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Factors determining the choice of hunting and trading bushmeat in the Kilombero Valley, Tanzania

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Conservation Biology

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The choice of hunting and trading bushmeat in the Kilombero Valley, Tanzania:

What factors are most likely to reduce the bushmeat trade effectively?

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Abstract

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Keywords: Choice experiment, bushmeat, poaching, wildlife management

Introduction

Despite high levels of *de jure* protection wildlife populations in most parks in the tropics are negatively affected by hunting (Craigie et al. 2010; Laurence et al. 2012; Geldmann et al. 2013), and conservation efforts have hence been considered to fail in relation to protected area management and regulating trade in wildlife products (Bennett 2011; Harrison 2011). This has prompted calls for the use of market-based instruments and other economic incentives to promote more efficient environmental regulation (Damiania & Hatch 2005). However, insufficient information is available on what determines illegal hunting effort (Wilkie et al. 2005) and on what factors more likely may induce actors to shift to an alternative occupation. Attempts to explicitly examine the sensitive choice to engage in hunting and trading bushmeat have rarely been made. But choice experiments, a stated preference method which has more than 20 years use in developing countries (Whittington 2010), may allow us to elicit comparable measures of preferences across factors and attributes of the choice to hunt/trade bushmeat relative to alternative options, while reducing the sensitivity of the issue by using hypothetical scenarios. While stated preference methods are vulnerable to hypothetical bias they are the only way to capture preferences *ex ante* of a change (Bateman et al. 2002). Careful attention to design reduces such bias yet it has to be considered in interpreting results.

Moro et al. (2012) recently undertook an inspiring attempt to determine what would most efficiently reduce bushmeat hunting in Serengeti using choice experiments. Their focus was on the trade-off between hunting effort and other livelihood strategies and their sample consisted of regular community members asked to imagine and answer as if they were hunters. While the subject may be less sensitive to this sample it may not well represent groups actively involved in the bushmeat trade. Several valuation studies show that familiarity with goods change the stated value, improve preference estimation (List 2005; Christie et al. 2006), and decrease uncertainty associated with

making the trade-offs (Olsen et al. 2011). The decision to undertake an illegal activity such as hunting and trading bushmeat is not just a question of expected income and economic rationality but also depends on subjective norms and the specific attitude towards the behavior (St John et al. 2010). These aspects affect individuals utility and hence the likelihood of engaging in a given activity. Combined with the many studies revealing distinct socio-economic and demographic characteristics of hunting households (Loibooki et al. 2002; Starkey 2004; Coad et al. 2010; Mifunda & Røskaft 2010), this suggests that preferences and trade-offs of non-hunters are likely to be different from those involved in hunting and trading bushmeat. Here we also focus on the choice between hunting/trading bushmeat and alternative occupations – but we use a sample of 325 individuals currently active in the bushmeat trade in the Kilombero Valley of Tanzania. Hence this study as far as we know constitute the first choice experiment with actors involved in a bushmeat commodity chain. In addition to providing results on actual as opposed to potential hunters preferences and trade-offs (i.e. Moro et al. 2012), this enables us to differentiate between actors with distinctly different roles in the bushmeat trade and hence assess the necessity of differentiated policies and management strategies.

Specifically we asked respondents to choose between a day of hunting/trading bushmeat and a day of salary based work, under varying conditions of law enforcement patrol frequency and magnitudes of fines for the former alternative; salary in the work option for the later alternative; and the price of substitute domestic animal meat and donation of a number of cows to the household common for both alternatives. We further model the choice contingent upon socioeconomic characteristics.

Methods

Study area

The study was conducted in the Kilombero Valley which is one of Africa's largest wetlands spanning more than 6,550 km^2 and a component of the greater Selous-Niassa ecosystem centered on the world heritage listed Selous Game Reserve to the south (Fig. 1). To the north the valley borders the Udzungwa Mountains, a component of the Eastern Afro Montane Biodiversity Hotspot, and to the east the Mikumi National Park. The standard of material well-being in the area is extremely low (Starkey et al. 2002). The study focuses on three anonymous villages located on the northern edge of the valley of which the central part is designated as the Kilombero Game Controlled Area (KGCA), below the Udzungwa Scarp Forest Reserve (USFR). The villages are known for unlicensed commercially oriented hunting and bushmeat trade resulting in marked declines of several species including the near endemic puku (*Kubus vardoni*) (TAWIRI 2009).

