Ecological Economics 91 (2013) 1–9

Contents lists available at SciVerse ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Prices, poaching, and protein alternatives: An analysis of bushmeat consumption around Serengeti National Park, Tanzania

Dennis Rentsch [a], Amy Damon [b,*]

[a] Frankfurt Zoological Society, PO Box 14935, Arusha, Tanzania
[b] Macalester College, 1600 Grand Ave, St. Paul, MN 55105, United States

ARTICLE INFO

Article history:
Received 21 November 2012
Received in revised form 4 March 2013
Accepted 22 March 2013
Available online xxxx

Keywords:
Demand analysis
Bushmeat
Almost Ideal Demand System
Food security
Tanzania

ABSTRACT

The consumption of meat from wild animals (or bushmeat) occurs throughout Africa and highlights the conflict between two distinct development goals: food security and biodiversity conservation. Growing human populations throughout the greater Serengeti ecosystem rely heavily on bushmeat as a source of protein, which places pressure on migratory wildlife populations. This paper uses unique data from protein consumption surveys from 131 households over 34 months in a generalizable empirical framework to estimate price, cross-price, and expenditure elasticities of protein sources, and analyze the potential economic effects of policies to mitigate bushmeat hunting and consumption. Results suggest that: (1) directly increasing the price of bushmeat through enforcement or other policies to reduce supply will have the most direct and largest effect of bushmeat consumption; (2) increasing income increases bushmeat consumption as well as consumption of other meat sources; (3) if surrounding fisheries experience a negative shock, or collapse, this will lead to a dramatic increase in bushmeat consumption. Overall, these results strongly indicate that policies to reduce bushmeat hunting while maintaining food security must be considered in a broad and comprehensive framework.

1. Introduction

Increasing human population density in Sub-Saharan Africa has resulted in more rural communities living in close proximity to protected wildlife populations. These protected areas are meant to ensure that wildlife is conserved for future generations. However, surrounding communities, with access to large wildlife populations, often rely on meat from wildlife hunting, or bushmeat, as an important source of protein. Consumption of bushmeat creates a conflict between the competing goals of wildlife conservation and household food security, especially if wildlife is not harvested sustainably. In West and Central Africa, bushmeat hunting has decimated many once common species. To mitigate the threat of bushmeat hunting to wildlife populations it is important to understand the dynamics of the bushmeat market.

The conflict between sustainability and bushmeat hunting as a means of maintaining food security has been documented in the literature (Barnett, 2000; Bennett, 2002; Fa et al., 2003; Loibooki et al., 2002; Mainka and Trivedi, 2002; Milner-Gulland and Bennett, 2003; Nasi et al., 2008; Robinson and Bennett, 2002; Robinson and Bennett, 2004). In Tanzania, where bushmeat hunting is illegal, rural poverty and food insecurity remain a challenge, with 36% of rural households living below the basic needs poverty line (National Bureau of Statistics Tanzania, 2002). The motivations for bushmeat hunting and consumption are diverse, lack of abundant protein sources is a key reason for bushmeat hunting (Barnett, 2000; Jambiya et al., 2007; Loibooki et al., 2002), however bushmeat consumption tends to be concentrated close to protected areas (Campbell et al., 2001; Knapp et al., 2010). Cultural preferences for bushmeat are also an important factor (Bennett, 2002; Campbell et al., 2001; Fa et al., 2003; Loibooki et al., 2002; Mainka and Trivedi, 2002; Ndibalema and Songorwa, 2008).

The threat of bushmeat hunting to conservation objectives has been examined both using theoretical models as well as empirical econometric models. Damania et al. (2005) and Barrett and Arcese (1998) both employ theoretical models to examine the likely interactions between economic incentives and bushmeat hunting. Damania et al. (2005) find that increased bushmeat prices will likely lead to changes in technologies used for bushmeat hunting, and that policies that address bushmeat sales rather than hunting are more likely to be effective. Barrett and Arcese (1998) suggest that directly addressing fluctuations in rural agricultural incomes will offer the most enduring solutions to the conflict between household food security and wildlife conservation. These theoretical findings provide important inputs into thinking about the bushmeat market using an empirical approach.

The use of data and empirical analysis is a more common methodology for examining the bushmeat market. Previous empirical studies have shown, for example, that an increase in bushmeat consumption is correlated with the decreased availability of alternative protein sources

* Corresponding author. Tel.: +1 651 696 6862.
E-mail addresses: dennisrentsch@fzs.org (D. Rentsch), adamon@macalester.edu (A. Damon).

0921-8009/$ – see front matter
http://dx.doi.org/10.1016/j.ecolecon.2013.03.021

including livestock and fisheries (Brashares et al., 2004; Kümpel et al., 2010; Nasi et al., 2008; Nyahongo et al., 2009; Rowcliffe et al., 2005; Wilkie et al., 2005; Loibooki et al., 2002). Several studies have previously examined income effects and price responses of bushmeat and other available meat protein sources directly. Wilkie et al. (2005) find that wealth and protein consumption are positively related in Gabon and Brashares et al. (2011) also find a positive relationship between wealth and protein consumption in a cross-country study in Ghana, Cameroon, Tanzania, and Madagascar. East et al. (2005) substantiate this positive relationship in urban Equatorial Guinea. Evidence of price and cross-price effects between bushmeat and other protein sources is scarcer. Wilkie et al. (2005) find suggestive evidence (though not statistically significant) that fish is a substitute for bushmeat while Apaza et al. (2002) find some evidence of this same substitution between bushmeat and fish as well as domestic livestock from Bolivia's Amerindian communities. Another study in Bolivia by Wilkie and Godoy (2001) finds that decreases in the price of domestic livestock prices will reduce the consumption of fish substantially but have little effect on the consumption of bushmeat.

The few previous attempts to estimate price, cross-price, and expenditure elasticities have generally employed a single equation approach, which is inconsistent with demand theory. In this study, we use data from monthly household surveys for 131 households that measure meat consumption, prices, and time-varying household characteristics. These data were collected from households in eight communities surrounding Serengeti National Park in Tanzania each month for 34 months. We apply a generalizable methodology using these data to rigorously evaluate the demand for bushmeat and other protein sources and obtain estimates on price, cross-price, and expenditure elasticities for bushmeat and other protein sources using an Almost Ideal Demand System (AIDS).

We add to this literature by estimating a demand system for animal based proteins to establish the price and income effects of various protein sources, including bushmeat, simultaneously. We employ the AIDS model to estimate these elasticities, which has numerous advantages over estimating elasticities using a single equation. Firstly, the AIDS model satisfies the axioms of choice, and can be used to test and impose the homogeneity and symmetry restrictions on parameters. Second, by estimating demand for multiple proteins in a system, we can account for cross-equation correlations that cannot be captured using a single equation approach. We assume that demand for multiple meat protein sources are likely to be influenced by similar factors and thus are assumed to be contemporaneously correlated. Lastly, determining which meat sources are substitutes for bushmeat in this system has important policy implications for developing conservation interventions in Serengeti and elsewhere. We use our estimates to quantitatively analyze bushmeat hunting policy in Tanzania. For example, understanding the relationship between bushmeat quantity consumed and fish price helps us understand the potential effects of the depletion of the Lake Victoria fishery on wildlife populations in the Serengeti. Understanding relationships between protein sources, like these, can help target policies more effectively to manage wildlife populations without compromising food security in poor households (Ling et al., 2002).

