knapp et al., 2017). Wildlife hunted for human consumption is a valuable ecosystem service particularly to the poor who otherwise see few benefits from protected areas (Coad et al., 2010; Schulte-Herbrüggen et al., 2013; Fischer et al., 2014). Quantifying the value of this ecosystem service is important to predict the consequences of enhanced enforcement, reducing the availability of this resource to local people (Golden et al., 2014).

In West and Central Africa, where bushmeat is mostly sold in open markets (Cowlishaw et al., 2005; McNamara et al., 2016; van Vliet et al., 2017) the value of bushmeat and income earned from bushmeat trade can more easily be quantified (Kümpel et al., 2010). In East African Savannahs, bushmeat hunting has long been regarded primarily as a subsistence activity, and bushmeat trade thought negligible (Lindsey et al., 2013). In Tanzania, the process of obtaining a hunting licence is economically and practically unfeasible for most local people making hunting of

local wildlife in principle illegal (Mfunda & Røskaft, 2010; Ceppi & Nielsen, 2014). This makes it difficult to quantify the income generated from the bushmeat trade as hunters and traders are reluctant to divulge information for fear of reprisal due to strict wildlife laws (Nielsen et al., 2014).

People living close to protected areas in Western Serengeti experience a range of constraint on agricultural expansion as well as high levels of crop and livestock depredation negatively affecting their livelihood opportunities (Galvin et al., 2008). Illegal bushmeat hunting is one of only a few sources of cash income to households through the bushmeat trade (Loibooki et al., 2002). Estimates of the number of people hunting in the protected areas vary considerably from 8 to 57% of all households in western Serengeti (Nuno et al., 2013). Most arrested hunters come from villages between 0 and 16 km from protected area boundaries, but some live as far away as 45km (Loibooki et al., 2002; Kideghesho 2010). Bushmeat prices are relatively low compared to domestic animal meat ranging from 0.85 to 1.0 US$ per kg (Rentsch & Damon, 2013). The lower price of bushmeat combined with culturally determined preferences increases bushmeat demand, especially by income-poor households (Ndibalema & Songorwa, 2007).

However, the sustainability of hunting in the Western Serengeti is questionable, and hunting intensity is expected to increase further as the human population adjacent to the protected areas continue to increase (Rentsch et al., 2015; Rogan et al., 2017). This study aimed to assess the contribution of bushmeat to household income as a function of distance from the core Serengeti National Park boundary and its dependence on socio-economic factors. We apply a Heckman sample selection model to test hypotheses about the determinants of the likelihood of being a hunter or a bushmeat trader vs a regular household and the determinants of the relative importance (i.e. reliance) of bushmeat income in hunter and bushmeat trader households' income portfolio. Specifically, we test four hypotheses: Distance to the Protected Area (PA) boundary is inversely related to H1) the likelihood of the household containing a hunter or bushmeat trader; and to H2) household bushmeat income reliance (i.e. share in total household income); Household socioeconomic characteristics determine H3) the likelihood of the household containing a hunter or bushmeat trader; and H4) household bushmeat income reliance. Relevant socio-economic predictors tested include household cash income per capita, household size, actor group (hunters or traders) and the age and gender of the household head.

2. Methods

2.1 Study Area

The study was conducted in three villages (Robanda, Rwamkoma and Kowak) located in the western part of the Greater Serengeti Ecosystem (GSE) (Figure 1). The GSE is a highland savannah region with plains and woodlands at an altitude of 1,000-1,800m above sea level. The area receives two rainy seasons; the short rains which normally start in late November to February and the long rains from March to May, with an average of annual rainfall ranging from 600 to 1,100mm (Mramba et al., 2017). The mean annual temperature fluctuates with minimum range of 13 to 19°C and maximum of 25 to 32°C (Campbell & Hofer, 1995). The GSE is composed of various protected areas including the Serengeti National Park (SNP) (14,763km^2), located between 1°28'-3°17'S and 33°50'-35°20'E in Tanzania. In addition to SNP, GSE also includes the Ikona Wildlife Management Area (WMA) (600km^2), Ikorongo Game Reserve (563km^2), Grumeti Game Reserve (416km^2), Kijereshi and Maswa Game Reserves (2,200km^2) in the Southwest, and Ngorongoro Conservation Area (8,292km^2) and Loliondo Game Controlled Area (4,000km^2) to the East.

The GSE is a World Heritage Site and a famous tourist attraction partly due to hosting the last remaining great wildlife migration comprised of wildebeest (*Connochaetes taurinus)* and other large herbivores. Community land in Western Serengeti acts as a corridor for the migration on its route to the Maasai Mara National Reserve in Kenya (Loibooki et al., 2002). The migration dramatically influences the availability of bushmeat to adjacent communities through illegal hunting (Nyahongo et al., 2009; Mwakatobe et al., 2012). The human population in the villages close to the SNP is increasing rapidly at a rate of 3.5% annually (Estes et al., 2012; URT, 2013). A large proportion of the population subsists on less than US$ 1 per day and is facing deteriorating well-being due to environmental degradation and lack of economic options (Loibooki et al., 2002; Kideghesho, 2010). The main economic activities are subsistence farming (maize, cassava, millet and sorghum), pastoralism (cattle, goat and sheep), poultry, hunting, fishing, charcoal making and making local brews (Loibooki et al., 2002; Kideghesho, 2010).

