UNIVERSITY OF STIRLING

Stirling Management School

An investigation of the determinants of household demand for bushmeat in the Serengeti using an open-ended choice experiment

Mirko Moro

Anke Fischer

EJ Milner-Gulland

Asanterabi Lowassa

Loiruck C Naiman

Nick Hanley

Stirling Economics Discussion Paper 2014-07

April 2014

Online at:

http://www.stir.ac.uk/management/research/economics/working-papers/

An investigation of the determinants of household demand for bushmeat in the Serengeti using an open-ended choice experiment

Mirko Moro[1, 2], Anke Fischer[3, 6], E.J.Milner-Gulland[4], Asanterabi Lowassa[5], Loiruck C. Naiman[6]

and Nick Hanley[1, *]

1. Economics Division, University of Stirling, Scotland, UK
2. Economic and Social Research Institute, Dublin, Ireland
3. Social, Economic and Geographical Sciences Group, James Hutton Institute, Craigiebuckler, Aberdeen, Scotland, UK
4. Department of Life Sciences, Silwood Park Campus, Imperial College London, UK
5. Tanzania Wildlife Research Institute, Arusha, Tanzania.
6. Frankfurt Zoological Society, Tanzania

*corresponding author

Postal address: Economics Division, University of Stirling, Stirling FK9 4LA, Scotland, UK

Email: n.d.hanley@stir.ac.uk

Telephone: +44 1786 466410

March 2014

ACKNOWLEDGEMENTS

The authors would like to thank the enumerators for their help with data collection, all study participants, and Dennis Rentsch and Deborah Randall for their advice on the design of the survey. This paper originates in a research project "Hunting for Sustainability" supported by the European Commission under the 7th Framework Programme for Research and Technological Development. EJMG's involvement is a contribution to Imperial College's Grand Challenges in Ecosystems and the Environment initiative.

Abstract

Illegal hunting for bushmeat is regarded as an important cause of biodiversity decline in Africa. We use a stated preferences method to obtain information on determinants of demand for bushmeat in villages around the Serengeti National Park, Tanzania. We estimate the effects of changes in the own price of bushmeat and in the prices of two substitute protein sources – fish and chicken. Promoting the availability of protein substitutes at lower prices would be effective at reducing pressures on wildlife. Supply-side measures that raise the price of bushmeat would also be effective.

Keywords: conservation, illegal bushmeat, stated preferences, open-ended choice experiments, price elasticity of demand, alternative protein sources, Tanzania.

JEL codes: Q51, Q57

1. Introduction

Hunting of wildlife for food is believed to be a key driver of serious population declines and local species extinctions in many parts of the world (Bennett et al. 2007, Davies & Brown 2007). In this paper, we make use of a stated preference method to investigate the effects of changes in the price of bushmeat and of protein substitutes on the demand for bushmeat by local people around the Serengeti National Park, Tanzania. In particular, we are interested in the relative effects of policies which decrease the prices of two potential substitute protein sources, namely chicken and fish. Using a stated preference approach, we estimate own-price and cross-price elasticities of demand for bushmeat, and show how these elasticities vary across socio-economic and cultural groups. This kind of information would assist the targeting of demand-side initiatives such as the provision of substitute protein sources to reduce pressure on threatened wildlife populations. We argue that the use of stated preference data has significant advantages in this context over revealed preference data such as consumer purchases.

In what follows, Section 2 reviews the existing literature on measuring the demand for bushmeat. Section 3 explains the use of a stated preference method to investigate demand in the context of this paper. Section 4 contains a description of the case study area and the experimental design. Results are reported in Section 5, and a Discussion and Conclusion follows in Section 6.

2. Policy Context and Existing Literature

Hunting of bushmeat is of particular concern in Africa, where populations of bushmeat species appear to be declining in many areas, both in savannahs (Lindsey et al. 2013) and in forests (Macdonald et al. 2012). Reductions in the availability of bushmeat adversely impact the food security of the rural poor in particular, as bushmeat makes up a disproportionately large fraction of their protein intake (Allebone-Webb 2009, Davies & Brown, 2007). Actions to improve the sustainability of bushmeat hunting can target both supply, for example through providing alternative livelihoods for hunters (van Vliet 2011; Moro et al, 2013); or demand, through changing the purchasing habits of consumers (Rentsch and Damon, 2012). Among the many approaches that have been suggested to reduce demand for bushmeat is the provision of alternative protein sources that are potential substitutes in household diets (Wilkie et al, 2005). For example, in the Nouabalé-Ndoki concessions of Northern Congo, timber companies have provided domestic animal protein to timber camp inhabitants as part of a strategy for reducing bushmeat harvests in the vicinity (Poulsen et al. 2007). Similarly, in the Serengeti region of Tanzania, the provision of veterinary care to improve chicken health and productivity was initiated as an approach to reduce the illegal hunting of bushmeat in the National Park (Rentsch 2012). However, there is still very little evidence of the impact of these types of approach in terms of actual reductions in bushmeat consumption. Without such evidence, the quantitative effects of conservation policies aimed at reducing household demand for bushmeat are unknown.

Changes in the quantity of bushmeat bought in an urban market or consumed in rural areas depend on a number of factors which affect both the own price and cross-price elasticities of demand for bushmeat (the effect of changes in price of the good itself and price and quantity of appropriate substitutes on quantity of the good demanded). These factors include consumer tastes and habits, household income and ethnicity. The drivers of bushmeat consumption need to be understood if demand-focussed conservation interventions are to succeed in reducing pressures on wildlife populations. Furthermore, it is important to be able to predict the effects of externally-driven changes in the price or availability of substitutes like fish or domestic livestock, so as to act proactively in the face of changes in substitute prices. For example, the price of marine fish in Ghana varied considerably over the period 1965-1998, as a function of catches, in turn determined by stock sizes and fishing effort (Brashares et al. 2004). Years of low supply (and thus high prices) coincided with periods of increased demand for bushmeat species, as consumers switched to cheaper bushmeat as a protein source, and away from more expensive fish. A supply side effect also occurred, in that as demand for bushmeat increased, observed hunting effort (as measured by the number of hunters spotted by wildlife rangers in Ghana) increased. The outcome was an increased rate of population decline of bushmeat species in years with higher fish prices, with this effect being stronger in National Parks closer to the coast.