1.1. The Serengeti Context

The Serengeti ecosystem includes one of the largest mammal migrations on earth, with more than 1.2 million wildebeest and more than 200,000 zebra that transverse the ecosystem annually. As the annual migration passes through various land-use types, wildlife herds are at risk from humans, particularly via bushmeat hunting. Bushmeat hunting is illegal in Tanzania without a permit but remains an important and prevalent economic activity for communities in the greater Serengeti ecosystem (Galvin et al., 2008; Holmern et al., 2004; Kaltenborn et al., 2005; Knapp, 2007, 2012; Loibooki et al., 2002). Illegal hunting, however, negatively affects wildlife populations (Sinclair et al., 2008; Thirgood et al., 2004) and is considered among the most serious threats to wildlife in the Serengeti ecosystem (Sinclair, 1995). Although selective hunting targeted towards rare and high-valued species bound for high-end external markets is also common, the majority of hunting in Serengeti appears to be more oriented toward local consumption and sale of bushmeat (Barnett, 2000; Campbell et al., 2001; Kaltenborn et al., 2005; Nyahongo et al., 2009). A large proportion of the illegally hunted meat is sold locally within communities, though some proportion is also exported outside of the ecosystem (Barnett, 2000; Campbell et al., 2001). Bushmeat hunting thus serves as both a source of food and income (Barnett, 2000; Bennett et al., 2002; Kaltenborn et al., 2005; Knapp, 2012; Knapp et al., 2010). The local consumption of bushmeat is responsible for the estimated 70,000–129,000 wildebeest deaths per year (Rentsch and Packer, 2012). Previous efforts to understand the motivation for hunting focus on the behavior of producers (hunters) who typically face limited livelihood options in rural agro-pastoral economies (Barrett and Arcese, 1998; Johannesen, 2005; Knapp, 2007, 2012; Loibooki et al., 2002), however this paper approaches this problem by understanding the behavior of the bushmeat consumer and examines the role of alternative protein sources in the decision to consume bushmeat.

The seasonal variation in bushmeat availability influences both prices and consumption of bushmeat and alternative protein sources. We use this seasonal variation in wildlife abundance at the community level to predict protein consumption in our empirical approach. This abundant wildlife access, high human population density in communities surrounding Lake Victoria, and favorable climate for livestock productivity provide a unique opportunity to examine the trade-offs in household consumption of bushmeat, fish, and domestic meat.

Several policy approaches have been used to mitigate illegal hunting in Serengeti. Primarily, bushmeat hunting is combated through enforcement, with extensive anti-poaching units operating throughout the national park and surrounding reserves. The national park has also engaged in community outreach in an effort to meet economic development needs in surrounding communities (Serengeti National Park, 2006), though these programs often suffer from limited funding. Another effort to reduce bushmeat consumption was a game cropping scheme that provided bushmeat legally within villages bordering protected areas (Holmern et al., 2002; Mbano et al., 1995). Despite on-going efforts and an overall increase in spending on law enforcement, all of these strategies to reduce illegal hunting within the ecosystem have had limited results. Understanding the importance of bushmeat in local households' food security strategies and their willingness to substitute away from bushmeat, may help more effectively target efforts to mitigate illegal hunting.

In the remaining sections we first discuss the data used in our analysis, we then present our empirical strategy, report results from the analysis and use the estimated elasticities in a policy simulation exercise, and conclude with a discussion of our results.

2. Data

We use household level dietary recall data collected monthly for 131 households over 34 months. Dietary recall surveys have been shown to be an effective method for measuring the food consumption choices of households (Baer et al., 2005; Bingham et al., 1994; Day et al., 2001; Gersovitz et al., 1978; Hebert et al., 1997). This study uses a weekly recall of only meat-based protein sources to gain a more comprehensive understanding of protein intake and to capture “rare” events, such as the consumption of different bushmeat species (Knapp et al., 2010). While 24-hour recall was found to be the most accurate food recall measure, food-frequency questionnaires which ask respondents to recall dietary intake over longer periods of time were found to be more efficient in that they provide a wider time horizon with which to assess varied diets (Baer et al., 2005; Bingham et al., 1994; Day et al., 2001; Gersovitz et al., 1978; Hebert et al., 1997). However, it is important to note that there are potential biases in both weekly and 24-hour recall dietary surveys and as such there is likely some measurement error in our consumption data.

The sample of households was chosen from eight villages within Serengeti and Bunda districts in Mara region, Tanzania. These villages were chosen randomly from a list of all villages immediately adjacent to protected wildlife areas (Serengeti National Park and Ikorongo–Grumeti Game Reserves) with the requirement that no two villages included in the sample border one another spatially. Two enumerators in each village, who were also village residents, were selected to assist with monthly data collection.[1] Four sub-villages were selected at random from each village to ensure a spatially diverse sample (villages were found to typically have between 6 and 10 sub-villages). Four to five households were selected from each of the four sub-villages by selecting one household at random, walking in a random compass direction, and skipping four households before approaching the next household to interview.

Each household was revisited monthly on the same day (+/− 1 day), and asked to recall the animal-based protein that was prepared at home for each of the previous seven days. The enumerator was instructed to prompt the respondent (usually a woman responsible for preparing food each day) by the days of the week. For each of the protein types (including various types of meat and fish), the respondent was asked to specify the method of meat preparation (whether dried or fresh) and the number of meals consumed, and to estimate the total weight of the meat protein source consumed. A second, independent assessment of weights of protein sources available at village level was also conducted using hand-held weighing to provide more precise price-per-unit data. Eight of the 16 enumerators collecting monthly data for the protein survey also collected weight data. These independent measurements were particularly important in reducing measurement error in reported bushmeat and fish weights. Respondents were also asked to recall how the household acquired the meat (e.g. purchased, slaughtered at home, given as a gift, fished or hunted themselves), and the price per unit, if purchased. Information on the primary occupation of the head of the household for the previous 30 days, number of people living in the household that week, and the number of children under five was also recorded as well as detailed questions about livestock ownership and livestock health, in particular the number of animals owned, slaughtered, sold and died in the previous month.

Collecting data that includes questions about bushmeat consumption is sensitive since bushmeat hunting is illegal. Using local enumerators, who are known to the respondents, meant that bushmeat consumption was less likely to be underreported in this study than in previous attempts to measure bushmeat consumption. As a result, these data directly measure consumption of bushmeat as well as multiple other protein sources.[2]

Prices for goat, sheep, and chicken were all higher per kilogram than beef, but they all had relatively few observations and high standard deviations. Goat, sheep, and chickens were often obtained from household stocks and slaughtered at home — typically for celebrations or special events. For example, only 15% of chicken consumption

Table 1
Average village price per kilogram.

	N	Average village price	Standard deviation	Min.	Max.
Beef	3156	3012.02	1354.39	833.33	10,000.00
Fish	3156	973.45	597.67	65.10	3000.00
Bushmeat	3156	1708.45	741.44	519.13	4697.37
Dagaa	3156	2020.43	1394.21	376.92	7131.31
Chicken	480	4434.96	2593.85	1000.00	12,162.16
Sheep	341	3144.43	1480.61	1000.00	70,00.00
Goat	1329	3265.08	2291.93	1000.00	18,300.00

observations had associated purchase prices. Weight per meal of fish was unknown by many respondents in the recall survey, and prices varied significantly (Table 1). Unknown weights were calculated using a "fish weight index" from consumers with known weights, and weight data provided by the enumerators within the village.[3]

A measure of wildlife abundance in the village provides a proxy for the presence of the wildlife migration in the area and was determined by asking respondents to mention the months in which "wildlife was most common in their village". Their responses were tallied, creating a frequency count for each month, indicating relative abundance. This abundance data was then included in the empirical analysis to control for the effect of seasonal abundance of wildlife and its influence on the consumption of bushmeat. We expect that increased wildlife abundance at the village level will increase the likelihood of bushmeat consumption during that month.