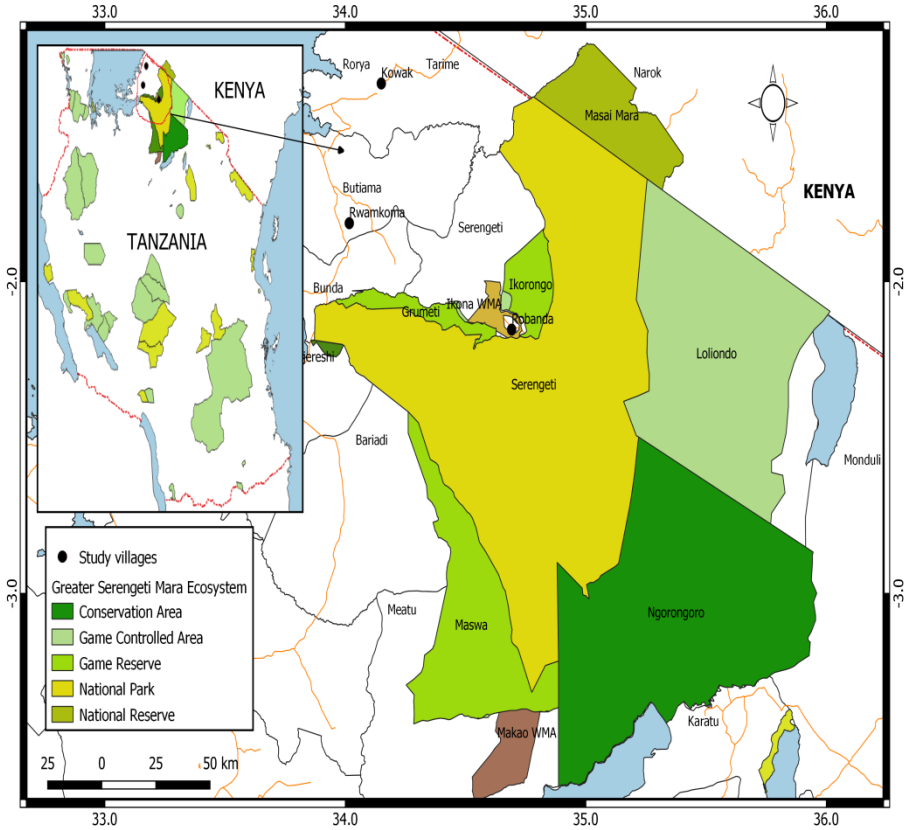

Figure 1. Map of the study area showing the study villages Robanda, Rwamkoma and Kowak indicated with black dots

2.2 Research Design and Sampling

The study villages were purposely selected based on distance from the western boundary of the SNP. Distances from the centre of the villages to the nearest SNP boundary are: Robanda 3km (close), Rwamkoma 27km (intermediate) and Kowak 58km (furthest). The household was the sample unit for this study, and a list of all households in each village was obtained from the village office. A household (HH) is defined as a person or group of persons who reside in the same compound but not necessarily in the same dwelling unit, have same cooking arrangements, and are answerable to the same household head (URT, 2013). Households, including hunters and traders, were identified and included using snowball sampling based on an initial sample of hunters and traders in each village who accepted being interviewed. Local assistants helped identify these first respondents. This sampling technique was selected because of the sensitive nature of hunting and trading bushmeat that may carry significant penalties upon arrest, and the approach is commonly used in studies of sensitive activities (Knapp, 2012; Nielsen et al., 2014).

2.3 Data Collection

Data were collected through observations and recording of bushmeat packages (kipande) and a household questionnaire survey conducted in October 2017 (dry season) and April 2018 (wet season). Bushmeat packages were recorded in the households of hunters and traders by local assistants, supervised by the lead author. Respondents were assured anonymity, and interviews were conducted in their households to ensure full confidentiality. The value of bushmeat in possession of hunters and bushmeat traders was estimated by multiplying the number of bushmeat packages by the current price of bushmeat. Bushmeat prices were identified in each village specifically for fresh and dried bushmeat in both the wet and the dry season. As there was no formal bushmeat market in the area, the price was determined based on information collected from hunters and traders and regular households during household questionnaire surveys.

Both hunters and bushmeat traders and the randomly selected regular households were subject to a face to face questionnaire survey taking departure in a semi-structured questionnaire targeting the household head in the case of the randomly selected households. In the absence of the household head, the wife (if the household was male

headed) or the oldest household member above 18 years of age was interviewed instead. A total of 96 respondents were identified as hunters and traders out of 246 households interviewed. Respondents were asked about environmental products harvested (including bushmeat) and income earned from all sources using one-month recall. Other information collected includes household demographic data and socioeconomic information, including productive and non-productive assets owned. All cash and subsistence income of all harvested and produced goods were recorded and measured in terms of its monetary value. Cash income means income generated through trade, while subsistence income is income generated through own production and consumption. Total household income was calculated by summation of cash and subsistence income from all sources including environmental harvesting (including bushmeat), agriculture (crop and livestock production) and non-agricultural activities such as employment and small scale business (formal, casual and self-employment) and other income (including remittance and pensions). Cash income from the sale of products was calculated by multiplying the quantity of a product sold by its average market price, whereas subsistence income was calculated by multiplying amount harvested by the appropriate market price per unit. Calculated incomes are net income, i.e., the gross value of products minus costs of purchased inputs but not excluding own-labour. Values were converted to US$ using the average annual exchange rate of 1 US$ = TZS 2,250 for 2018. Reliance on bushmeat income was calculated as the percentage contribution to total household income.