Evidence on the sign and magnitude of such elasticities of demand for bushmeat is to date rather limited. This is partly due to the difficulty of observing prices for an informal, often illegal good such as bushmeat in poor countries with low institutional capacity for regular monitoring. Long-term datasets on prices and quantities of bushmeat are rare, and those that include substitutes are non-existent (Crookes et al. 2005). The first study to estimate the cross-price elasticities of bushmeat and substitutes (Wilkie & Godoy, 2001) uses a dataset for 443 households in Bolivia, and found that bushmeat consumption did not respond to the price of some protein substitutes. However, they were only able to generate proxies for bushmeat prices (fish prices), casting some doubt on the interpretation of some of their elasticity estimates in the present context. Wilkie et al (2005) surveyed 1208 rural and urban households in Gabon and found a negative own-price elasticity of demand for bushmeat, with a statistically significant and positive cross-price elasticity between bushmeat consumption and fish as a protein substitute. However, there was no significant effect of chicken prices (another substitute protein source) on household bushmeat consumption. Brashares et al. (2011) found a negative effect of the ratio of bushmeat price to alternative protein prices on bushmeat consumption. Using detailed primary data on household consumption patterns for 131 households in the Serengeti, Rentsch and Damon (2013) found that beef, dried sardines and other fish all acted as substitutes for bushmeat in western Serengeti, Tanzania. They also found that increases in the price of bushmeat had “direct and large... effects on bushmeat consumption”. These studies all used revealed preference data to estimate elasticities. However, stated preference techniques may be more appropriate for the study of bushmeat systems, as discussed in section 3.

A range of non-price factors which potentially influence consumption, alongside own prices and the price of substitutes, have been investigated in the empirical literature on bushmeat consumption. Among the main factors found to be important have been the following, which were used to inform the modelling exercise described in Section 5.

- Household income or wealth: Bushmeat consumption can be rising or falling with income, depending on whether rural or urban demands are considered. In rural areas, the evidence to date suggests that poor rural households are generally disproportionately reliant on bushmeat both for protein and income (e.g. Allebone-Webb 2009, Coad et al. 2010, Macdonald et al. 2012, Nielsen 2006), while in urban areas bushmeat is likely to be more of a luxury good for the rich (Wilkie et al, 2005, East et al. 2005). Wilkie et al (2005) found a non-linear effect of wealth on bushmeat consumption in Gabon, with small increases in the wealth of poorer households having bigger, positive effects on bushmeat consumption than equivalent increases in wealth for richer households. Rentsch and Damon (2013) show that in the western Serengeti, increasing income would lead to growing demand for bushmeat, as well as for other protein types. Brashares et al (2011) find a significant interaction effect between household wealth and the price of bushmeat relative to the prices of other protein sources.
- Consumer tastes: Very obviously, changes in consumer tastes will produce effects on demand for bushmeat. Understanding the link between bushmeat consumption and preferences is important, since if people would prefer to eat bushmeat but cannot at present afford it, then this has rather different implications over time compared with a situation of people eating bushmeat rather than a more preferred protein source because it is cheaper. Schenck et al (2006) carried out a taste test amongst 237 consumers in Gabon, Central Africa, which showed that in blind tests people were able to distinguish bushmeat (porcupine and blue duiker) from substitutes (chicken and beef). Only a minority of respondents in three locations (city, town,

village) preferred bushmeat over substitutes and also had clear preferences over which type of bushmeat they preferred, indicating that it would be possible to get consumers to substitute away from eating endangered species to more abundant ones. Taste preferences evolve, both as a function of availability of different foodstuffs and social changes. For example, East et al. (2005) found a mismatch between the wishes of urban consumers in Bata, Equatorial Guinea (for fresh bushmeat and fish) and what they could afford to buy (frozen fish and chicken). This is of concern because with the oil boom in Equatorial Guinea, the wealth of consumers in Bata is increasing, which may lead to a rapidly increasing trend in bushmeat consumption.

- Ethnicity: Cultural preferences for hunted meat may differ between ethnic groups. In the western Serengeti, qualitative studies into cultural aspects of bushmeat hunting suggest strong preferences for bushmeat over other meats and fish (Lowassa et al. 2012). Fa et al (2002) found clear cultural differences between two ethnic groups on Bioko island, Equatorial Guinea; the Fang, who are continental in origin, preferred a range of species including many not found on the island, and also had a wide range of meat taboos, while Bubi agriculturalists preferred species more often found in agricultural areas. In a study by Ndibalemma and Songorwa (2007) in western Serengeti, Ikoma tended to consume more meat, including more bushmeat, than Sukuma, followed by Kurya. Mfunda and Røskaft (2010) suggest that this might be due to the Ikoma's hunter-gatherer tradition, as opposed to the Sukuma's and Kurya's history as agro-pastoralists.

Following on from these insights, it is clear that there is a need to understand the socio-demographic factors underlying the demand for bushmeat, as well as the proximate, marginal, effects of changes in prices and quantities of bushmeat and substitute protein sources. In particular, differences in elasticities between demographic and socio-economic groups are vital to understanding the drivers of bushmeat consumption, and therefore for formulating robust and sustainable policy for management of bushmeat hunting. We make use of a stated preferences approach to estimate these demand elasticities, since this has some important advantages over alternative approaches, as explained below.

3. Choice of Methodology

In order to understand the likely responsiveness of consumer demand for bushmeat to price changes for substitute sources of protein such as chicken or fish, the need is for a method which reveals changes in demand for a wide range of price changes, whilst controlling for other influences on demand. Stated preference approaches have been widely used in a range of fields, including environmental economics, health economics and transport research since the 1970s. A stated preference approach (in which individuals state their choices for alternative hypothetical consumption options, rather than revealing their preferences through actual purchases) permits the analyst to consider intended behavioural responses to changes in attribute levels both across and beyond the range of current observations. This supports the design of interventions which aim to promote substantial changes in system dynamics.