3. Empirical Strategy

Bushmeat consumption is examined in a demand system with other meat protein sources such as fish, beef, and *dagaa* (a small dried sardine-like fish). An AIDS model (Deaton and Muellbauer, 1980) with a refinement proposed by Heien and Wessells (1990) is used to estimate own-price, cross-price, and expenditure elasticities. The AIDS model satisfies the axioms of choice, is relatively flexible, easy to estimate and interpret, and can be used to test and impose the homogeneity and symmetry restrictions on parameters. Second, by estimating demand for multiple proteins in a system, we can account for cross-equation correlations that cannot be captured using a single equation approach. We assume that demand for multiple meat protein sources are likely to be influenced by similar factors and thus are likely correlated. The AIDS model approach has been effectively used to test the effect of price and expenditure changes on consumer demand for various protein sources in many other studies (e.g. Coffey et al., 2011; Eales and Unnevehr, 1988; Marsh et al., 2004; Piggott and Marsh, 2004). Further, given the large number of censored observations for consumption in these data, we employ a two-step process following Heien and Wessells (1990) to account for bias resulting from a large portion of observations being censored at zero (Heien and Wessells, 1990; Jabarin, 2005). The AIDS model can be defined as

$$w_{it} = \alpha_i + \sum_j^n \gamma_{ij} \ln p_{jt} + \beta_i \ln\left(\frac{X_t}{P_t}\right) + u_{it} \quad i = 1, \ldots, n \tag{1}$$

where w_{it} is the expenditure share of the ith good in time period t; p_{jt} is the nominal price of the jth good, X is the total expenditure on all

[1] Enumerators were selected on the criteria that they were literate, had lived in the village for more than 5 years, were known to many members of the village, and did not spend more than 1 month a year away from home. Enumerators were typically village primary school teachers, health workers or assistant livestock officers. Each enumerator received 3–4 days of training in the use of the questionnaire and process of household selection.

[2] While local enumerators reduce reporting bias, they likely do not eliminate it completely. It is nearly impossible to know the exact size of this bias, but the direction is likely to be an underreporting of bushmeat consumption rather than an over reporting. This bias should not affect elasticity estimates unless the price responsiveness of bushmeat consumption is misreported. We do not have any evidence to suggest if this is the case.

[3] To standardize fish quantities into kilograms, since many households reported their consumption in number of fish rather than kilograms, we determined an index for the kilograms of fish consumed per household member per week using those 157 incidences where the respondent reported fish consumption in kilograms. Using the average for this index, we calculated the average weight per fish consumed by multiplying the fish index value by the total fish consumed, and the number of people in the household. This gave us an estimate of the average kilograms per fish consumed.

protein sources in time period t, and ln P_t is the translog price index defined as:

$$\ln P_t = \alpha_0 + \sum \alpha_j \ln p_j + \frac{1}{2}\sum_i^n \sum_j^n \gamma_{it} \ln p_{it} \ln p_{jt} \quad t = 1, \ldots, \mathrm{T}. \tag{2}$$

The problem with using this specification of the price index is that the system in non-linear makes estimation difficult. Deaton and Muellbauer (1980) suggest a linearized version of this price index, referred to as Stone's geometric price index. When the linearized version of the price index is employed the AIDS model is referred to as the Linearized Approximation of the AIDS or LA-AIDS. Therefore, following Deaton and Muellbauer and Green and Alston (1990) we use Stone's geometric price index, P^*, instead of P_t to estimate the LA-AIDS which is equal to:

$$\ln P^* = \sum_{i=1}^{n} w_{it} \ln P_{it}. \tag{3}$$

The linearization of the price index, as shown in the LA-AIDS model has been demonstrated by Asche and Wessells (1997) to yield results that are comparable to the AIDS model, which, in its original specification, uses a price index specification that makes the system non-linear. Eq. (1) is then reduced to:

$$w_{it} = \alpha_i + \sum_j^n \gamma_{ij} \ln p_{jt} + \beta_i \left(\ln \mathrm{X} - \sum_{i=1}^{n} w_{i,t} \ln p_{it} \right) + u_{it}. \tag{4}$$

There are several empirical considerations when estimating demand elasticities for the four protein sources in our study. First is the large number of consumption observations censored at zero since households in our sample do not consume all protein sources in all observed time periods. In our sample, 75% of beef consumption, 36% for dagaa, 73% of fish, and 55% of bushmeat observations are censored at zero.

Second, households with zero consumption for a protein source in a given month also have missing prices for that protein source in that month. As Coffey et al. (2011) explain, this problem has been approached several ways in the literature. We use the most straightforward approach, which is to assume that households face a common village price and use a village average to fill in missing price data. For villages with only a single price point for a given protein in a month, we use the average of the price of that month for the two closest villages in our sample. While endogenous prices are still an additional concern, the use of the village average mitigates this concern to some degree. Further, we conducted this same analysis using predicted prices to address the endogenous price problem and results were qualitatively the same.

Implementing the AIDS model with village prices, while failing to account for the zero quantities consumed, would lead to biased estimates (Park et al., 1996). It is likely that households self-select into consuming a protein source during a certain month and this non-random self-selection bias must be accounted for. To address the potential selection bias we use the Amemiya–Tobin approach which is to include a selection correction term to account for censored data employed by Heien and Wessells (1990), and has since been used in a variety of similar studies (Heien and Wessells, 1990; Jabarin, 2005; Liu et al., 2009; Shonkwiler and Yen, 1999; Taljaard et al., 2004). We first estimate a probit model to explain the household's (h) decision to consume protein source, i, in a given month, t, and then construct an inverse Mills ratio which is used in the estimation of the LA-AIDS model. The probit equation takes the form

$$\begin{aligned} d_{iht} &= \gamma_0 + \gamma_1\, p_{ivt} \\ &\quad + \sum_j \gamma_{2j} p_{jvt} + \gamma_3 Vil + \beta_4 WildlifeAbundance_{vt} + \beta_6 hhsize_{it} + e_{iht}. \end{aligned} \tag{5}$$

The variable d_{iht} takes a value of 1 if the protein i was consumed in month t and 0 if protein i was not consumed in month t. Next, p_{ivt} is the village, v, average price for protein i in month t, and j indexes alternative proteins. A variable measuring the abundance of wildlife at the village level is used as an identifying variable in this first stage equation. From Eq. (5) an inverse Mills ratio (IMR) for each protein is calculated and equal to:

$$IMR_{jh} = \frac{\varphi\left(p_{jvt}, X_h, Wildlife_{vt}\right)}{\Phi\left(p_{jvt}, X_h, Wildlife_{vt}\right)} \tag{6}$$

where, φ is the probability density function and Φ is the cumulative distribution function. For those households that did not consume the protein in a given month the IMR is equal to:

$$IMR_{jh} = \frac{\varphi\left(p_{jvt}, X_h, Wildlife_{vt}\right)}{1 - \Phi\left(p_{jvt}, X_h, Wildlife_{vt}\right)}. \tag{7}$$

The IMR is then used in the estimation of the AIDS system such that the system is now characterized as:

$$\begin{aligned} w_{it} &= \alpha_i + \sum_j^n \gamma_{ij} \ln p_{jt} + \beta_i \left(\ln X - \sum_{i=1}^n w_{i,t-1} \ln p_{it} \right) \\ &\quad + \sum_i IMR_{it} + u_{it}. \end{aligned} \tag{8}$$

The system of equations in Eq. (8) is estimated using a three staged least squares seemingly unrelated regression.