2.4 Data Analysis

Hunter and bushmeat trader households were combined as one group in all comparisons with regular households. Comparisons of means were conducted after testing the normality assumption using the Shapiro-Wilkes test. The variation in the contribution of bushmeat income to total household income between villages was analysed using the Kruskal-Wallis test, and significance of differences was tested using Dunn's post-hock test. The factors predicting the likelihood of a household participating in hunting or trading bushmeat and determining these households reliance on bushmeat income were evaluated using a Heckman sample selection model (Toomet & Henningsen, 2008; Bakkegaard et al., 2016). Standard regression model approaches may suffer from selection bias when households self-select into the activity studied (Certo et al., 2016). However, the Heckman model allows simultaneous estimation of factors determining households' self-selection into hunting and trading bushmeat (i.e. compared to regular households) as well as the factors determining their reliance on income from these activities. The model consists of an integrated two-part estimation of selection into the activity and its outcome, which overcomes common issues of endogeneity arising from sample selection in other models (Toomet & Henningsen, 2008). The selection equation is defined as:

$$w^*_i = \gamma' Z_i + u_i \quad (1)$$

where, w^*_i is the latent variable, related to a set of exogenous variables, Z_i, and where $w_i = 1$ if $w_i > 0$ and $w_i = 0$ otherwise. The probability of observing participation, i.e. $w_i = 1$, as a function of Z_i is defined by a probit model:

$$\text{Prob}(w_i = 1|Z_i) = \phi(\gamma' Z_i) \quad (2)$$

$$\text{Prob}(w_i = 0|Z_i) = 1 - \phi(\gamma' Z_i) \quad (3)$$

When $w_i = 1$, we observe an outcome of bushmeat income reflected in bushmeat reliance above zero for household i, which we call y_i. The outcome part of the model will then describe the outcome in terms of the reliance on bushmeat income, and its relation to a subset of variables X (which may overlap with Z):

$$y_i = \beta' x_i + \varepsilon_i, \text{ where } w_i = 1 \quad (4)$$

We assume the error terms to be distributed as (u_i, ε_i) * bivariate normal $[0, 0, 1, \sigma_\varepsilon, \rho]$, allowing for possible correlations in the error terms.

Selection of explanatory variables was based on general economic theory and relevant empirical findings (Knapp et al., 2010; Fischer et al., 2014; Bakkegaard et al., 2016). Specifically, the model tested the influence of distance to the PA boundary (in km), household cash income per capita, household size (number of household members), actor group (hunters or traders), age and gender of the household head (Table 1). All statistical tests were done in R-Studio (Version 1.1.456) using a significant level of $P \leq 0.05$.

Table 1. Explanatory variables and an expected sign of the coefficient in the Heckman model testing hypotheses about the likelihood of participation in hunting and trading bushmeat and its outcome as the magnitude of reliance on bushmeat income

Variable	Unit	Expected sign		Hypothesis
		Participation	Reliance	
Distance to the PA boundary	km	-	-	Households are more likely to hunt/trade and rely more on bushmeat income the closer they are to the boundary due to lower opportunity costs and higher availability.
Household cash income	Cash income from all household income sources in US$	-	-	Households with higher income from other sources are less likely to hunt/trade and relies less on bushmeat income due to more remunerative alternatives.
Gender of the household head	Male-headed =1 or female-headed = 0	-	-	Female-headed households are less likely to contain hunters/traders and hence relies less on bushmeat income due to lower skills and labour availability.
Age of the household head	Years	+	+	Households with older heads are more likely to hunt/trade and rely more on bushmeat income than households with younger heads due to fewer alternatives.
Household size	Number of people in the household	+	-	Larger households have more excess labour and are more likely to contain hunters/traders but are also more efficient in wealth generation and therefore rely less on bushmeat income.
Actor group	Hunter =1 or trader = 2	NA	+	Hunting households rely more on bushmeat income than traders.

3. Results

3.1 Demographic and Socio-Economic Characteristics of Respondents

The general characteristics of the respondents and the sample percentage composition are summarised in Table 2. There were significant differences between hunters and traders and regular households (i.e. non-hunter and non-traders) in terms of the age and gender of the household head, occupation (in the category "other"), as well as distance to the PA boundary. However, no difference was observed in household participatory wealth rank between hunters and traders and regular households (Table 2).