Data Collection

A focus group discussion in each village, conducted in June 2011, with 5-7 key informers involved in the bushmeat trade was used to assist our identification of factors likely to affect individuals' choice between hunting/trading bush meat and alternative occupations. Participants were identified over the course of a one year study of the bushmeat trade in 2008 and 2009 (MRN unpublished data). The survey was undertaken October and November 2011 in Swahili with the aid of two research assistants. A snowball sampling strategy (Patton 1990), based on the local knowledge of collaborating actors, was applied to attempt to identify and interview all individuals in the three villages engaged in the bushmeat trade. The long term relations with the actors in the bushmeat trade in the area, and the local insight of research assistants, enabled us to obtain all identified

actors' confidence, ensure their collaboration and open discussion on the subject. A structured questionnaire was used to collect demographic and socio-economic household information incl. on income and selected productive and nonproductive assets owned (land, domestic animals and household assets) (see Appendix 1, Supporting Information). Income was converted to per Adult Equivalent Units (AEU) following Cavendish (2002). Detailed information on function in the bushmeat commodity chain was collected through an open-ended question. Respondents were placed in three main actor groups based on their own description of activities undertaken. Hence the sample consists of 80 hunters, 169 traders and 76 local retailers where: hunters undertake the killing and initial processing (chopping into lager parts); traders transport the meat to villages, make smaller packages of meat and sell to an established clientele of customers; or hire retailers who sell the meat in the streets (number of actors per villages is presented in Table S1, Supporting Information). After the initial questions, respondents were presented with the choice experiment.

Choice experiment design

Relevant attributes of the choice between hunting/trading bushmeat and alternative occupations were selected on the basis of what was considered important by participants of the focus group discussions, the first author's experience from the area (cf. above) and informed by economic theory and the literature on drivers of the bushmeat trade (cf. below). The five selected attributes includes dairy cows donated (a commonly suggested and pursued extension strategy [e.g. Mockrin et al. 2005]), the price of domestic animal meat, daily salary in an unspecified but available alternative occupation of similar strenuousness, patrolling frequency by law enforcement staff and magnitude of the fine if caught (see Table 1). The underlying hypotheses are based on standard economic theory and empirical evidence indicating: 1) that people would be less likely to engage in hunting/trading bushmeat illegally if they had more domestic animals producing meat and dairy

products for own subsistence use and income generation (Mockrin et al. 2005); 2) that a higher price of domestic animal meat will encourage hunting both to supply households own animal protein needs and to supply increased demand for cheaper bushmeat (Wilkie & Godoy 2001; Apaza et al. 2002; Brashares et al. 2004; Wilkie et al. 2005); 3) that higher wages increase the utility of choosing a salary job and hence reduce the propensity to choose the hunting/trading bushmeat option (Sirén et al. 2006; Gill et al. 2012; Sayer et al. 2012); and 4) that increased expected cost in terms of the product of frequencies of patrolling and fines reduce the inclination to choose the hunting or trading bushmeat option (Milner-Gulland & Clayton 2002; Damania et al. 2005).

Combining all attribute levels would result in 768 alternatives. However, it is common practice to apply a fractional factorial design, selecting a subset of all possible combinations, yet maintaining estimation ability for main effects and some second order effects. The design software Ngene version 1.1.1. was used to generate such a design consisting of 12 scenarios (see example in Appendix 2, Supporting Information) optimized for d-efficiency. Scenarios were then grouped into three blocks each consisting of four choice sets. Each respondent was first randomly presented with one block. Subsequently they were presented with a random block of the two remaining blocks, where the scenarios in addition included the donation of four dairy cows (i.e. regardless of choice). The context of the experiment and the scenarios was furthermore described as a hypothetical game to reduce incentives for strategic answers (for further detail see Appendix 2, Supporting Information). Individual preferences were uncovered trough asking respondents to choose between the salary work option or continue hunting/trading bushmeat under these eight different circumstances.