The advantage of the AIDS model is its consistency with demand theory, namely the demand equations must adhere to the adding up restriction:

$$\sum_i \alpha_i = 1, \quad \sum_i \gamma_{ij} = 0, \quad \sum_i \beta_i = 0 \tag{9}$$

the homogeneity restriction:

$$\sum_j \gamma_{ij} = 0 \tag{10}$$

and the symmetry restriction:

$$\gamma_{ij} = \gamma_{ji}, i \neq j. \tag{11}$$

Another advantage of the AIDS model is that these restrictions are easily tested (Wadud, 2006). Given this specification, expenditure elasticities, uncompensated (Marshallian) price elasticities, and Hicksian (compensated) price elasticities can be calculated by following Green and Alston (1990). The expenditure elasticities are of the form:

$$e_{ix} = 1 + \frac{\beta_i}{w_i}. \tag{12}$$

Expenditure elasticities are a proxy for income elasticities in this context since it is reasonably assumed that since poor households save very little, expenditure is highly correlated with income. The Marshallian (uncompensated) price elasticities are defined as:

$$\eta_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i} \tag{13}$$

where δ_{ij} is the Kronecker delta such that $\delta_{ij} = 1$ when $i = j$, and $\delta_{ij} = 0$ for $i \neq j$. Marshallian price and cross-price elasticities are the most commonly reported elasticities and are a result of maximizing utility subject to a budget constraint. They include both the income and substitution effect. The Hicksian price elasticities are:

$$\eta_{ij}^{*} = \eta_{ij} + w_j\left(1 + \frac{\beta_i}{w_i}\right) = \eta_{ij} + w_j e_{ix}. \tag{14}$$

Hicksian elasticities are "income-compensated" elasticities based on the compensated demand function. We expect these two elasticities for the same good to be similar if the share of income devoted to the good is small and the income (expenditure) elasticity of the good is small.

The elasticity estimates above are presented as a means to analyze different policy approaches to bushmeat below. These represent our best estimates of these elasticities, and given their robustness to different specifications they are effective tools to discuss policy options, however several caveats should be considered. Firstly, the exclusion of chicken consumption and prices means that we are excluding an additional meat type in this system. This necessarily excludes chicken from the following policy analysis, but it is possible that there are more policy options around chicken production that cannot be discussed effectively here. Second, prices used in the analysis are self-reported and even though we use village averages to mitigate an endogenous price problem, it is still possible that these prices could suffer from endogeneity. Given that our predicted prices did not offer significant improvements in our estimates, we opted to keep our village price analysis, but this is a weakness of this analysis.

4. Results

Households within the sample consumed an average of 8.14 kg of meat- or fish-based protein sources per week, of which the majority consisted of dagaa (35%), followed by bushmeat (29%), fish[4] (14%), beef (10%) and chicken (8%), see Table 2. Sheep and goat were consumed relatively rarely consisting of 1% and 3% of protein intake respectively. Therefore goats, sheep and chicken were not included in the AIDS model due to their relatively low contribution to the diet.

Tables 3 and 4 provide Marshallian and Hicksian (income compensated) elasticity estimates, and their standard errors, for bushmeat, beef, dagaa and fish. These estimates are based on estimates from a seemingly unrelated regression (SUR). The complete joint estimation SUR results are provided in Appendix Tables A and B. As expected in Table 3, all protein sources have a negative own-price Marshallian elasticity ranging from −0.696 for dagaa to −1.427 for fish. Dagaa has the lowest own-price elasticity, which is consistent with dagaa being a relative necessity among meat protein sources. Further, we see that bushmeat is relatively own-price elastic at −1.122. Marshallian cross-price elasticities can provide important insight about how people substitute between protein sources in their household food security strategy. A positive and significant cross-price elasticity between bushmeat consumption and the price of fish and beef indicates that they are substitutes for bushmeat and as the price of these proteins rise households consume more bushmeat. Bushmeat and dagaa have a significant cross-price relationship, however the signs between bushmeat and dagaa and dagaa and bushmeat are contradictory. In the income-compensated estimates in Table 4, we see that dagaa and bushmeat are consistently net substitutes. This result indicates that the contradictory results between bushmeat and dagaa are likely a result of an income effect, which is netted out in the Hicksian elasticities in Table 4. These results differ from results obtained in West Africa, where it was found that bushmeat consumption did not vary significantly based on price of protein sources (Wilkie et al., 2005).

Expenditure elasticities in Table 3 are all positive, with bushmeat, beef, and fish all having expenditure elasticities greater than 1, while

Table 2
Mean number of kilograms of each protein consumed per household per week.

	Average weekly household consumption (in kg)	Standard deviation	Minimum	Maximum	Dietary share
Beef	0.90	2.18	0.00	28.00	10.44%
Fish	1.11	2.48	0.00	26.88	13.81%
Bushmeat	2.70	4.40	0.00	56.00	29.35%
Dagaa	2.11	2.85	0.00	55.00	34.59%
Chicken	0.68	1.62	0.00	17.76	7.58%
Sheep	0.17	1.46	0.00	28.00	1.01%
Goat	0.48	2.33	0.00	42.00	3.22%
Total protein	8.14	6.85	0.13	56.00	100%

Note: N = 3156.

dagaa has expenditure elasticity of 0.649. All four of the protein sources are normal goods and as income (expenditure) increases, consumption of these protein sources will also increase. Consistent with anecdotal evidence, bushmeat and beef are the most expenditure elastic while we see that dagaa is the least. This result is consistent with dagaa being the most commonly consumed source of meat protein in low-income households and has important implications for both development practitioners in rural Tanzania as well as conservationists. As efforts are being made throughout the Serengeti ecosystem to improve household welfare through increased household incomes, these results suggest that we should anticipate a corresponding rise in consumption of beef, bushmeat, fish, and dagaa. In particular, these results suggest that rising incomes will result in relatively large increases (increases in consumption that are greater than increases in income in percentage terms) in beef, bushmeat, and fish consumption. This will, in turn, place more pressure on the wildlife populations hunted for meat throughout the ecosystem.

Hicksian (or income compensated) elasticities, presented in Table 4, also have negative own-price elasticities as expected, but in general the magnitudes are smaller than Marshallian estimates. This result is not surprising since Hicksian elasticities are net of the income effect. The Hicksian elasticities also provide information about which protein sources are net substitutes or complements. Bushmeat is a net substitute for all other protein sources. This result is highly significant at the 1% level for all bushmeat relationships. There is evidence that beef and fish are also net substitutes. Other protein relationships are less consistent in terms of their sign and significance level.

A similar secondary analysis was used to estimate the Marshallian and Hicksian elasticities for the meat demand system but this time results for bushmeat were separated into two categories: migratory (wildebeest and zebra) species and non-migratory species.[5] As expected all own-price elasticities are negative and significant. Migratory bushmeat is found to be more price-elastic than non-migratory bushmeat suggesting that non-migratory bushmeat is likened more to other, more constantly available, protein sources. Marshallian estimates also suggest that fish and migratory species are substitutes and further dagaa and non-migratory bushmeat are complements. We see some evidence that migratory wildlife species and beef and fish are substitutes but these estimates are not highly significant. Expenditure elasticities for migratory and non-migratory bushmeat are comparable at 1.201 and 1.155, respectively, suggesting that migratory species are slightly more expenditure elastic, but not by much. The expenditure elasticity results for both bushmeat types are still the highest of the protein sources presented which is consistent with those presented in Table 3. The income-compensated elasticity estimates tell a slightly stronger story. Hicksian results suggest that beef and fish are substitutes for all types of bushmeat. We also see that migratory and non-migratory bushmeat are substitutes for each other (see appendix D and E).