Table 2. Percentage composition of the sample and comparison of means between hunters and traders and regular households

Variable (%)	Hunters and Traders (n=96)	Regular households (n=150)	Z	P
Distance to PA (km)				
3 (Robanda)	79.17	32.67		
27 (Rwamkoma)	11.46	30.67	-4.182	<0.001
58 (Kowak)	9.38	36.67	-4.763	<0.001
Gender				
Male	76.04	40.00		
Female	23.96	60.00	-4.362	<0.001
Age				
21-28	10.42	18.00		
29-44	68.75	48.00	2.687	0.007
45 and above	20.83	34.00	1.232	0.218
Occupation				
Peasants	36.46	62.67		
Pastoralists	23.96	26.00	1.443	0.149
Others	39.58	11.33	2.858	0.004
Wealth				
Poor	67.71	59.33		
Middle	23.96	27.33	0.820	0.412
Rich	8.33	13.33	-0.576	0.564

3.2 Bushmeat Packages Recorded

A total of 149 bushmeat packages were recorded in possession of hunters and traders (n=96) in the study villages. Wildebeest was the most common species in terms of the proportion of bushmeat packages recorded (Figure 2). More bushmeat packages were recorded during the dry season (77.2%) than in the wet season (22.8%). The majority of the packages (76.5%) were dried meat, and the rest were fresh meat (23.5%). Significantly more hunters claimed to hunt mostly inside the SNP (65%) followed by WMAs (22.5%) and Game Reserves (12.5%) (Kruskal-Wallis test; H=44.507; P<0.001).

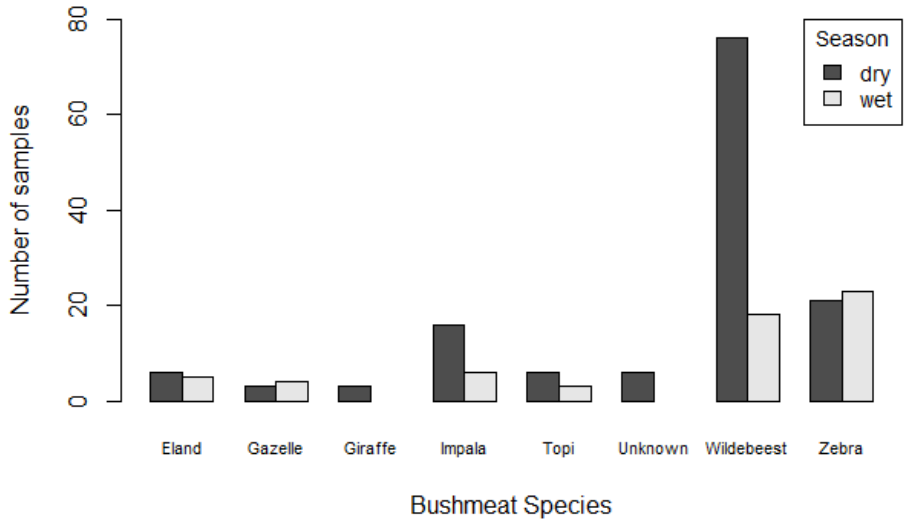

Figure 2. Wildlife species contribution to total bushmeat packages recorded in the dry and the wet season

3.3 Contribution of Income Sources to Total Household Income as a Function of Distance

Overall, average total household income was significantly higher in Robanda than in Rwamkoma and Kowak (Figure 3; Kruskal-Wallis test; H=10.975, P=0.004). A post-hoc Dunn's test reveals significant differences between Robanda and Rwamkoma (Dunn's tests; Z=-2.236; P=0.051) as well as between Robanda and Kowak (Z=3.04; P=0.007), while the difference between Rwamkoma and Kowak was not significant (Z=0.68; P=0.496). Overall, regular households on average obtained significantly higher total household income than hunter and bushmeat trader households (Wilcoxon test; W=5741; P=0.0074). However, comparisons at the village level revealed no significant differences.

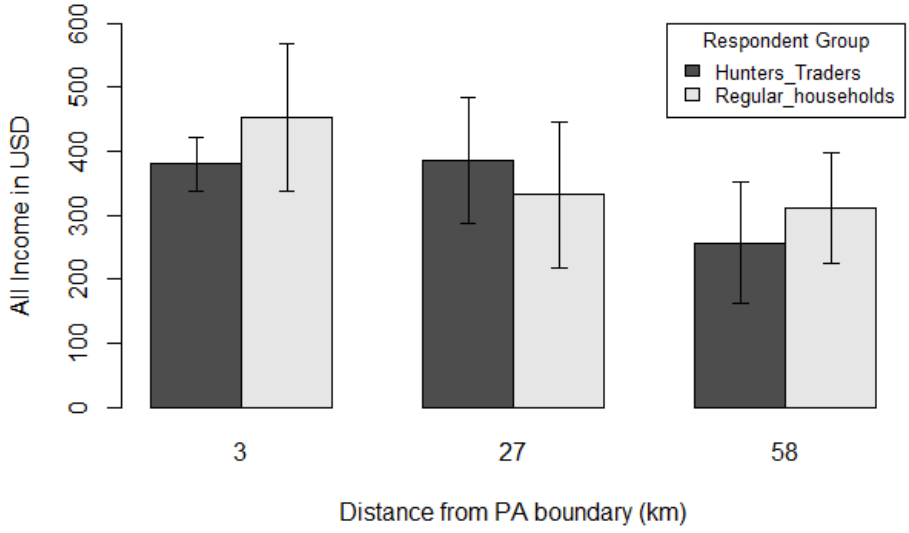

Figure 3. Average total income in hunter and bushmeat trader and regular households at increasing distance from the PA boundary

