Price effects and the demand for illegally-hunted bushmeat in the Serengeti.

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Abstract

Illegal hunting for bushmeat is regarded as an important cause of biodiversity decline in Africa. In this paper, we consider how those who buy bushmeat as a source of protein – and thus sustain the demand which results in hunting pressure – could be induced to reduce their purchases through falls in the price of substitute sources of protein. The study is a novel application of the stated preference approach to demand estimation, using a choice experiment to elicit bushmeat consumption choices. We estimate the effects of changes in the own price of bushmeat and in the prices of two substitute protein sources – fish and chicken – for households living around the Serengeti in Tanzania. We also investigate how the sensitivity of demand for bushmeat varies across households according to factors including wealth, ethnicity, tastes and household size. We find that a 10% increase in the bushmeat price leads to a decrease in the quantity of bushmeat demanded equal to around 7%. 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. Promoting the availability of either would be effective at reducing demand for bushmeat, and thus pressures on hunted species of wildlife. So would supply-side measures that raise the price of bushmeat.

Keywords: conservation, choice experiment, price elasticity of demand, alternative protein sources, Tanzania, consumption.

1. Introduction

Hunting of wildlife is believed to be a key driver of serious population declines and local species extinctions in many parts of the world (Robinson and Bennett, 2004). Hunting for bushmeat is of particular concern in Africa, where reductions in the population of bushmeat species are of conservation concern, and also adversely impact the livelihoods of the rural poor (Davies & Brown, 2007). Actions to improve the sustainability of bushmeat hunting can target both supply (e.g. through providing alternative livelihoods for hunters: van Vliet 2012; Moro et al, 2013) or demand (through changing the purchasing habits of consumers). Among the many approaches that have been suggested to reduce demand for bushmeat is the provision of alternative protein sources that are potential substitutes for bushmeat 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, that is, 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, for example, consumer tastes and habits, household income and composition, and the effects need to be understood if demand-focussed conservation interventions are to succeed in reducing bushmeat consumption. Furthermore, it is also 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 trends in food 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 good like 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, no significant effect of chicken prices (another substitute protein source) on household bushmeat consumption was found. 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" (page 2).

A range of non-price factors which potentially jointly determine consumption, alongside own prices and the price of substitutes, have been investigated in the empirical literature on bushmeat consumption. Among the main factors considered have been the following.

- 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 (Allebone-Webb 2008, Coad et al. 2010, Albrechtsen et al. 2011), while in urban areas bushmeat is more of a luxury good for the rich (Wilkie 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 to people eating bushmeat rather than a more preferred protein source because it is cheap. 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. (2008) 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. In western Serengeti, qualitative studies into cultural aspects of bushmeat hunting suggest that women have strong preferences for bushmeat over other meats and fish (Lowassa et al. 2012).

- Ethnicity: Cultural preferences for hunted meat may differ between ethnic groups. 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. The empirical strategy we follow is to estimate these elasticities while controlling for factors suggested by the literature to be important determinants of consumption. 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. This analysis enables both the prediction of the effects of potential external shocks on bushmeat consumption, but also 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. 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.

2. 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. 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. The key attributes in our application are the price of bushmeat and the

price of two substitute protein sources, namely fish and chicken. Moreover, the method allows the analyst to control for other influences on demand than the attributes included in the experimental design, such as household income. A stated preference approach can also allow the parameters of the demand function to be estimated without encountering the simultaneity problems or endogeneity bias which might be problematic in using actual market or revealed preference data. Finally, it is a method which is particularly well-suited to an environment with poor market price data availability and/or poor data on household consumption expenditures.