Stated preference methods offer advantages over revealed preference methods in the context of our study. In summary, these are (i) much bushmeat hunting is illegal, so consumers have an incentive to under-report their actual purchases, so that market data may be unreliable or unobtainable; (ii) revealed preference data based on household consumption surveys can be subject to recall errors; (iii) the stated preference approach allows us to look at potential substitution opportunities which are not currently available to consumers; (iv) stated preference data are not confounded with seasonal variations in the populations of wildlife which is hunted for bushmeat (e.g. seasonal wildebeest migrations in the Serengeti; Thirgood et al. 2004). Our approach also allows us to investigate the variations in bushmeat demand across a wide set of household characteristics, which helps conservationists better to target their interventions and to predict the effects of interventions such as price and availability changes on vulnerable groups such as poor households. Our stated preference approach also avoids the endogeneity problem which complicates the use of market transactions data to identify the parameters of demand. Of course, problems also exist with stated preference methods, notably their lack of incentive compatibility - incentive to answer truthfully - except in very particular circumstances (Vossler et al, 2012) and the sensitivity of preference and value estimates to the information provided to respondents (Munro and Hanley, 2002). However, the advantages were judged to outweigh these disadvantages in the present context.

4. Case study design.

Survey area and experimental design

We carried out this study in the area west of the Serengeti National Park, which is important both for conservation and because it is home to a poor and growing rural population (Sinclair & Packer 2008). Hunting of bushmeat species carried out within the National Park is illegal, and hunting outside the Park is de facto illegal because it requires a permit which is rarely obtained. Despite this, hunting still occurs to a considerable degree (Nuno et al., 2013). Four features of the stated preference experimental design were crucial:

The first concerns the choice of substitute goods. In the western Serengeti, bushmeat is bought dried in informal markets in units of "pieces". Qualitative survey development work with households in the area suggested that a series of three-way choices between bushmeat, fish and chicken would be too hard for people to complete. Thus, choices were simplified to two-way choices between bushmeat and fish, or between bushmeat and chicken. We used two split sample treatments to evaluate consumer demand for this illegal good, one in which participants were offered pieces of dried bushmeat and "live adult healthy" chickens as substitutes for bushmeat at a range of prices ("chicken SP", from now on), and another in which participants were offered pieces of dried bushmeat and pieces of good quality dried fish (“fish SP” in the remainder). We used a piece of paper to show survey participants how big the “piece” of bushmeat or fish we were referring to was, choosing a size approximating the amount bought in a typical single purchase for an average household. Feedback from survey enumerators and responses from households to the survey showed that people understood well the hypothetical choices that they were being asked to make.

The second important design feature concerned price levels for bushmeat, fish and chicken. The range of prices used was based on the experience of enumerators in the study area. In each split sample treatment, every respondent was confronted with six choice situations and asked how many pieces of bushmeat and fish (or chicken) they would buy, given specified price levels. The price levels for 1 piece of bushmeat consisted of: TSh 500, TSh 1,500, TSh 3,000 and TSh 4,500; the price levels for 1 piece of good quality fish was TSh 1,000, TSh 3,000, TSh 5,000 and TSh 7,000; whilst a chicken had four price levels: Tsh 6,000; Tsh 9,000; Tsh 12,000 and Tsh 15,000 (at the time of writing, 1US$ = 1636 Tsh).

The third crucial aspect regards the need to reduce possible hypothetical bias arising in such experiments. The questionnaire thus reminded participants to think about their budget constraints in deciding how much they would buy at any price, and that it was perfectly acceptable to state that they were not willing to buy any quantity at a given price. A “cheap talk” script was also used, reminding people that respondents often overstate their willingness to pay in stated preference studies (List et al, 2006)[1].

The fourth feature of the design is how respondents state their preferences. We decided to adapt a standard choice experiment method to one where respondents are asked to state how many units of each good they would purchase at a range of prices, based on the study by Corrigan et al (2009).

[1] The text used was as follows: “Often, people respond to questions like this in a different way than they act in real life. It is quite common to find that people say they are willing to buy more than they are really willing to buy in real life. Please consider how much money you have. It is perfectly fine if you are not willing to buy anything.”

This “open-ended choice experiment” mimics the consumption decision which households face when purchasing bushmeat and other proteins in real markets (see Appendix 1). Attribute combinations were obtained using a fractional factorial design. We generated 12 choice situations randomly from the full set and included blocking so that each respondent was shown 6 choice tasks (i.e., cards) from the total of 12. The design was obtained using Ngene software. Information on socio-demographic characteristics at individual and household levels was collected after the administration of the choice tasks.

Data collection

We conducted our survey in six villages in western Serengeti, located between the Serengeti National Park, Lake Victoria and Grumeti Game Reserve. Bushmeat hunting takes place either locally near the villages when the wildebeest and zebra migration moves through the western corridor – usually twice a year – or occurs illegally in protected areas, often through hunting trips that can take several weeks (Moro et al, 2013). The villages were located between 2 and 24 km from the national park, and between 0 and 40 km from the game reserve. Lake Victoria is an important source of fish for this area, and is available in markets mostly in a dried form.

Frankfurt Zoological Society (FZS) and the Tanzania Wildlife Research Institute (TAWIRI) have conducted regular surveys in these villages over several years, and enumerators and respondents had built up trust with both organisations. Members of 16 households per village were interviewed by two local enumerators in each village, leading to an overall sample size of *n*=200. Most enumerators and half of the sample had participated in previous surveys conducted by FZS and TAWIRI and were thus broadly familiar with interviews of this kind. Half of the respondent households were part of a panel that had previously been selected at random for a different survey looking at protein intake (Rentsch 2012). The remaining households were selected as the nearest neighbours of the households in this existing panel.

The person in the household who usually did the food purchase and preparation was chosen where available, usually the wife of the household head. Where these were not available, we interviewed the household head or another male in the household. Overall, around 45% of respondents were female.

All enumerators were thoroughly trained in the administration of the choice experiments and conducted several interviews supervised by the team. After a qualitative pre-test and a quantitative pilot test, the enumerators conducted the main survey between December 2010 and February 2011. Choice sets were evenly distributed within each village. Each version of the stated preference exercise was administered to 100 households, with a final sample size of n=87 for the fish SP, and n=94 for the chicken SP. Table 1 summarises the data used in the econometric analysis.