3.4 Contribution of Bushmeat to Household Income as a Function of Distance

Bushmeat income and reliance on bushmeat income were significantly higher in the closest village Robanda compared to the more distant villages, Rwamkoma and Kowak (bushmeat income; Figure 4; Kruskal-Wallis tests; H=24.025; P<0.001 and bushmeat reliance; Figure 5; H=24.789; P<0.001). A post-hoc Dunn's test reveals significant differences in bushmeat income between Robanda and Rwamkoma (Z=-4.315; P<0.001) as well as between Robanda and Kowak (Z=2.966; P=0.006), while the difference between Rwamkoma and Kowak was not significant (Z=-0.771; P=0.441). Similar differences were also observed in reliance on bushmeat income where the differences between Robanda and Rwamkoma (Dunn's tests; Z=-4.009; P<0.001) as well as between Robanda and Kowak (Z=3.264; P=0.002) were significant, while the difference between Rwamkoma and Kowak was not significant (Z=-0.318; P=0.751). The average income earned from bushmeat was significantly higher for bushmeat traders (231.63 ± 12.47) than hunters (146.32 ± 7.44) (Wilcoxon test; W=830; P=0.021). Most hunters (72.22%) claimed to catch only one animal per hunting trip, and the majority (58.33%) claimed to hunt only one time per month on average during both seasons.

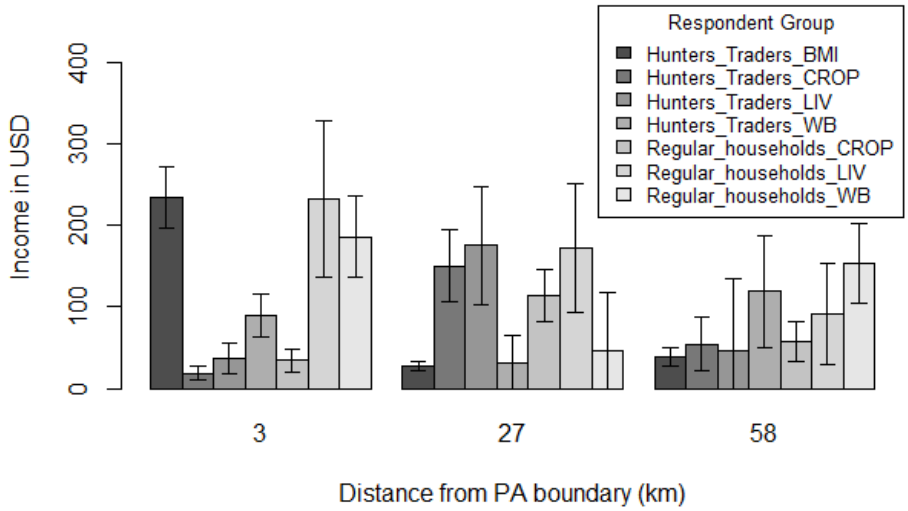

Figure 4. Average household bushmeat (BMI), livestock (LIV), crop (CROP) and wage and business (WB) income for hunters and bushmeat traders and regular households at increasing distance from the PA boundary

Other income sources (agricultural and non-agricultural income) and their contribution to hunters and traders' total household income also differed between study villages (Figure 4 and Figure 5). Crop income was significantly lower in the closest village Robanda than in more distant villages Rwamkoma and Kowak (Kruskal-Wallis test; H=29.43; P<0.001). A post-hoc Dunn's test reveals significant differences between Robanda and Rwamkoma (Z=5.214; P<0.001) as well as between Robanda and Kowak (Z=-2.091; P=0.037), while the difference between Rwamkoma and Kowak was non-significant (Z=2.103; P=0.071). Household reliance on crop income was significantly lower in the closest village Robanda than in more distant villages Rwamkoma and Kowak (Kruskal-Wallis test; H=30.508; P<0.001). The differences between Robanda and Rwamkoma (Dunn's tests; Z=5.15; P<0.001) as well as between Robanda and Kowak (Z=-2.58; P=0.02) were significant, while the difference between Rwamkoma and Kowak was insignificant (Z=1.67; P=0.094).

Overall, regular households income from crop production was on average significantly higher than hunter and trader households (68.47±6.01 vs 37.35±3.77) (Wilcoxon test; W=8409; P=0.018) whereas, comparisons at the village level revealed no significant differences. Overall, household reliance on crop income was significantly higher in regular households than in hunter and trader households (Wilcoxon test; W=8733; P=0.003). At the village level regular households also had a significantly higher reliance on crop income than hunters and traders in the closest village, Robanda (W=2211; P=0.047) but not in the more distant villages Rwamkoma (W=296; P=0.615) and Kowak (W=170.5; P=0.21).

Hunters and traders income from livestock production also differed significantly between villages (Figure 4; Kruskal-Wallis test; H=16.165; P<0.001). The differences were significant between Robanda and Rwamkoma (Dunn's tests; Z=3.918; P<0.001) as well as between Rwamkoma and Kowak (Z=3.16; P=0.003), while the

difference between Robanda and Kowak was not significant (Z=0.445; P=0.657). Reliance on livestock income was significantly higher in the intermediate village (Rwamkoma) than in the closest (Robanda) and the most distant village (Kowak) (Figure 5; Kruskal-Wallis test; H=17.553; P<0.001). A post-hoc Dunn's test reveals significant differences between Robanda and Rwamkoma (Dunn's tests; Z=4.09; P<0.001) as well as between Rwamkoma and Kowak (Z=3.26; P=0.002), while the difference between Robanda and Kowak was not significant (Z=0.42; P=0.68).