The choice experiment was followed by a direct open-ended contingent valuation [i.e. Willingness to Accept (WTA)] question, with a provision point mechanism, on the daily income respondents

would require from an alternative occupation in order to drop hunting/trading bushmeat (for further

detail see Appendix 2, Supporting Information).

Analysis of choice experiment data

As the choice experiment has only two outcomes (hunt/trade bushmeat or conduct salary work) we

use a random effects logit model with a respondent identification number set as a group variable.

The model include main effects of donated cows, price of domestic animal meat and salary, but an

interaction term for the fine and patrol frequency attributes (henceforth referred to as the patrol-fine

interaction). The two individual attributes must be dropped as the marginal effect of neither can be

validly estimated without consideration of the other. We included a number of socioeconomic and

demographic variables to examine the influence of wealth and other household characteristics.

Hence the resulting model is a binary logit random effects model according to which the likelihood

of choosing hunting/trading bushmeat (s=1) over salary work (s=0) is given by:

$$ln\frac{p_{(s=1)}}{1-p_{(s=1)}} = \beta_{1,v}Cd_1 + \beta_{2,v}Dp + \beta_{3,v}S + \beta_{4,v}PF + \beta_{5,v}Av + \beta_{6,v}Lc + \beta_{7,v}I + \alpha_v$$

s= 0 or 1 and v=1…325   (1)

where v is the individual index and α_v is a panel effect capturing the individual specific variance.

The notation for the attributes and socioeconomic variables is described in Table 1.

We tested for learning and fatigue effects across the choice experiment and for scale differences

(scale is the inverse to the variance) between market actors and applied scale parameters where

significant (for further detail see Appendix 3, Supporting Information). Marginal effects of one unit

change, averaged over observations in other variables in the models was calculated using the

EFFECTS command. Finally a model including interaction between actor groups and the various

attributes and socioeconomic variables was estimated to test for significant differences between

actor groups. The analysis was conducted in Nlogit 5/Limdep 10.

Results

The overall model is shown in Table 2. All attributes and socioeconomic variables were significant

with the expected signs. In addition Mcfaddens pseudo R^2 was relatively high at 0.56 suggesting

that the co-variates significantly improve choice prediction. The model predicts accurately 81% of

actual choices made. Data was adjusted for scale differences between the first and last four choice

sets and between actor groups (see Appendix 3, Supporting Information).

The results reveal that donation of cows, higher daily salary in an alternative available occupation, a

higher patrol-fine interaction and cultivation of more land, significantly reduce the likelihood that

the average person in the sample choose to hunt/trade bushmeat (Table 2). A higher price of

domestic animal meat, having more value invested in selected assets per AEU (on the 0.1 level) and

earning higher total annual household income per AEU was on the other hand associated with

significantly higher likelihood of choosing to continue hunting/trading bushmeat. Marginal effects

of one unit change, averaged over observations in other variables in the model reveal that an

additional salary of 1,000 TZS per work day reduces the likelihood that the average person in the

sample chooses to hunt/trade bushmeat by approximately 11% (Table 2). The effect of donation of

four cows and an acre land cultivated per AEU reduces the likelihood by 9% and 4% respectively.

A 10,000 unit increase in the patrol-fine interaction, however, had negligible but still significant

negative marginal effect. A 1,000 TZS increases in the price of one kg domestic animal meat had

very limited but still significant positive effect. On the other hand, for each additional million TZS

household assets owned and each million TZS higher annual household income, the likelihood of choosing hunting/trading bushmeat increase by almost 28% and 12% respectively.