5. Econometric specification

The empirical strategy we follow is to estimate elasticities of demand for bushmeat while controlling for factors suggested by the literature to be important determinants of bushmeat consumption (section 2). Specifically, we test for the effects of household wealth (proxied by cattle ownership and number of people in employment), tastes, cultural factors as proxied by ethnic group membership, and household size, as bigger households might be more sensitive to price changes than smaller ones . We also interact household and respondent characteristics for which a plausible effect on preferences could be postulated and for which we have data; these are the education level of the head of household, and the gender and age of the respondent.

The basic model to be estimated from each of the two sub-samples (fish as a substitute for bushmeat, chicken as a substitute) was specified as:

$$bq_{i,t} = \alpha_i + \beta_1 \log(bp_{i,t}) + \beta_2 \log(sp_{i,t}) + \gamma' \big(\log(bp_{i,t})\big)(h_i) + \vartheta' \big(\log(sp_{i,t})\big)(h_i) + \varepsilon_{i.t} \qquad (1)$$

where:

- $bq_{i,t}$ is a count variable of the quantity (pieces) of bushmeat chosen by individual *i* in choice set t,
- $bp_{i,t}$ is the the price of bushmeat,
- $sp_{i,t}$ is the price of the substitute good, either fish or chicken,
- h_i is a variable (and sometimes a vector of variables) which represents household characteristics which are household size, ethnicity, and household wealth, here operationalised as cattle ownership and number of occasional/full time workers in the household, or individual characteristics related to respondent's taste preferences towards fish/chicken and bushmeat (measured on a Likert scale), respondent's education, gender and age. These variables reflect the factors set out in Section 2 as being potentially important factors in determining consumer demand for bushmeat in Africa.

Given the count nature of our dependent variable, we chose to use the Poisson quasi-maximum likelihood estimator (QMLE) as it produces robust standard errors and consistent estimates under the relatively weak assumption that only the conditional mean is correctly specified (Wooldridge 1999)[2]. This implies that the conditional distribution of the dependent variable need not be Poisson distributed. A common concern that arises when implementing a Poisson model is the possibility of over- or under-dispersion in the data, as this can lead to an under-estimate of the standard errors. An attractive feature of the quasi-maximum likelihood framework that we have adopted is that produces robust standard errors even in the case of over- or under-dispersion (Simcoe 2007; Wooldridge, 1999, 2002).

Because the same respondent answered multiple choice sets we also included individual fixed-effects in the results reported in Table 2. Differences brought about by wealth and other socio-demographic characteristics are controlled for by these individual fixed effects. For these reasons, the model just described constitutes our favourite model. However, for robustness purposes, we also run

[2] This is estimated using the –xtpoisson- command with –fe- and –robust- options in Stata 11.

random-effects Poisson regressions[3]. In every model, β_1 and β_2 can be interpreted as elasticities while the coefficients on the interaction terms, γ' and ϑ', between prices and socio-demographic characteristics provide a test of whether these elasticities vary statistically significantly across different groups.

6. Results

Table 2 reports the results of the simplest models in which bushmeat quantity is regressed on the log of prices of bushmeat and each of the substitute protein source prices one at a time. The first two rows present models which control for variations in *individual* (observed and unobserved) characteristics as a fixed effects estimator has been used. In addition, recall that inference is based on standard errors robust to both over-dispersion and heteroskedasticity. The coefficients on the log of prices can be directly interpreted as elasticities. As expected, the quantity of bushmeat demanded was negatively associated with the price of bushmeat, while it was positively associated with prices of both substitute goods. Elasticity estimates were statistically significant in each of the specifications shown. The demand for bushmeat was inelastic with regard to its price and to the price of protein substitutes. A 1% increase in the bushmeat price led to a decrease in the quantity of bushmeat demanded roughly equal to 0.7%, on average. The change in the price of fish has a slightly bigger effect on the quantity demanded of bushmeat than a change in the price of chicken. A 1% increase in the fish price was associated with a 0.37% increase in the quantity demanded for bushmeat (on average), while a 1% increase in chicken price was related to an increase of bushmeat demanded of about 0.29% (on average). Given that households consume on average 2.7 kg of bushmeat a week (Rentsch & Damon, 2013), and there are around 52,600 households in the area (calculation based on household size estimated in the study and

[3] Random effects models are estimated using the –xtpoisson- command with –re- option in Stata11. Random effects models require the individual-level residual to be uncorrelated with any of the covariates, which is a very strong assumption. Any individual unobserved factor is “differenced out” when using fixed-effects models.

population estimate from the 2002 census; NBS Tanzania 2006), a 1% bushmeat price increase would lead to a drop in weekly bushmeat consumption in the area of about 1 tonne, ceteris paribus. Results are similar when using random effects. Thus, in what follows we present only fixed-effects models.

Table 3 extends the analysis by studying heterogeneous preferences across socioeconomic and ethnic groups by running regressions in which the log of the price of bushmeat and the log of the price of each substitute protein is interacted with individual or household characteristics as described in Table 1. We report two versions for chicken and for fish, the first being where household size and household wealth are excluded, and the second where these variables are included. Interaction terms effectively test for the equality of elasticity values across the characteristics reported in Table 1. The bottom row of the table reports the average marginal effects for each focal variable (bushmeat or substitute price). The effect of a marginal change in the price on bushmeat quantity is computed for every observation and the effects are then averaged. These average marginal effects correspond to elasticities that are directly comparable with Table 2. The own-price elasticity of demand for bushmeat is robustly estimated to be around 0.66-0.69 across all models. Cross price elasticities are somewhat higher than in Table 2, around 0.32 for chicken and around 0.48-0.53 for fish.

The effects of these household and individual factors on consumption choices were generally much less strong than the price effects, and they differed between the two substitute goods. Many of these variables have insignificant effects on choices. Household size, however, seems to matter: Consumption of bushmeat was more sensitive to the price of bushmeat in the chicken SP for larger households. The cross-price elasticity is higher in larger households when fish was used as substitute. Individuals stating a higher degree of preference towards bushmeat were less sensitive to changes in its price, and more responsive to the price of the substitute protein. Consumption of bushmeat was not affected by the price of chicken for individuals who rated chicken higher. Neither household wealth (as proxied by cattle holding) nor household income (as proxied by number of household members with a paid job) were significant determinants of the size of the own- or cross-price elasticity estimates.