Overall, hunters and traders had significantly lower income from livestock production than regular households (164.17±18.1 vs 53.77±6.36) (Wilcoxon test; W=8818.5; P=0.001). Similar significant differences were observed in the closest village, Robanda (Wilcoxon test; W=2550.5; P<0.001) while no significant difference was observed in the more distant villages Rwamkoma (W=211; P=0.257) and Kowak (W=258; P=0.553). Overall, household reliance on livestock income was significantly higher in regular households than in hunter and trader households (Wilcoxon test; W=8835.5; P<0.001). At the village level regular households also had significantly higher livestock reliance than hunters and traders in the closest village, Robanda (W=2577; P<0.001) but not in more distant villages Rwamkoma (W=265; P=0.938) and Kowak (W=259; P=0.537).

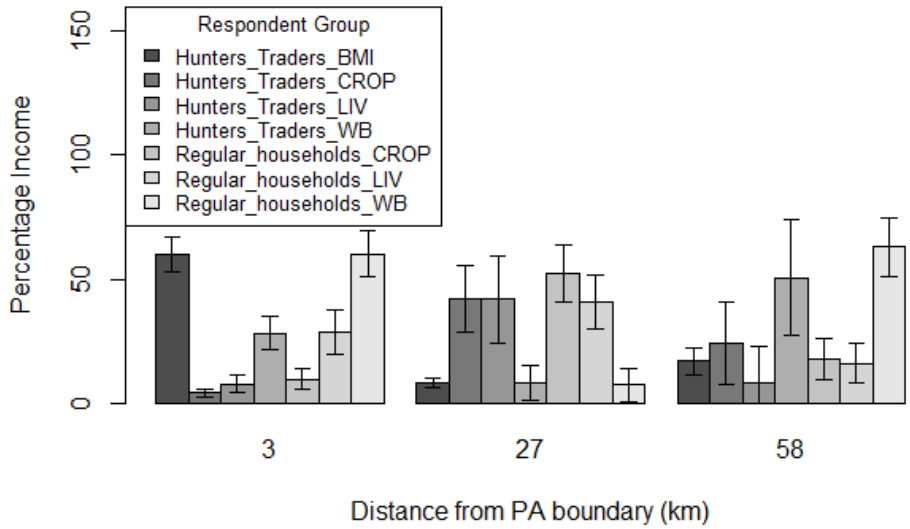

Figure 5. Reliance (percentage contribution to total household income) of bushmeat (BMI), livestock (LIV), crop (CROP) and wage and business (WB) income of hunters and bushmeat traders and regular households at increasing distance from the PA boundary

Hunter and trader households income from business, wage work and other sources (pension and remittances) also differed between study villages (Figure 4) with significantly lower income in Rwamkoma than Robanda and Kowak (Kruskal-Wallis test; H=8.271; P=0.016). The differences between Robanda and Rwamkoma (Dunn's test; Z=-2.579; P=0.019) as well as between Rwamkoma and Kowak (Z=-2.608; P=0.027) were significant, while the difference between Robanda and Kowak was non-significant (Z=-0.965; P=0.335). Reliance on business, wage and other income was also significantly lower in the intermediate village Rwamkoma than in the distant village Kowak and the closest village Robanda (Figure 5; Kruskal-Wallis test; H=11.297; P=0.004). A post-hoc Dunn's test reveals significant differences between Robanda and Rwamkoma (Z=-2.58; P=0.02) as well as between Rwamkoma and Kowak (Z=-3.3; P=0.003), while the difference between Robanda and Kowak was not significant (Z=-1.85; P=0.065).

Overall, income from business, wage and other sources and reliance on this income did not differ significantly between hunter and trader and regular households (BW income; Wilcoxon test; W=7933.5; P=0.169 and BW reliance; W=7975.5; P=0.146). Comparisons at the village level showed that regular households obtained significantly higher income from business, wage and other sources than hunters and traders in the closest village, Robanda (Wilcoxon test; W=2648; P<0.001) and in the intermediate village, Rwamkoma (W=196.5; P=0.019) but not in the most distant village, Kowak (W=227; P=0.894). Similar significant differences were also observed for reliance on business, wage and other income in Robanda (Wilcoxon test; W=2886; P<0.001) and Rwamkoma (W=201.5; P=0.029) but not in Kowak (W=304.5; P=0.132).

3.5 Predictors of Household Reliance on Bushmeat Income

The results of the Heckman sample selection model evaluating factors associated with household participation in hunting and trading bushmeat and predicting these households reliance on bushmeat income are presented in Table 3. The selection part of the model reveals that the probability of households participation in hunting and the bushmeat trade is associated with distance from the village to the PA boundary and the gender of the household head. Female-headed households are less likely to participate in hunting and trading bushmeat. And the further the village is from the PA boundary, the less likely that households participate in hunting and trading bushmeat. Other factors such as household cash income, household size and age of the household head were not significantly associated with participation in hunting and trading bushmeat. The outcome part of the model revealed that age and gender of the household head and distance to PA boundary were negatively associated with bushmeat income reliance, whereas none of the other predictors was significantly associated with bushmeat income reliance.