Choice Experiments (CE) are a stated preference method with which demand for any good can be characterised as dependent on multiple attributes of that good. The CE method is now well-known within many branches of economics, and a full description of the principles underlying the method can be found in a number of sources, including Louviere et al (2000) and Hensher, Rose and Green (2005). For brevity, we do not repeat these details here. The "consumption choice experiment" used in the research reported in this paper belongs to the family of hypothetical choice experiment in which participants are presented with multiple goods for sale at different prices. Such choice experiments have a long tradition in the marketing literature (see, e.g., Gabor, Granger and Sowter, 1970, Pilon, 1998). Agricultural economists have more recently begun estimating the value of private goods using non-hypothetical choice experiments. Two papers most similar to the approach used here are Maynard et al. (2004) and Corrigan et al. (2009). Our strategy is closest to the experiment used in Corrigan et al (2009), who asked respondents in the Philippines to specify the quantities of two different kinds of rice (conventional rice, and a genetically modified "golden" rice with enhanced Vitamin A levels) they would purchase at a range of prices for each. Corrigan et al found this approach to perform well relative to a uniform price auction. One of the strengths of this experimental design is that it recreates a familiar situation, similar to the one experienced while buying food, where decisions concern the amount and mix of goods to purchase at different prices. Using a variant of this approach, our choice experiment is

able to identify the degree of substitutability between bushmeat and other sources of protein, such as fish and chicken, and how this varies according to respondent characteristics.

Our study is the first to use a CE to estimate the elasticities of demand for bushmeat. Relative to the revealed preference demand modelling approach (eg Rentsch and Damon, 2013), the CE approach is advantageous since it allows each respondent to face a wide range of prices for bushmeat and the substitute product (fish or chicken), rather than just the range experienced in their local market at the time of the survey. It also avoids the problem of matching regional market prices to the actual prices paid by any individual, and the problem of recall errors in terms of amounts purchased. This application also demonstrates the power of the CE approach in poor rural areas with low literacy levels, and where the good in question is informally traded or even, as in our case study site, illegal. We test for whether people find the CE difficult to understand, to assess whether this approach is suitable for use in areas where education levels are low.

3. Case study: bushmeat demand in villages around the Serengeti National Park, Tanzania.

3.1 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). All hunting carried out within the National Park is illegal, but hunting still occurs to a considerable degree (Nuno et al. in press). Three features of the choice experiment design were crucial. The first concerns the choice of substitute goods. In the western Serengeti, bushmeat is bought dried in black markets in units of “pieces”. According to Rentsch (2012), both fish and chicken are substitute protein sources for bushmeat amongst households in the study area – however, in practice, bushmeat is often preferred. Policy recommendations have promoted chicken consumption to reduce demand for bushmeat. We

thus decided to use two split sample treatments, one in which participants were offered "live adult healthy" chickens and pieces of dried bushmeat (henceforth "chicken CE") at a range of prices, and another in which participants were offered pieces of dried bushmeat and pieces of good quality dried fish ("fish CE" in the remainder). We used a piece of paper to show survey participants how big the "piece" of bushmeat we were referring to was, choosing a size approximating the amount bought in a typical single purchase for an average household.

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 chicken had four price levels: Tsh 6,000; Tsh 9,000; Tsh 12,000 and Tsh 15,000.

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 hypothetical markets[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 situations (i.e., cards) from the total of 12. The design was obtained using Ngene software.

[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."

Information on socio-demographic characteristics at individual and household levels was collected after the administration of the CEs (see Appendix 1 for an excerpt from the survey).

3.2 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 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, which is available on the markets mostly in a pre-fried (i.e. 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 (e.g., 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, i.e., 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 of both choice experiments, the enumerators conducted the main survey between December 2010 and February 2011. Choice sets were evenly distributed within each village. Each version of the CE was administered to 100 households, with a final sample size of n=87 for the fish, and n=94 for the chicken CEs. Table 1 summarises the data used in the econometric analysis.

4. Econometric specification

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

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

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 log of the price of bushmeat,
- $sp_{i,t}$ is the log of the price of the substitute good, either fish or chicken,
- h_i is a variable (and sometimes a vector of variables) which represents <u>household characteristics</u> which are household size, ethnicity, and household wealth, here operationalised as cattle ownership and number of occasional/full time workers in the household, or <u>individual characteristics</u> 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 1 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). 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. β_1 and β_2 can be interpreted as semi-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.