[4] Defined here as larger lake fish and differentiated locally from "dagaa".

[5] Results are available upon request.

Table 3
Marshallian elasticities.

Expenditure shares		Marshallian (uncompensated) elasticities				Expenditure elasticity
		Beef	Fish	Bushmeat	Dagaa	
Beef	0.162	−0.965***	−0.032	0.126***	−0.158***	1.184***
	(0.287)	(0.068)	(0.049)	(0.026)	(0.018)	(0.034)
Fish	0.119	−0.002	−1.427***	0.287***	−0.132***	1.006***
	(0.256)	(0.036)	(0.054)	(0.019)	(0.014)	(0.040)
Bushmeat	0.322	0.206***	0.680***	−1.122***	−0.128***	1.322***
	(0.374)	(0.055)	(0.055)	(0.041)	(0.020)	(0.020)
Dagaa	0.397	−0.175***	−0.300***	0.109***	−0.696***	0.649***
	(0.377)	(0.047)	(0.050)	(0.025)	(0.024)	(0.016)

Note: Standard errors are in parenthesis, except for budget shares which are standard deviations. *** means significant at the 1% level. N = 3156 Marshallian (or uncompensated) elasticities are based on demand functions that are a function of both prices and income.

The elasticity and seemingly unrelated regression results are robust to a number of different specifications. Firstly, elasticity estimates are qualitatively the same with both the inclusion and exclusion of the inverse Mills ratio selection correction term in the seemingly unrelated regression estimation. We also have a version of this model that uses predicted prices to address the issue of endogenous prices instead of village level prices, and the results were quite similar. Lastly, we have also included chicken quantities and prices in previous iterations of this model, but even though the elasticity estimates were similar in magnitude we lost many observations and we opted to exclude chicken to improve the precision of our estimates with a larger sample.

5. Sensitivity Analysis: Analysis of Anti-Poaching Strategies

The elasticity estimates reported in the previous sections allow us to better understand the effects of several policy approaches that governmental and non-governmental organizations have used or proposed to reduce bushmeat consumption around Serengeti National Park. By conducting a sensitivity analysis of the results of own, cross-price, and expenditure elasticities in Table 3, we can estimate the effects of price changes on the average household diet and speculate about the broader effects of various policies aimed at reducing illegal hunting of wildlife and decreasing consumption of wildlife. We examine three common policies: increased enforcement against illegal hunting, increasing household income through income generation programs, and increasing the production of alternative protein sources. We lastly examine the effect of a negative shock to fisheries (e.g. a fishery collapse in Lake Victoria) on bushmeat demand. A summary of the sensitivity and quantitative policy analysis can be found in Table 5. It is important to note that while we only include scenarios for a 10% change and 100% change in fish or bushmeat prices, any level of change can be easily derived since changes in prices and quantities are proportionally related.

Table 4
Hicksian (compensated) elasticities.

	Hicksian (compensated) elasticities			
	Beef	Fish	Bushmeat	Dagaa
Beef	−0.773***	0.108**	0.508***	0.311***
	(0.067)	(0.049)	(0.029)	(0.023)
Fish	0.161***	−1.308***	0.611***	0.267***
	(0.036)	(0.053)	(0.022)	(0.021)
Bushmeat	0.421***	0.836***	−0.696***	0.396***
	(0.055)	(0.055)	(0.041)	(0.021)
Dagaa	−0.069+	−0.223***	0.318***	−0.438***
	(0.046)*	(0.050)	(0.025)	(0.023)

Note: Standard errors are in parenthesis. ** and *** means significant at the 15%, 5% and 1% level respectively. Hicksian (compensated) elasticities are based on demand functions that are a function of prices and a given level of utility, or are net of the income effect.

5.1. Increased Enforcement

The Tanzanian government invests heavily in enforcement activities within Serengeti National Park. Increased enforcement efforts by the government increase the cost of hunting to hunters. If enforcement decreases the quantity of bushmeat in the market, the price faced by consumers will increase. Predicting the response in hunting behavior to different levels of enforcement spending will depend largely on the effectiveness of the expenditure, and is beyond the scope of this paper, but it is reasonable to assume that an increase in enforcement expenditures will increase the price of bushmeat. The effect of an increase in the price of bushmeat by 10 and 100% is found in Table 5. The 100% change is to examine what would happen to the protein demand system if the bushmeat supply experienced a dramatic negative shock. If there was a total wildebeest population collapse, for example, we would expect the bushmeat price to increase more than 100% but without knowing this percent change exactly we examine the case of a 100% increase as an example. Further, we do not know the bushmeat elasticity of supply so we cannot say how much reduction in the production of bushmeat would increase bushmeat price.

Table 5 shows the percent change in the quantity of protein sources demanded and the increase or decrease in the amount demanded based on the average consumption per household. For example, if the price of bushmeat increased by 10% (policy 1) we would see a 2.87% increase in the consumption of fish or an increase of

Table 5
Policy analysis results.

Policy	Fish	Beef	Dagaa	Bushmeat
(1) Increase in the price of bushmeat by 10%				
Percent change in quantity demanded	2.87	1.26	1.09	−11.22
Change in quantity demanded (in kg)	0.03	0.01	0.02	−0.30
(2) Increase income by 10%				
Percent change in quantity demanded	10.06	11.84	6.49	13.22
Change in quantity demanded (in kg)	0.11	0.11	0.14	0.36
(3) Decrease in price of protein alternative by 10%				
Percent change in bushmeat consumption	−6.8	−2.06	1.28	–
Change in quantity demanded of bushmeat	−0.08	−0.02	0.03	–
(4) Increase in the fish price by 100%				
Percent change in quantity demanded	−142.7	−3.2	−30	68
Change in quantity demanded (in kg)	−1.58	−0.03	−0.86	1.84
(5) Increase in the bushmeat price by 100%				
Percent change in quantity demanded	28.7	12.6	10.9	−112.2
Change in quantity demanded (in kg)	0.32	0.11	0.23	−3.03

Note: Policy 1 is the effect of an increase in the price of bushmeat on protein alternatives, policy 2 is the effect of an increase in income on protein alternatives, policy 3 is the effect of an increase in price protein alternatives on bushmeat quantity demanded, and policy 4 is the effect of shock to fisheries on meat consumption.

0.03 kg of fish consumed per week per household, or an increase of 0.02 kg of dagaa. At the same time, this 10% increase in bushmeat price would lead to a reduction of 0.30 (+/−0.01) kg of bushmeat consumed per week per household.

If the bushmeat population experienced a shock, increasing its price by 100% (policy 5), we see the dramatic increase in the price of bushmeat would have a secondary effect on other protein sources. In particular, this analysis suggests that a large increase in the price of bushmeat would put significant pressure on surrounding fisheries, in this case predominately Lake Victoria. The quantity demanded of fish would increase by 28.7%, or 0.32 kg per household per week. Further, we would see an 11 and 13% increase in the quantity demanded of dagaa and beef respectively.

5.2. Increasing Income by Providing Alternative Income Generating Activities

Our analysis suggests that increasing household expenditure (a proxy for income) will significantly increase the consumption of all protein sources, especially bushmeat. This result is consistent with findings from elsewhere in Africa, which show a robust and positive relationship between wealth and wildlife consumption (Brashares et al., 2011; East et al., 2005; Wilkie et al., 2005). Table 5 reports the effects of an increase in expenditure by 10% on the quantity demanded of all four meat protein sources. Bushmeat, interestingly, is the most responsive to increases in income. For example, if household expenditure increases by 10% the quantity of bushmeat demanded would increase by 13.22%, or an increase of nearly 0.36 kg of bushmeat per household per week on average. Further, consumption of other protein sources would also increase. If expenditure were to increase by 10%, beef consumption would increase by 0.11 (+/−0.01) kg per week per household, fish consumption would increase by 0.11 (+/−0.005) kg per household, and dagaa would increase by 0.14 (+/−0.01) kg per week.