Table 3. Heckman sample selection model predicting household participation in hunting and trading bushmeat and reliance on bushmeat income

Variables	Coefficients	SE	T	P
Selection equation				
Distance to PA boundary (km)	-0.0274	0.0046	-6.001	<0.001
Gender of the HH head	-1.0280	0.1883	-5.461	<0.001
HH cash income (US$ per capita)	0.00004	0.0003	0.123	0.902
Age of HH head	-0.0458	0.0546	-0.840	0.402
Number of household members	-0.0322	0.0428	-0.752	0.453
Intercept	2.0710	0.3988	5.192	<0.001
Outcome equation				
Distance from PA boundary (km)	-0.0335	0.0122	-2.754	0.006
Gender of the HH head	-1.0550	0.4469	-2.360	0.019
Age of HH head	-0.1235	0.0549	-2.252	0.025
HH cash income (US$ per capita)	0.00009	0.0005	0.207	0.837
Actor group (hunters or traders)	0.0957	0.1214	0.788	0.431
Intercept	1.5430	0.4218	3.657	<0.001
InvMillsRatio	1.3366	0.5844	2.287	0.023
Rho	1.2289			

Multiple R-Squared: 0.229, Adjusted R-Squared 0.177; N = 246.

4. Discussion

4.1 Source of Bushmeat

The main source of bushmeat to local people in Western Serengeti was wildebeest. Wildebeest constituted the largest portion of bushmeat packages recorded in households hunting or trading bushmeat. Similar results have been obtained by Rentsch and Packer (2015) who found that wildebeest composed two third of the total harvest. Bushmeat hunting was done inside and outside protected areas and occurred mostly during the dry season when large groups of wildebeest and zebras migrated through areas close to village land (Nyahongo et al., 2009). The migration of these herbivores influenced bushmeat hunting outcomes due to increased availability of wild animals in the area. During the wildebeest migration, animals pass through village land with different land use types and are exposed to an elevated risk of being hunted by local people for bushmeat (Sinclair et al., 2015). More hunting (65%) was conducted inside the SNP compared to the WMA (22.5%) and Game Reserves (12.5%) because the vast area of the SNP makes it difficult for Park Rangers to discover the hunters and also direct boundary between Robanda and SNP makes it easy to access the park. The majority of hunters claimed to use wire snares but also other hunting tools such as pitfall traps, motorcycles, dogs and torches were used for hunting. Most hunters prefer snaring because it was the easiest and most cost-effective method, and has also been observed in previous studies (Holmern et al., 2006; Nyahongo et al., 2006; Knapp 2012). Bushmeat was either consumed (47%) in the household or sold (53%) locally as fresh (23.5%) or dried (76.5%) meat. Dried bushmeat were preferred because of prolonged time to spoiling in the hot climate and ease way of handling when sold door to door. There was no formal bushmeat market in the area.

4.2 Distance to the PA Boundary is Inversely Related to the Likelihood of the Household Containing a Hunter or Bushmeat Trader and to Household Bushmeat Income Reliance

The results of the study support both hypothesis 1 and 2 through comparison of means and the results of the Heckman model, including relevant control variables. Household participation in hunting and trading bushmeat and reliance on bushmeat income was negatively associated with distance to the PA boundary. Hence, households located further from the PA boundary were less likely to be involved in hunting and trading bushmeat probably due to higher costs of transportation and the elevated risks associated with transporting bushmeat further away from the SNP (Knapp, 2012). Both descriptive statistics and model analysis revealed that the contribution of bushmeat to household income was higher in the closest village (Robanda) than in more distant villages (Rwamkoma and Kowak). In the closest village, the abundance of wildlife is higher, making it easy for hunters to access wild animals (Rentsch & Packer, 2015). Previous studies in Western Serengeti have found that local people hunt mostly to fulfil their protein requirements, with few motivated by income generation per see (Mfunda & Røskaft, 2010).

In villages further from the PA boundary, the contribution of bushmeat to hunter and trader household income was lower compared to the closest village (Figure 5). Households in more distant villages were less likely to be involved in hunting and trading bushmeat and relied more on other income sources, although not significantly so with the exception of business, wage and other income in the intermediate village. Sanctions for illegal hunting can involve imprisonment and high fines (Knapp et al., 2017), and the decision to engage in illegal bushmeat hunting activities is presumably the result of a cost-benefit analysis. However, previous studies have found that household dependence on bushmeat was negatively associated with income from agriculture and other sources suggesting that poverty is a driving factor (Kideghesho, 2009). This study found that households participating in hunting and trading bushmeat in more distant villages relied more on agricultural and non-agricultural income than bushmeat income whereas, in the closest village, most households participating in hunting and trading bushmeat had a lower contribution of income from other sources (Figure 5). However, household income portfolios also differed between villages for other reasons, including differences between geographical locations and inhabitant people's background.