5. Results

Table 2 reports the results of the simplest models in which bushmeat quantity is regressed on the log of prices of bushmeat and of substitutes one at the time. Recall that this basic model still controls for variations in *individual* characteristics as a fixed effects estimator has been used. 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. This is in accord with standard economic theory for normal 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, 2012), and there are around 52,600 households in the area (calculation based on household size estimated in the study and population estimate from the 2002 census (NBS Tanzania 2006), a 1% bushmeat price increase would lead to a drop in weekly bushmeat consumption of about 1 tonne, ceteris paribus.

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 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 differed between the two substitute goods. Many of these variables have insignificant effects on choices. Household size seemed to matter. Consumption of

bushmeat was more sensitive to the price of bushmeat in the chicken CE 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) or 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 response to changes in the substitute protein price when the substitute is chicken. When the substitute is fish, Ngoreme are again more responsive to substitute price changes, but Kurya are 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.

6. Discussion and conclusions

This study uses a stated preferences approach with a choice experiment to establish own and cross-price elasticities for bushmeat consumption in an iconic ecosystem where bushmeat hunting is widespread and perceived as both a threat to biodiversity and a key component of livelihoods. Despite bushmeat hunting in the National Park being illegal and difficult to measure (Nuno et al, in press), the pre-existing relationship between researchers, enumerators and study participants gave us a foundation of trust. The choice experiment 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 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 (in fact many of our respondents were part of their study also). 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), and with recall and the lack of price information when meat is not purchased. The strengths are in the fact that the data represents real rather than hypothetical behaviour. They estimated Hicksian (income compensated) elasticities of -0.69 for bushmeat's own price and +0.61 to +0.83 for the elasticity of bushmeat compensation to fish prices (Rentsch and Damon, 2013, Table 4) . They 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 cross-price elasticity estimate for fish is higher than

our estimates 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. Our estimates also chime with other studies' estimates of bushmeat as a normal price-inelastic good.

Our cross-price elasticity results suggest that any reduction in the price of either fish or chicken would reduce bushmeat consumption. As a low input product that is raised by individual households, there is therefore the potential to target chicken for livelihood improvement projects that could raise the nutritional status of poor households while reducing 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, as 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 modulated 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.

Ethnicity can have profound effects on people's cultural heritage and therefore on their food consumption behaviour (cf Fa et al. 2002). In our case, we only found significant effects of ethnicity for the Ngoreme and Kurya peoples, but none for the Ikoma, a group in western Serengeti that has in previous studies been found to consume more bushmeat than others, possibly due to their hunter-gatherer ancestry (Ndibalemma and Songorwa 2007; Mfunda and Røskaft 2010).

Our findings demonstrate the usefulness of a method (choice experiments) which new to bushmeat research (aside from the parallel study in Moro et al (2013)), and which at the broader scale has not much used to explore policy options in developing countries. The 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: most of 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 alternative protein sources ands and supply-side measures (such as increased law enforcement, or providing livelihood alternatives to illegal hunting) in reducing demand for bushmeat. However we also need to bear in mind that changes in the price of substitutes can be triggered by factors external to conservation interventions; it is important that conservationists anticipate potential trends in price or availability of substitute goods when planning conservation actions, to be able to address the effects of increasing prices of substitutes before they have an impact on wildlife populations.

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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
	(1)	(2)
Log of bushmeat price	-0.657**	-0.703**
	(0.06)	(0.058)
Log of substitute price	0.286**	0.371**
	(0.078)	(0.052)
Observations	522	562
Number of id	87	94
AIC	1017.687	1001.831
Log-likelihood	-534.5	-498.9

Notes: Coefficients obtained by estimating fixed effects (QMLE) Poisson regressions. Heteroskedastic and overdispersion-robust standard errors in parentheses. ** p<0.01, * p<0.05. 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 consumption choice 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.