Increasing income has been cited as an effective means of reducing illegal hunting (Barrett and Arcese, 1998; Kaltenborn et al., 2005; Loibooki et al., 2002), however our results suggest that, at least in the short-run, increasing income would also increase protein consumption across all protein types and place more pressure on wildlife populations, fisheries, and likely increase demand for grazing land for beef. It could, however, result in a significant increase in bushmeat prices if hunting (quantity supplied) is reduced and consumption (quantity demanded) is increased concurrently. Further, the potential second round effect of this kind of policy could be increased enforcement costs as the incentive to hunt from increased prices is increased. While this analysis only examines bushmeat consumption, it is clear that policies must address both consumption and production sides of the bushmeat market.

5.3. Increase the Production of Alternative Protein Sources (Decrease the Price of Alternatives)

Table 5 shows that decreasing the price of fish and beef are viable policy options to reduce the quantity demanded of bushmeat. Beyond increasing the price of bushmeat directly, decreasing the price of protein alternatives has the largest negative effect on total bushmeat consumption. If, for example, a subsidy or other policy could artificially decrease the price of fish by 10% this would lead to about a 6.8% (+/−.55) reduction in the quantity demanded of bushmeat, or 0.08 kg (+/−.01) of bushmeat per week. A decrease of 10% in beef prices however would only decreases bushmeat consumption by 2.06%.

One important caveat to this approach is that a decrease in the price of an alternative protein will affect the quantity demanded of that protein as well as other proteins in the system. For example, the own-price elasticity of fish suggests that a 10% decrease in the price of fish, induced by improved fishing practices, or fish farming, would increase the quantity demanded of fish by over 14.3%.

5.4. Changes in Fish Prices

Results suggest that there is significant interdependence between fish and bushmeat consumption. If we consider again a shock scenario, such as a fishery collapse, this would cause a significant increase in the price of fish. We analyze the case of a dramatic, 100%, increase in the price of fish. Table 5 suggests that if fish prices were to increase significantly we would see a dramatic decrease in fish consumption (143% +/−5.5%), and a decrease in quantity demanded of dagaa and beef. But, we would see an increase in the quantity demanded of bushmeat by 68% (+/−5.6%), or an increase in the average consumption of bushmeat per week by 1.84 kg (+/−.3), leading to an average consumption of 4.53 kg per week per household. This result intimately ties these two natural resources together and suggests a somewhat different policy approach to bushmeat reduction, which is to encourage sustainable fishing practices in surrounding fisheries.

6. Discussion and Conclusions

The results of this study have direct implications for conservation and wildlife management interventions. Previous efforts to reduce illegal poaching have relied heavily on enforcement techniques — anti-poaching patrols carried out under the authority of protected area managers (Hilborn et al., 2006; Holmern et al., 2007; Nyahongo et al., 2009). A few community-based conservation programs have attempted to provide benefits such as legal bushmeat at reduced prices to local communities, as means to reduce participation in wildlife hunting (Barrett and Arcese, 1998; Holmern et al., 2002). While both enforcement and community conservation have merits, previous schemes often suffer from a lack of understanding of the dynamics underlying bushmeat consumption. Enforcement addresses the symptom of hunting without considering the underlying cause. For example, the previous bushmeat provision program attempted to undercut the market for bushmeat by making it readily available. This program may have inadvertently increased the demand for bushmeat once the program ceased to operate as people adjusted preferences toward this protein source. Also, this game-cropping scheme provided a modest 250–500 wildebeest per year (Barrett and Arcese, 1998; Holmern et al., 2002), not nearly enough to change the price of illegal bushmeat in any meaningful way. In order to direct more effective mitigation efforts, it is essential to understand the role of bushmeat and other protein sources in households' food security strategies. This study provides estimates of own, cross, and expenditure elasticities to inform policy makers and conservationists as to the potential effects of implementing certain policies.

As cross-price elasticities in this study demonstrate, for example, an increase in the price of bushmeat through increase law enforcement, or by restricting access to wildlife by local communities, would lead to corresponding increases in beef, dagaa, and fish consumption. Beef, dagaa, and fish were all shown to be substitutes for bushmeat. Among the protein sources examined, bushmeat displayed large and significant coefficients for Marshallian cross-price elasticities, suggesting that households would readily switch away from bushmeat consumption given a sufficient price incentive to move toward alternative protein sources. Our results suggest that a significant increase in the supply of beef may lower the price sufficiently to reduce bushmeat consumption locally, however this would lead to high negative externalities as cattle grazing competes with migratory wildlife for scarce grassland and water access (Belsky, 1992; Prins, 1992; Prins, 2000).

Our analysis suggests that increasing the price of bushmeat is the most effective way to decrease bushmeat consumption. For example, with a 30% increase in bushmeat price, bushmeat consumption decreases by 34% and fish consumption increases by 8.61%, while a 30% reduction in fish price would decrease bushmeat consumption by 20% and increase fish consumption by 43%. Improving access to alternative protein sources may also serve to change the relative price and increase consumption of these alternatives, but to a lesser extent than increasing the price of bushmeat directly. Further, there are undoubtedly ecological costs to increasing the supply of other proteins such as livestock and fish. For communities living next to the Serengeti ecosystem, bushmeat is likely to remain a key source of meat-based protein.

Further, examination of various policy options suggests that substitution away from bushmeat means a significant increase in fish consumption, likely exacerbating the problem of overharvesting of fish from Lake Victoria. With a population growth rate of more than 3% per annum (Tanzania National Bureau of Statistics, 2002), the commercial fisheries of Lake Victoria are unlikely to accommodate the corresponding rise in local quantity demanded for fish (Bokea and Ikiara, 2000; Bruton, 1990; Ntiba et al., 2001). We see that the sustainability of fisheries and the wildlife populations in Serengeti are inextricably linked. If fisheries were to collapse, for example, causing a spike in fish prices, there would be a large increase in the quantity demanded of bushmeat, thus likely leading to an unsustainable harvest of bushmeat.

There is no “magic bullet” to decrease bushmeat consumption around Serengeti National Park. Our expenditure elasticity results indicate that income generation is complicated from a conservation perspective as it undoubtedly reduces poverty but also increases the demand for all protein sources, thereby likely increasing harvesting of bushmeat and fish, and increasing production of beef. While these trends are positive from a food security perspective, if the production of these meat protein sources are not managed effectively it could lead to unsustainable harvesting or production around this sensitive ecosystem. Strategies aimed at increasing income are more likely to have an impact on reducing bushmeat hunting if income were linked to direct conservation outcomes. Conservation performance payments, for example, may be an effective way to reduce the incentive for hunting, while increasing household income (Ferraro, 2001; Ferraro and Simpson, 2002), though concrete examples of such strategies and their effectiveness are minimal in the Serengeti context.

Total consumption of meat (including bushmeat) is likely to increase as households accumulate more wealth through increased agricultural production and wage employment opportunities. This paints a dire picture for the sustainability of wildlife populations around Serengeti ecosystem. Development and conservation groups working throughout the ecosystem to achieve the Millennium Development Goals of reducing poverty and biodiversity conservation would be best served to strategically target interventions aimed at the producers of bushmeat, illegal hunters. Targeted alternative income-generating opportunities to producers of bushmeat coupled with anti-poaching measures may curb production of bushmeat and significantly increase the price of bushmeat relative to alternatives, shifting consumption away from wildlife.