4.3 Other Factors Influencing Household Participation and Reliance on Bushmeat Income

Female-headed households were less likely to engage in hunting and trading bushmeat presumably due to limited labour surplus in female-headed households. Female-headed households may also encompass less experience with hunting and trading bushmeat, activities that are traditionally carried out by men and therefore relied more on other income sources such as small scale business, agriculture and employment. Other predictors such as household income, household size and age of the household head were not significantly associated with participation in hunting and trading bushmeat mirroring lack of difference between hunters and traders and regular households (non-hunters and non bushmeat traders) in several of these categories in the basic descriptive comparison (Table 2). Household cash income was not a significant factor influencing household's participation in hunting and trading bushmeat presumably because the majority of the sample including both hunters and traders and regular households are poor and differences in their wealth status or income were not statistically significant (Table 2 and Figure 3). Reasons for the areas general poverty includes limited livelihood opportunities, constrains on agricultural activities and inadequate skills due to low education with most people having only primary education.

Reliance on bushmeat income was negatively associated with the age of the household head, meaning that younger household heads who were involved in hunting or trading bushmeat relied less on this income. Households with older male heads are more likely to have lower education, further limiting their access to alternative jobs and simultaneously have more experience with hunting. Experience with hunting lacks in younger people who have spend more time in school. Contrary to other studies (Nielsen et al., 2018), we found no association between household cash income and bushmeat reliance. However, hunting and trading bushmeat is inversely related to household wealth (Brashares et al., 2011) and households that depend on bushmeat income have few alternative income sources (Fischer et al., 2014; FAO, 2015). Households engaged in hunting and trading bushmeat were generally poor but not poorer than regular households in the same village and traded bushmeat as one of the few alternative income sources in the area. The contribution of bushmeat income was higher than agricultural and non-agricultural income (Figure 5). Other studies have found that household participation in bushmeat hunting was due to lack of alternative livelihood strategies and that need for cash income was the reason for hunting (Knapp, 2007, 2012). In Robanda, the village closest to the PA boundary, the contribution of bushmeat income was higher than both agricultural and non-agricultural income. Regular households in the same village obtained more income from agricultural production (crop and livestock income) and non-agricultural activities (business, wage and other income) than hunters and bushmeat traders. But due to high bushmeat income hunters and traders on average did not have lower income than regular households. Agricultural activities in Robanda are reduced by

crop raiding and livestock depredation (Galvin et al., 2008). However, located close to the PA boundary this village also earns income from tourism activities and some people are employed in the surrounding PAs (Kyando et al., 2019). Due to high income from Ikona Wildlife Management Area (WMA) the community in Robanda village is considered the richest in the district. However, the community level income does not directly benefit individual households and this is among the reasons for the high level of bushmeat hunting despite the objectives of the WMA in the area.

Farming is the main economic activity in the area, although most farms are small-scale with production constrained by poor farming practice. Combined, the high level of wildlife depredation and poor agricultural output encourage people to look for other income generating options including hunting and trading bushmeat. Increasing the number and diversity of alternative income-generating activities could reduce the prevalence of hunting and the bushmeat trade. A study by Rentsch and Packer (2015) also found that households with more labour intensive income generating activities are less involved in illegal hunting and in trading bushmeat. This may be part of the reason for the lower participation in hunting and reliance on bushmeat in the intermediate village, Rwamkoma, where regular households rely mostly on agricultural production both crop and livestock income. In addition to economic factors, the decision to engage in hunting and trading bushmeat is also influenced by cultural factors (Kideghesho, 2008). Some ethnic groups and individual people, for instance, believe that wild meat is healthier than domesticated animals and relish the tastes (Kidegesho, 2008). Bushmeat is furthermore a cheap substitute for other meat types that are more expensive, especially in villages close to protected areas (Fischer et al., 2014; Manyama et al., 2019). Finally, there was no significant difference between actor groups (hunter or trader) in reliance once other aspects were controlled for in the model.

5. Conclusion and Recommendations

This study shows that bushmeat is an important source of income for hunters and bushmeat traders, particularly in the village close to the PA boundary. The likelihood of a household participating in hunting and trading bushmeat is inversely related to distance to the PA boundary, and female-headed households and younger households involved in this activity rely less on bushmeat income. The latter suggests that the prevalence of hunting and the bushmeat trade may decline over time. Until then increasing the number of alternative livelihood opportunities for older male-headed households in villages close to the PA boundary may reduce reliance on bushmeat income and hence the combined hunting pressure on wildlife populations in the GSE. Increasing the availability and reducing the price of alternative meat types can also help to reduce bushmeat demand and consumption in the area (Walelign et al., 2019). This can be done by promoting the production of alternative meat protein food such as fish and chicken through the establishment of fish farms and poultry projects in villages close to protected areas. In addition to law enforcement, which is currently the standard response and considered the most effective approach to control illegal hunting by some scholars (Rentsch & Damon, 2013), other strategies may need to be used to control illegal hunting in Western Serengeti. These strategies should focus on key stakeholders engaged in hunting and trading bushmeat as identified in this study to cut the supply of bushmeat and reduce the bushmeat trade. Incentive schemes should address the root causes of people engaging in illegal hunting (Duffy et al., 2019). Such strategies could involve providing capital for small-scale business, employment opportunities in the tourism sector and conservation jobs targeted for hunters and bushmeat traders and promoting the consumption of other meat types. Finally, the high level of hunting and bushmeat trade in a village that is part of a high income earning through WMA building on its wildlife resources indicates conceptual or practical problems in this concept likely involving few benefits reaching the household level or an unclear coupling between sustainable wildlife management objectives and these benefits.

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Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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