However, the model incorporating interactions between actor groups and the attributes and socioeconomic variables indicates that there are significant differences between actors in some effects (Table 3). This includes a significant lower effect of cows donated that is almost cancelled (-1.64 +1.22) for hunters while remaining negative for traders and retailers (the reference group). There is no significant difference between actors in the effect of price of domestic animal meat, salary or the fine-patrol interaction. However, the effect of land cultivated and total income is significantly more negative respectively positive for hunters and traders relative to retailers.

Answers to the CV-format WTA question on how much income from an alternative source would be required for the respondent to drop hunting/trading bushmeat indicated an average daily salary of 7,649 TZS/day (840 95% CI) for the combined sample, 10,016 (1,100 95% CI) for hunters, 7,022 (771 95% CI) for traders and 6,553 (720 95% CI) for retailers with significant difference only between hunters and retailers (F=13; P<0.01). The assessed current daily salary rate for casual work in the area is around 3,000 TZS/day. The required amount may thus reflect a higher expected return from hunting/trading bushmeat. It may, however, also be somewhat inflated by strategic or hypothetical bias (cf. the discussion below).

Discussion

Effect of fines and patrol frequency

The results reveal that traditional conservation approaches based on patrolling and fines have very low influence on the choice to hunt/trade bushmeat. This applied although the ranges were extended

beyond the frequencies and fines currently used in the Kilombero Valley. Moro et al (2012) in their study find a much larger effect of enforcement in terms of the likelihood of apprehension, but this was based on a sample of the general population in the area. Therefore, in addition to the basic difference between the relevant attributes (see Appendix 2, Supporting Information) this may be explained by the currently very low patrol effort in KGCA and the fact that our sample consist of individuals actually involved in hunting/trading bushmeat who are likely to be fundamentally less averse to these specific risks than individuals not involved in these illegal activities (Milner-Gulland 2001). Other studies have, however, found that hunting have declined as a result of increased law enforcement (Milner-Gulland & Clayton 2002; Jachmann 2008).

Salary in an available alternative occupation

Not surprising, the most important attribute affecting the choice is the daily salary in the alternative occupation, representing the opportunity costs of continuing hunting/trading bushmeat relative to taking salary work. Non-linear prediction (i.e. estimating the conditional mean) at the approximate current level of other attributes (price of 3,000 TSK/kg domestic animal meat; patrol frequency of once per month; fine of 50,000 TZS), indicate that the likelihood that the average individual will choose hunting could be reduced to 10% (arbitrarily selected level as a complete stop is probably unrealistic) if a job opportunity providing a salary of 5,400 TZS/day was available, all else equal, with likely positive effects on wildlife populations (cf. below). Recent evidence from Equatorial Guinea in support of this result found decline in the bushmeat trade following the outmigration of hunters to seek employment in the construction industry in a period of rapid economic growth (Gill et al. 2012).

We chose to measure the salary attribute in terms of daily salary rather than monthly wage. This means that we cannot make direct inference as to whether respondents would make the same choice confronted with an opportunity for a longer term employment with a monthly salary. However, it is

likely that greater job security would be associated with willingness to accept a lower salary per day.

Donation of livestock and the price of domestic animal meat

The second most important attribute of the choice was donation of livestock with the same direction of effect as observed by Moro et al. (2012). Non-linear predictions at the current level of other attributes (c.f. above) and assuming that no salary work is available indicate that the likelihood that the average individual would choose hunting could be reduced to less than 20% through donation of four cows. Just as any alternative economic activity that directly absorb labor and raise the opportunity cost, increased focus on livestock production may reduce the bushmeat trade directly by affecting individuals' cost-benefit considerations. Specifically, livestock production may provide income through offspring, dairy products, and meat as well as contributing to substituting bushmeat as a source of meat for the household.