There were some effects of ethnic group on the reaction to a change in the price of bushmeat and the protein substitute. Relative to people from the Sukuma group, people from the Ngoreme group were more responsive to changes in bushmeat prices. Relative to the Sukuma group, people from Ngoreme and Kurya groups were more responsive to changes in the substitute protein price when the substitute was chicken. When the substitute was fish, Ngoreme reacted again more strongly to substitute price changes, but Kurya were less sensitive. We note that most Ngoreme in our sample lived relatively far from the protected areas and thus from the main hunting areas, and were hence used to relatively high bushmeat prices.

We also ran models in which we investigated the effects of the education level of the head of the household, and the gender and age of respondent as interactions with own- and cross-price elasticities. In most cases, no significant effect was found. Finally, we included interaction terms between a variable which measured how difficult respondents found the choice experiment with the own- and cross-price elasticities, but this was never significant. To save space, these additional model results are not reported here, but can be supplied on request.

7. Discussion and conclusions

This study used a stated preference approach known as an open-ended choice experiment to establish own- and cross-price elasticities for bushmeat consumption. We undertook this work in an iconic ecosystem where illegal bushmeat hunting is widespread (Nuno et al, 2013) and perceived as a threat to biodiversity and to the livelihoods of poor rural households. The stated preference exercise method produced highly significant and robust estimates of demand elasticities, showing bushmeat to be a normal good, inelastic to its own price and to the price of its substitutes. We also showed that fish and chicken are indeed substitute goods for bushmeat in the region, as evidenced by the significance of the elasticity estimates; this has been shown elsewhere in various other studies (e.g. Brashares et al. 2004; Wilkie et al, 2005; Brashares et al, 2011). This is evidence in support of policies which aim to reduce hunting pressure on threatened wildlife populations by reducing the demand for bushmeat.

It is interesting to compare the results reported here with Rentsch and Damon (2013), who used a revealed preference technique based on dietary recall surveys of protein consumption by 131 households over a 34 month period in the same study area. Revealed preference studies have limitations of zero inflation (73% of fish and 55% of bushmeat consumption data points were zeros in their study, for example), with recall accuracy, and lack of price information when meat is not purchased legally. The strengths are in the fact that the data represent real rather than hypothetical behaviour. Rentsch and Damon could not estimate a chicken model because chicken is usually slaughtered at home rather than bought, so that only 15% of their observations had associated prices for chicken. Their Hicksian (income compensated) cross-price elasticity estimate for fish of 0.61-0.83 is higher than our estimate of 0.48-0.53 (Table 3), whilst their bushmeat own price estimate of -0.69 is very close to our estimate of -0.66 to -0.69 (Rentsch and Damon, 2013, Table 4).

Our cross-price elasticity results suggest that any reduction in the price of either fish or chicken would decrease bushmeat consumption. As chicken is a low input product that is produced by individual households there is the potential to target it for livelihood improvement projects that could raise the nutritional status of poor households while reducing the demand for bushmeat. This was the rationale behind the chicken health project instituted by FZS and reported in Rentsch (2012). However, according to our enumerators, for many families, chicken is a valuable source of income. Live chickens are often sold on the market to purchase bushmeat, because for the same price, a much larger amount of bushmeat can be bought than the amount of meat one single chicken provides. This implies that conservation support for chicken husbandry might indirectly increase demand for bushmeat. Aquaculture may have potential as a way of increasing fish availability and thereby reducing price; however, lack of water in dry season and malaria risks related to fish ponds can be seen as obstacles to the local production of fish.

Conversely, an increase in the price of substitutes would increase demand for bushmeat. This is possibly the finding from our study with the highest conservation relevance, as it highlights that bushmeat demand depends not only on bushmeat prices, but also on the prices of their substitutes – which might rise due to external factors, such as an increase in the human population of the area, or a decline in the Lake Victoria fishery (Sinclair & Packer 2008). The coefficient on the own-price elasticity of bushmeat is higher that of the substitutes, however, and so consumption is more sensitive to increases in the bushmeat price than to substitute prices. Increasing the price of bushmeat is potentially more achievable by conservation authorities. For example an increase in law enforcement that raised the cost of poaching in the National Park would simultaneously protect wildlife and raise bushmeat prices if much of the current supply is, as suspected by conservationists, emanating from the National Park. Transport costs are significant components of the cost of bushmeat supply (Crookes et al. 2005), and therefore if it needed to be sourced from elsewhere, the price would be likely to rise.

We did not find a strong effect of wealth or household income on consumer responses to price changes. Other studies have estimated positive income elasticities of bushmeat consumption (e.g. Wilkie et al. 2005, Brashares et al. 2011), as did Rentsch & Damon (2013) using expenditure as a proxy for income. Fa et al. (2009) found a relationship between wealth and bushmeat consumption but showed that it exhibited substantial geographic variation. Brashares et al. (2011) found no significant effect of wealth on bushmeat consumption, but showed that wealth moderated the effects of relative price and distance from market. They cautioned that many studies investigating the relationship between wealth and bushmeat consumption without reference to these other factors may be affected by confounding variables and that the relationships found may therefore be misleading. Our study is rather different in estimating the effects of wealth on people's responses to price changes, rather than on total consumption, which may explain the lack of an effect.

Our findings demonstrate the usefulness of a stated preference method (open-ended choice experiments) which is new to bushmeat research. Choice experiments have been used to some degree to investigate other issues in bushmeat hunting, for example hunter behaviour (Moro et al, 2013), and of course more widely to explore policy options for conservation in developing countries (Naidoo and Adamowicz, 2005; Minin et al, 2012). The open-ended choice experiment employed here proved to be a useful tool for modelling the responsiveness of consumers to changes in bushmeat prices and the prices of substitutes: our respondents understood the choice tasks well, and found the choices to be realistic.