Acknowledgments

The authors would like to thank the Tanzanian Wildlife Research Institute (TAWIRI), Tanzania National Parks (TANAPA), the Commission for Science and Technology (COSTECH), and the participating communities for permission and cooperation during the data collection. We also thank the European Union and Frankfurt Zoological Society for funding for this project under the HUNT and CREATE projects. Helpful comments were provided by Paul Glewwe, E.J. Milner-Gulland, Craig Packer, Steven Polasky, Jennifer Schmidt, participants of the 2012 HUNT conference, and two anonymous reviewers on a previous version of this paper. Thanks to Alais J. Lendii and Martin Andimile for their assistance. All errors are our own.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ecolecon.2013.03.021.

References

Apaza, Lilian, Wilkie, D., Byron, E., Huanca, T., Leonard, W., Perez, E., Reyes-Garcıa, V., Vadez, V., Godoy, R., 2002. Meat prices influence the consumption of wildlife by the Tsimane' Amerindians of Bolivia. Oryx 36 (4), 382–388.

Asche, Frank, Wessells, Cathy R., 1997. On price indices in the Almost Ideal Demand System. American Journal of Agricultural Economics 79, 1182–1185.

Baer, Heather, Blum, Robin, Helaine, R.H., Rockett, Jill Leppert, Gardner, Jane, Suitor, Carol, Colditz, Graham, 2005. Use of a food frequency questionnaire in American Indian and Caucasian pregnant women: a validation study. BMC Public Health 5, 135.

Barnett, R., 2000. Food for thought: the utilization of wild meat in eastern and southern Africa. TRAFFIC Report. 264.

Barrett, C.B., Arcese, P., 1998. Wildlife harvest in integrated conservation and development projects: linking harvest to household demand, agricultural production, and environmental shocks in the Serengeti. Land Economics 74 (4), 449–465.

Brashares, J.S., Arcese, P., Sam, M.K., Coppolillo, P.B., Sinclair, A.R.E., Balmford, A., 2004. Bushmeat hunting, wildlife declines, and fish supply in West Africa. Science 306, 1180–1183.

Belsky, A.J., 1992. Effects of grazing, competition, disturbance and fire on species composition and diversity in grassland communities. Journal of Vegetation Science 3 (2), 187.

Bennett, E.L., 2002. Is there a link between wild meat and food security? Conservation Biology 16 (3), 590.

Bennett, E.L., Milner-Gulland, E.J., Bakarr, M., Eves, H.E., Robinson, J.G., Wilkie, D.S., 2002. Hunting the world's wildlife to extinction. Oryx 36 (4), 328.

Bingham, S.A., Gill, C., Welch, A., Day, K., Cassidy, A., Khaw, K.T., Sneyd, M.J., Key, T.J.A., Roe, L., Da, N.E., 1994. Comparison of dietary assessment methods in nutritional epidemiology: weighed records v. 24 h recalls, food-frequency questionnaires and estimated-diet records. British Journal of Nutrition 72 (4), 619.

Bokea, Crispin, Ikiara, Moses, 2000. The Macroeconomy of the Export Fishing Industry in Lake Victoria (Kenya). IUCN.

Brashares, J.S., Golden, C.D., Weinbaum, K.Z., Barrett, C.B., Okello, G.V., 2011. Economic and geographic drivers of wildlife consumption in rural Africa. PNAS 108 (34), 13931–13936.

Bruton, M.N., 1990. The conservation of the fishes of Lake Victoria, Africa: an ecological perspective. Environmental Biology of Fishes 27 (3), 161.

Campbell, K., Nelson, V., 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. DFID Animal Health and Livestock Production Programmes, Project R7050.

Coffey, B.K., Schroeder, T.C., Marsh, T., 2011. Disaggregated household meat demand with censored data. Applied Economics 43, 2243–2363.

Damania, R., Milner-Gulland, E.J., Crookes, D.J., 2005. A bioeconomic analysis of bushmeat hunting. Proceedings of the Royal Society B: Biological Sciences 272 (1560), 259–266.

Day, N.E., McKeown, N., Wong, M.Y., Welch, A., Bingham, S., 2001. Epidemiological assessment of diet: a comparison of a 7-day diary with a food frequency questionnaire using urinary markers of nitrogen, potassium and sodium. International Journal of Epidemiology 30 (2), 309.

Deaton, A., Muellbauer, J., 1980. An almost ideal demand system. The American Economic Review 70 (3), 312.

Eales, J.S., Unnevehr, L.J., 1988. Demand for beef and chicken products: separability and structural change. American Journal of Agricultural Economics 70 (3), 521.

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

Fa, J.E., Currie, D., Meeuwig, J., 2003. Bushmeat and food security in the Congo Basin: linkages between wildlife and people's future. Environmental Conservation 30 (1), 71.

Ferraro, P.J., 2001. Global habitat protection: limitations of development interventions and a role for conservation performance payments. Conservation Biology 15 (4), 990–1000.

Ferraro, P.J., Simpson, D., 2002. The cost-effectiveness of conservation payments. Land Economics 78 (3), 339–353.

Galvin, K.A., Polasky, S., Costello, C., Loibooki, M., 2008. Human response to change: modeling household decision making in western Serengeti. In: Sinclair, A.R.E., Packer, C., Mduma, S.A.R., Fryxell, J.M. (Eds.), Serengeti III: Human Impacts on Ecosystem Dynamics. University of Chicago Press, Chicago, p. 325.

Gersovitz, M., Madden, J.P., Smiciklas-Wright, H., 1978. Validity of the 24-hr. dietary recall and seven-day record for group comparisons. Journal of the American Dietetic Association 73 (1), 48.

Green, R., Alston, J., 1990. Elasticities in AIDS models. American Journal of Agricultural Economics 72, 442–445.

Hebert, J.R., Ockene, I.S., Hurley, T.G., Luippold, R., Well, A.D., Hamatz, M.G., 1997. Development and testing of a seven-day dietary recall. Journal of Clinical Epidemiology 50 (8), 925.

Heien, D., Wessells, C.R., 1990. Demand system estimation with microdata: a censored regression approach. Journal of Business and Economic Statistics 8, 365–371.

Hilborn, R.P., Arcese, M., Borner, J., Hando, J.G., Hopcraft, M., Loibooki, S., Mduma, A.R., Sinclair, A.R.E., 2006. Effective enforcement in a conservation area. Science 314 (5803), 1266.

Holmern, T., Roskaft, E., Mbaruka, J., Mkama, S.Y., Muya, J., 2002. Uneconomical game cropping in a community-based conservation project outside the Serengeti National Park, Tanzania. Oryx 36 (4), 364–372.

Holmern, T., Johannesen, A.B., Mbaruka, J., Mkama, S., Røskaft, E., 2004. Human–wildlife Conflicts and Hunting in the Western Serengeti, Tanzania. NINA Norwegian institute for nature research, Trondheim, Norway.