The study also has implications for broader policy debates about the viability of alternative protein sources as a way of reducing demand for bushmeat. We have shown that the price elasticities of demand for bushmeat are substantial and significant enough for price changes to have potentially large impacts on the quantity of bushmeat consumed. This suggests that it would be worthwhile for conservationists to explore the potential both of demand-side measures focussed on alternative protein ources as well as on supply-side measures (such as increased law enforcement, or providing livelihood alternatives to illegal hunting in reducing pressures on endangered wildlife populations.

References

Allebone-Webb, S. (2009) Evaluating dependence on wildlife products in rural Equatorial Guinea. PhD thesis, Imperial College London. Available online at www.iccs.org.uk.

Bennett, E.L., Blencowe, E., Brandon, K., Brown, D., Burn, R.W., Cowlishaw, G.C., Davies, G., Dublin, H., Fa, J., Milner-Gulland, E.J., Robinson, J.R., Rowcliffe, J.M., Underwood, F., Wilkie, D. (2007) Hunting for Consensus: a statement on reconciling bushmeat harvest, conservation and development policy in west and central Africa. *Conservation Biology* 21, 884-887.

Brashares J., Arcese P., Sam M., Coppolillo P., Sinclair A. and Balmford A. (2004) “Bushmeat hunting, wildlife declines and fish supply in West Africa”. *Science*, 12 November, 306, 1180-1183.

Brashares J, Christopher D. Golden, Karen Z. Weinbaum, Christopher B. Barrett, and Grace V. Okello (2011) “Economic and geographic drivers of wildlife consumption in rural Africa” *PNAS* 2011 108 (34) 13931-13936

Campbell, K.L.I., Nelson, V. and Loibooki, M. (2001) "Sustainable use of wildland resources: ecological, economic and social interactions: an analysis of illegal hunting of wildlife in Serengeti National Park, Tanzania". National Resources Institute, Final Technical Report, Chatham, Kent, UK, Department for International Development (DFID) Animal Health Programme and Livestock Production Programmes.

Coad, L., Abernethy, K., Balmford, A, Manica, A, Airey, L., Milner-Gulland, E.J. (2010) Distribution and use of income from bushmeat in a rural village, Central Gabon. *Conservation Biology* 24, 1510-1518

Corrigan J., Pura D., Depositario T., Nayga R., Wu X. and Laude T. (2009) “Comparing open-ended choice experiments and experimental auctions: an application to golden rice” *American Journal of Agricultural Economics* 91(3), 837-853.

Crookes, D.J., Ankudey, N., Milner-Gulland, E.J. (2006) The value of a long-term bushmeat market dataset as an indicator of system dynamics. *Environmental Conservation* 32, 333-339.

Davies G. and Brown D. (2007) *Bushmeat and Livelihoods: Wildlife Management and Poverty Reduction.* Oxford: Blackwell Publishing.

East T., Kumpel N., Milner-Gulland E.J. and Rowcliffe M. (2005) “Determinants of urban bushmeat consumption in Rio Muni, Equatorial Guinea” *Biological Conservation*, 126 (2), 206-215.

Fa, J. E., Juste, J., Burn, R. W., & Broad, G. (2002). Bushmeat consumption and preferences of two ethnic groups in Bioko Island, West Africa. *Human Ecology*, *30*(3), 397-416.

Fa, J.E., L. Albrechtsen, P. J. Johnson, D. W. Macdonald (2009) Linkages between household wealth, bushmeat and other animal protein consumption are not invariant: evidence from Rio Muni, Equatorial Guinea *Animal Conservation*, 12: 599–610

Gabor, A., C. Granger, and A. Sowter. (1970). "Real and Hypothetical Shop Situations in Market Research." *Journal of Marketing Research* 7:355–59.

Lindsey PA. et al (2013) "The bushmeat trade in African savannas: impacts, drivers and possible solutions". *Biological Conservation,* 160, 80-96.

List, J.A., Sinha, P., Taylor, M.H. (2006) "Using choice experiments to value non-market goods and services: Evidence from field experiments" *Advances in Economic Analysis and Policy*, 6 (2), pp. 23-61

Lowassa, A., Tadie, D. & Fischer, A. (2012). On the role of women in bushmeat hunting – insights from Tanzania and Ethiopia. *Journal of Rural Studies* **28**, 622-630.

Maynard, L., J. Hartell, L. Meyer, and J. Hao. (2004). "An Experimental Approach to Valuing New Differentiated Products." *Agricultural Economics* 31:317–25.

MacDonald D., Johnson B., Albrechtsen L, Seymour S., Dupain J., Hall A. and Fa J. (2012) "Bushmeat trade in the Cross-Sanaga rivers region: evidence for the importance of protected areas" *Biological Conservation,* 147 (1), 107-114.

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

Minin E.D., Fraser I., Slotow R. and MacMillan D. (2012) "Understanding heterogeneous preferences of tourists for big game species: implications for conservation and management" *Animal Conservation,* 16, 249-258.

Moro M, A. Fischer, M. Czajkowski, D. Brennan, A. Lowassa, L. C. Naiman and N. Hanley (2013) "An investigation using the choice experiment method into options for reducing illegal bushmeat hunting in western Serengeti" *Conservation Letters,* 6: 37-45.

Munro, A., and Hanley, N. D., 2002. Information, Uncertainty, and Contingent Valuation. In: *Valuing Environmental Preferences*, I. J. Bateman and K. G. Willis, eds., Oxford University Press.

Naidoo R. And Adamowicz W. (2005) "Economic benefits of biodiversity exceed costs of conservation at an African rainforest reserve" *Proceedings of the National Academy of Sciences,* 102 (46), 16712-16716.

NBS Tanzania. (2006) Tanzania Census 2002 - Analytical Report.

Ndibalemma, V.G., Songorwa, A., N. 2007. Illegal meat hunting in Serengeti: dynamics in consumption and preferences. *African Journal of Ecology* 46: 311-319.

Nielsen M.R. (2006) "Impacts, causes and effects of bushmeat hunting in the Udzungwa Mountains, Tanzania" *Biological Conservation*, 128, 509-516.

Nuno, A., Bunnefeld, N., Naiman, L., Milner-Gulland, E.J. (2013) Applying novel methods to assess the prevalence and drivers of illegal bushmeat hunting in the Serengeti *Conservation Biology*, 27 (6), 1355-1365.

Pilon, T. 1998. "Extensions to the Analysis of Choice Studies." Sawtooth Software Research Paper Series. Available at: http://www.sawtoothsoftware.com/download/techpap/extend.pdf

Poulsen, J.R., Clark, C.J., Mavah, G.A. (2007) Wildlife management in a logging concession in northern Congo: Can livelihoods be sustained through sustainable hunting? P.140-157 In: Eds G. Davies & D. Brown, *Bushmeat and Livelihoods: Wildlife management and poverty reduction.* Blackwell, Oxford.

Rentsch, D. (2012). The nature of bushmeat hunting in the Serengeti Ecosystem, Tanzania – socio-economic drivers of consumption of migratory wildlife. PhD dissertation, University of Minnesota.

Rentsch, D., Damon, A. (2013). "Prices, Poaching, and Protein Alternatives: An analysis of bushmeat consumption around Serengeti National Park, Tanzania". *Ecological Economics*, 91: 1-9.

Schenck M., Effa E., Starkey M., Wilkie D., Abernethy K., Telfer P., Godoy R. and Treves A. (2006) "Why people eat bushmeat: results from two-choice taste tests in Gabon" *Human Ecology*, 34 (3), 433-445.

Simcoe, T. (2007). XTPQML: stata module to estimate fixed-effects Poisson quasi-ml regression with robust standard errors. Boston: Boston College Department of Economic

Sinclair A. and C. Packer, editors. *Serengeti III: human impacts on ecosystem dynamics.* University of Chicago Press, Chicago, IL. 2008

Thirgood S. , A. Mosser, S. Tham, G. Hopcraft, E. Mwangomo, T. Mlengeya, M. Kilewo, J.Fryxell, A. R. E. Sinclair and M. Borner (2004) "Can parks protect migratory ungulates? The case of the Serengeti wildebeest" *Animal Conservation* **7**, 113–120

Van Vliet, N. (2011) Livelihood alternatives for the unsustainable use of bushmeat. *Report prepared for the CBD Bushmeat Liason Group. Convention on Biological Diversity Technical series* 60.

Vossler, Christian A., Maurice Doyon, and Daniel Rondeau (2012) “Truth in Consequences: Theory and Field Evidence on Discrete Choice Experiments.” *American Economic Journal: Microeconomics*, 4 (4), 145-171.

Wilkie D.S. and Godoy R.A.(2001) Income and price elasticities for bushmeat demand in lowland Amerindian societies *Conservation Biology,* 19 (1), 268-274.

Wilkie D.S., Starkey M., Abernethy K., Effa E., telfer P. and Godoy R. (2005) Role of prices and wealth in consumer demand for bushmeat in Gabon, Central Africa *Conservation Biology,* 19 (1), 268-274.

Wooldridge, J. M. (1999). Distribution-free estimation of some nonlinear panel data. *Journal of Econometrics,* 90(1), 77–97.

Wooldridge, J. M. (2002). *Econometric analysis of cross section and panel data.* Cambridge: MIT Press.

Table 1 Descriptive statistics of respondents in the chicken and fish choice experiments.

Variable	Description	Chicken CE				Fish CE			
		Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Log of bushmeat quantity	Continuous variable	1.91	2.00	0	10	1.81	2.45	0	20
Log of bushmeat price	Continuous variable	7.49	0.83	6.21	8.41	7.48	0.83	6.21	8.41
Log of substitute price	Continuous variable	9.20	0.34	8.70	9.62	8.07	0.73	6.91	8.85
HH Wealth	Dummy variable taking the value of 1 if household owns # of cattle > than median	0.57	0.49	0	1	0.52	0.50	0	1
# of HH in full-time job	Continuous variable indicating number of household members with full-job	0.14	0.43	0	2	0.27	0.61	0	3
# of HH members w/ job	Continuous variable indicating number of household members with some job	1.11	1.39	0	8	0.79	1.17	0	5
HH size	Continuous variable indicating total number of household members	7.59	3.45	2	18	8.13	3.60	1	22
Bushmeat rating	Continuous variable rating preference for? bushmeat on a scale from 0 to 10	6.29	3.41	0	10	7.04	2.86	0	10
Substitute rating	Continuous variable rating preference for substitute on a scale from 0 to 10	8.25	2.68	0	10	7.48	2.89	0	10
Sukuma	Dummy variable taking the value of 1 if household belong to the Sukuma ethnic group	0.16	0.37	0	1	0.20	0.40	0	1
Ngoreme	Dummy variable taking the value of 1 if household belong to the Ngoreme ethnic group	0.17	0.38	0	1	0.16	0.37	0	1
Nata	Dummy variable taking the value of 1 if household belong to the Nata ethnic group	0.13	0.33	0	1	0.09	0.29	0	1

Ikoma	Dummy variable taking the value of 1 if household belong to the Ikoma ethnic group	0.28	0.45	0	1	0.32	0.47	0	1
Kurya	Dummy variable taking the value of 1 if household belong to the Kurya ethnic group	0.17	0.38	0	1	0.13	0.33	0	1
Others	Dummy variable taking the value of 1 if household belong to the Singita, Jita, Zanaki, Isenye, Ikizu, Manyema, Luo, Kisii, Hangaza, Simbiti ethnic groups	0.09	0.29	0	1	0.10	0.29	0	1
Female	Dummy variable taking the value of 1 if the respondent is female	0.37	0.48	0	1	0.50	0.50	0	1
Old	Dummy variable taking the value of 1 if the respondent's age is above sample median age	0.49	0.50	0	1	0.51	0.50	0	1
Education	Continuous variable indicating years of education of respondent	6.33	2.99	0	12	6.50	2.91	0	13
CE difficult	Variable taking the value of 1 if the respondent answered "no" or "so-so" if the respondent found the CE difficult, = 2 otherwise.	1.60	0.49	1	2	1.51	0.50	1	2

Table 2 Bushmeat price and cross price elasticities from a simple stated choice model

Effects on bushmeat quantity purchased when substitute is...				
	Chicken	Fish	Chicken	Fish
	Fixed effects QMLE		Random effects	
	(1)	(2)	(3)	(4)
Log of bushmeat price	-0.657**	-0.703**	-0.656**	-0.705**
	(0.06)	(0.058)	(0.040)	(0.040)
Log of substitute price	0.286**	0.371**	0.287**	0.371**
	(0.078)	(0.052)	(0.108)	(0.058)
Observations	522	562	600	598
Number of id	87	94	100	100
Log-likelihood	-534.5	-498.9	600	598

Notes: Fixed Effects QMLE indicates coefficients obtained by estimating fixed effects (QMLE) Poisson regressions. Heteroskedastic and overdispersion-robust standard errors in parentheses.. Fixed effects at the level of the individual respondent are included.