Holmern, T., Muya, J., Røskaft, E., 2007. Local law enforcement and illegal bushmeat hunting outside the Serengeti National Park. Tanzania Environmental Conservation 34 (1), 55.
Jabarin, A.S., 2005. Estimation of meat demand system in Jordan: an almost ideal demand system. International Journal of Consumer Studies 29 (3), 232.
Jambiya, George, Milledge, S., Mtango, N., 2007. Night Time Spinach' Conservation and Livelihood Implications of Wild Meat Use in Refugee Situations in North-western Tanzania. TRAFFIC East/Southern Africa, Dar Es Salaam, Tanzania.
Johannesen, A.B., 2005. Wildlife conservation policies and incentives to hunt: an empirical analysis of illegal hunting in western Serengeti, Tanzania. Environment and Development Economics 10, 271–292.
Kaltenborn, B.P., Nyahongo, J.W., Tingstad, K.M., 2005. The nature of hunting around the Western Corridor of Serengeti National Park, Tanzania. European Journal of Wildlife Research 51 (4), 213–222.
Kümpel, N.F., Milner-Gulland, E.J., Cowlishaw, G., Rowcliffe, J.M., 2010. Incentives for hunting: the role of bushmeat in the household economy in rural Equatorial Guinea. Human Ecology 38 (2), 251–264.
Knapp, Eli, 2007. Who poaches? Household economies of illegal hunters in western Serengeti, Tanzania. Human Dimensions of Wildlife 12 (3), 195–196.
Knapp, E.J., 2012. Why poaching pays: a summary of risks and benefits illegal hunters face in western Serengeti, Tanzania. Tropical Conservation Science 5 (4), 434–445.
Knapp, E.J., Rentsch, D., Schmitt, J., Polasky, S., Lewis, C., 2010. A tale of three villages: choosing an effective method for assessing poaching levels in western Serengeti, Tanzania. Oryx 44 (2), 178.
Ling, S., Kumpel, N., Albrechtsen, L., 2002. No new recipes for bushmeat. Oryx 36 (04), 330.
Liu, Hongbo, Parton, Kevin A., Zhou, Zhang-Yue, Cox, Rod, 2009. At-home meat consumption in China: an empirical study. The Australian Journal of Agricultural and Resource Economics 53, 485–501.
Loibooki, Martin, Hofer, Heribert, Campbell, Kenneth L.I., East, Marion L., 2002. Bushmeat hunting by communities adjacent to the Serengeti National Park, Tanzania: the importance of livestock ownership and alternative sources of protein and income. Environmental Conservation 29 (3), 391–398.
Mainka, S.A., Trivedi, M. (Eds.), 2002. Links Between Biodiversity Conservation, Livelihoods and Food Security: the Sustainable Use of Wild Species for Meat. Gland, Switzerland and Cambridge. IUCN, UK.
Marsh, T.L., Schroeder, T.C., Mintert, J., 2004. Impacts of meat product recalls on consumer demand in the USA. Applied Economics 36 (9), 897.
Mbano, B.N.N., Malpas, R.C., Maige, M.K.S., Symonds, P.A.K., Thompson, D.M., 1995. The Serengeti regional conservation strategy. Serengeti II: Dynamics, Management, and Conservation of an Ecosystem "The Serengeti Regional Conservation Strategy.". University of Chicago Press, Chicago, p. 605.
Milner-Gulland, E.J., Bennett, E.L., 2003. Wild meat: the bigger picture. Trends in Ecology & Evolution 18 (7), 351.
Nasi, R., Brown, D., Wilkie, D., Bennett, E., Tutin, C., van Tol, G., Christophersen, T., 2008. Conservation and Use of Wildlife-based Resources: the Bushmeat Crisis. Secretariat of the Convention on Biological Diversity & Center for International Forestry Research (CIFOR), Montreal, Canada.
National Bureau of Statistics, 2002. Tanzania 2002 Population and Housing Census. The United Republic of Tanzania, Dar Es Salaam, Tanzania.
National Bureau of Statistics Tanzania, 2002. Household Budget Survey: 2000/2001 Dar Es Salaam. Ministry of Finance and Economic Affairs, Tanzania.
National Park, Serengeti, 2006. Serengeti National Park General Management Plan. 2006–2016.
Ndibalema, V.G., Songorwa, A., 2008. Illegal meat hunting in Serengeti: dynamics in consumption and preferences. African Journal of Ecology 46 (3), 311.
Ntiba, M.J., Kudoja, W.M., Mukasa, C.T., 2001. Management issues in the Lake Victoria watershed. Lakes Reservoirs 6 (3), 211.
Nyahongo, J.W., Holmern, T., Kaltenborn, B.P., RØskaft, E., 2009. Spatial and temporal variation in meat and fish consumption among people in the western Serengeti, Tanzania: the importance of migratory herbivores. Oryx 43 (2), 258.
Park, J., Holcomb, R.B., Raper, K.C., Capps, O., 1996. A demand systems analysis of food commodities by US households segmented by income. American Journal of Agricultural Economics 78, 290–300.
Piggott, N.E., Marsh, T.L., 2004. Does food safety information impact US meat demand? American Journal of Agricultural Economics 86, 154–174 (February).
Prins, Herbert H.T., 1992. The pastoral road of extinction: competition between wildlife and traditional pastoralism in east Africa. Environmental Conservation 19 (2), 117–123.
Prins, Herbert H.T., 2000. Competition between wildlife and livestock in Africa. In: Prins, H.H.T., Dolan, T.T. (Eds.), Wildlife Conservation by Sustainable Use. Kluwer Academic Publishers, Boston.
Rentsch, D., Packer, C., 2012. Bushmeat Consumption and Local Demand for Wildlife: Wildebeest Offtake Estimates for Western Serengeity (mimeo).
Robinson, J.G., Bennett, E.L., 2002. Will alleviating poverty solve the bushmeat crisis? Oryx 36 (4), 332.
Robinson, J.G., Bennett, E., 2004. Having your wildlife and eating it too: an analysis of hunting sustainability across tropical ecosystems. Animal Conservation 7 (4), 397.
Rowcliffe, J.M., Milner-Gulland, E.J., Cowlishaw, G., 2005. Do bushmeat consumers have other fish to fry? Trends in Ecology & Evolution 20 (6), 274–276.
Shonkwiler, J.S., Yen, Steven T., 1999. Two step estimation to a censored system of equations. American Journal of Agricultural Economics 81 (4), 972–982.
Sinclair, A.R.E., 1995. Serengeti past and present. Serengeti II: Dynamics, Management, and Conservation of an Ecosystem "Serengeti Past and Present.". University of Chicago Press, Chicago, p. 1.
Sinclair, A.R.E., Hopcraft, J.G., Olff, H., Mduma, S.A.R., Galvin, K.A., Sharam, G.J., 2008. Historical and future changes to the Serengeti ecosystem. In: Sinclair, A.R.E., Packer, C., Mduma, S.A.R., Fryxell, J.M. (Eds.), Serengeti III: Human Impacts on Ecosystem Dynamics. University of Chicago Press, Chicago, p. 7.
Taljaard, P.R., Alemu, Z.G., van Schalkwyk, H.D., 2004. The demand for meat in South Africa: an almost ideal estimation. Agrekon 43 (4), 430–443.
Thirgood, Simon, Mosser, A., Tham, S., Hopcraft, M., Mlengeya, T., Kilewo, M., Fryxell, J., Sinclair, A.R.E., Borner, M., 2004. Can parks protect migratory ungulates? The case of the Serengeti wildebeest. Animal Conservation 7, 113–120 (113).
Wadud, A., 2006. An analysis of meat demand in Bangladesh using the Almost Ideal Demand System. The Empirical Economic Letters 5 (1), 30–35 (January).
Wilkie, D.S., Godoy, R.A., 2001. Income and price elasticities of bushmeat demand in lowland Amerindian societies. Conservation Biology 15 (3), 761.
Wilkie, D.S., Starkey, M., Abernethy, K., Effa, E.N., Tefler, P., Godoy, R., 2005. Role of prices and wealth in consumer demand for bushmeat in Gabon, Central Africa. Conservation Biology 19 (1), 268–274.