Table 3. Models of stated choice when household and individual-level characteristics are included.

	Regressions of bushmeat quantity when substitute is...			
	Chicken		Fish	
	(1)	(2)	(3)	(4)
Log of bushmeat price	-0.215	-0.138	-0.478	-0.551
	(0.378)	(0.358)	(0.336)	(0.350)
Log of substitute price	0.125	0.101	0.974**	0.734**
	(0.274)	(0.351)	(0.256)	(0.250)
(# of HH in full-time job)*(Log of bushmeat price)	-0.163	-0.072	-0.008	-0.041
	(0.133)	(0.127)	(0.070)	(0.062)
(# of HH in full-time job)*(Log of substitute price)	0.122	0.122	-0.034	-0.059
	(0.106)	(0.109)	(0.080)	(0.080)
(# of HH members w/ job)*(Log of bushmeat price)	-0.037	-0.035	0.006	0.003
	(0.035)	(0.038)	(0.059)	(0.057)
(# of HH members w/ job)*(Log of substitute price)	-0.038	-0.037	0.048	0.047
	(0.033)	(0.037)	(0.060)	(0.058)
(Rating of bushmeat)*(Log of bushmeat price)	-0.008	-0.005	-0.028	-0.039
	(0.015)	(0.015)	(0.023)	(0.023)
(Rating of bushmeat)*(Log of substitute price)	-0.048*	-0.047*	-0.047**	-0.054**
	(0.023)	(0.023)	(0.018)	(0.018)
(Rating of substitute)*(Log of bushmeat price)	-0.043	-0.031	-0.008	-0.014
	(0.035)	(0.030)	(0.021)	(0.020)
(Rating of substitute)*(Log of substitute price)	0.015	0.016	-0.032	-0.040*
	(0.023)	(0.023)	(0.018)	(0.017)
(Others)*(Log of bushmeat price)	-0.333	-0.377	-0.051	0.005
	(0.257)	(0.257)	(0.209)	(0.215)
(Ngoreme)*(Log of bushmeat price)	0.303*	0.303*	0.224	0.207
	(0.144)	(0.151)	(0.214)	(0.212)
(Nata)*(Log of bushmeat price)	0.114	0.088	-0.250	-0.246
	(0.194)	(0.193)	(0.151)	(0.159)
(Ikoma)*(Log of bushmeat price)	-0.060	-0.101	0.150	0.157
	(0.178)	(0.173)	(0.185)	(0.189)
(Kurya)*(Log of bushmeat price)	0.047	-0.078	-0.141	-0.272
	(0.153)	(0.180)	(0.200)	(0.206)
(Others)*(Log of substitute price)	0.317	0.321	0.198	0.305
	(0.256)	(0.262)	(0.246)	(0.243)
(Ngoreme)*(Log of substitute price)	0.899**	0.907**	0.719*	0.727*
	(0.266)	(0.252)	(0.336)	(0.328)
(Nata)*(Log of substitute price)	0.120	0.126	-0.116	-0.035
	(0.199)	(0.193)	(0.164)	(0.172)

(Ikoma)*(Log of substitute price)	0.371	0.370	-0.098	-0.047
	(0.276)	(0.286)	(0.163)	(0.155)
(Kurya)*(Log of substitute price)	0.615**	0.617**	-0.311	-0.434*
	(0.229)	(0.224)	(0.194)	(0.188)
(HH Wealth)*(Log of bushmeat price)		0.161		0.081
		(0.130)		(0.124)
(HH Wealth)*(Log of substitute price)		0.005		-0.101
		(0.157)		(0.085)
(HH size)*(Log of bushmeat price)		-0.037*		0.020
		(0.017)		(0.015)
(HH size)*(Log of substitute price)		-0.0001		0.047**
		(0.024)		(0.014)
Average marginal effect of bushmeat price	-0.660**	-0.669**	-0.699**	-0.697**
	(0.051)	(0.048)	(0.049)	(0.048)
Average marginal effect of substitute price	0.329**	0.326**	0.489**	0.537**
	(0.073)	(0.072)	(0.062)	(0.059)
Observations	522	522	557	557
Number of id	87	87	93	93
Log-likelihood	-516.2	-511.3	-479.9	-476.3

APPENDIX 1

Extract from stated preference experiment (chicken and bushmeat sub-sample)

“Now we are going to do a little experiment. I am going to ask you to imagine being in a situation in which you can buy 1 piece of dried bushmeat and 1 chicken for your **household** at the prices given below. Have a look at this piece (show piece of paper), this is how big the piece of bushmeat would be. The chicken would be a live adult male, healthy chicken. How many pieces of bushmeat and how many chicken would you buy?”

“Let me explain to you with the help of a simple example.

So, for example, imagine that I am a vendor who is coming to your house and is offering you 1 piece of dried bushmeat for TSh 2000 and 1 cockerel for Tsh10,000. You have to imagine that you **cannot find** bushmeat or chicken at any other price than this. You can also buy chicken AND bushmeat if you like, and you can buy as many as you can afford.

(*Show the respondent the following prices)*.”

	Desired number of pieces of bushmeat	Desired number of chickens
Price of 1 piece of dried bushmeat Tsh 2000 Price of 1 chicken Tsh 10000		

Now we are going to show you 8 combinations of prices like the one we just showed you. Each represents a different situation with different combinations of prices.