An increase in availability of domestic animal meat at the aggregated level following a massive donation of livestock, could furthermore potentially reduce the price of domestic animal meat sufficiently to affect the relative demand for and price of bushmeat. But hard evidence that demand for bushmeat would lessen if livestock was more available is limited (Wilkie et al. 2005). Furthermore, while the marginal effect at an individual level is significant, implementation of such a policy at the aggregate level (particularly if scaled up to include other relevant villages) raises other concerns. Studies for instance indicate that competition and spread of diseases from livestock to wildlife already has adverse effects on wildlife populations in the Kilombero Valley (Bonnington et al. 2007). Thus donation of livestock does not easily suggest itself as a panacea for reducing bushmeat hunting, though it could be part of a combined policy.

The price of domestic animal meat has very limited effect on the choice, and non-linear prediction reveals that the likelihood of choosing to hunt/trade bushmeat can be reduced only to 30% even if the price of domestic animal meat was reduced to a third of the current level when salary work is unavailable (i.e. adjusting the scenario described above). This may reflect the significant difference in price between domestic animal meat and bushmeat and respondents expectations of continued shortage of meat. Fresh bushmeat (all species combined) is sold in packages weighing about 2 kg (but varying depending on demand) and on average cost 2,609 TZS (33 95% CI) whereas cow meat on average cost 4,392 TZS (27 95% CI) per kg.

Socioeconomic factors

Respondents preferences, and hence choices, may vary systematically with socio-economic and demographic factors. We find that wealthier households, in terms of income (particularly hunters and traders) and value of assets are more likely to choose to continue hunting/trading bushmeat consistent with reluctance to relinquish what they know generates high profit (c.f. Appendix 4, Supporting Information), and because they perhaps are more productive at this than others, being less credit constrained, or subject to less risk in terms of enforcement implications. Our focus was exclusively on individuals involved in the bushmeat trade, but this result is consistent with recent studies indicating that within rural communities the middle or even higher income groups harvest most bushmeat (de Merode et al. 2004; Starkey 2004; Kümple et al. 2010). Similarly the negative effect of acres of agricultural land cultivated suggests that people (particularly hunters and traders) with more land more readily abort trading bushmeat perhaps in expectation of sufficient agricultural income and as a result of higher opportunity costs of labor on land. This result is consistent with the findings of Johannesen (2005) indicating that people cultivating less land in the Serengeti ecosystem are more likely to be involved in hunting.

Hypothetical and strategic bias

As all stated preference methods, this study is subject to hypothetical bias and particularly strategic bias. This could be further exacerbated by the developing country context including insecure institutions, low education and resulting lack of trust (Whittington 2010). In particular one could expect that attributes related to negative incentives such as patrolling frequency and fines could be underestimated compared to attributes representing positive incentives. We cannot exclude the occurrence of strategic answers. But inspecting the coefficient of the patrol-fine interaction it is evident that it is so low that even a severe downward strategic or hypothetical bias will not change the result that very high patrol frequencies or fines are needed to seriously affect the choice. Similarly, the estimated required salary to accept an alternative occupation (and the stated WTA income required to drop hunting/trading bushmeat), although higher than payments from available casual labor, is still within the same order of magnitude. Another common reason for hypothetical bias relates to unfamiliar contexts (List 2005; Christie et al. 2006). However, as we sample individuals currently involved in hunting/trading bushmeat and have selected attributes based on their relevance according to focus group discussions and interviews with similar individuals this aspect is unlikely to be a significant source of bias compared to e.g. Moro et al. (2012).

Recommendations and future directions

This paper supports the findings of Moro et al. (2012) in illustrating that choice experiments have a potential in providing specific and relevant information for policy development and selection of management strategies on the sensitive subject of the bushmeat trade. In spite of fairly modest sample sizes we are able to obtain significant estimates and make valid inferences on variables, and our models predict observed choices well. While the use of hypothetical scenarios likely have contributed to making the process of elicitation of preferences less sensitive, the previously established long term relations with these actors in the bushmeat market may also have contributed.

Future studies applying this approach should identify, target and elicit preferences from people who are actually involved in the bushmeat trade, rather than approximating these by asking a broader sample of community members to respond as if they were hunters (as in Moro et al. 2012). As people self-select into these activities and those involved may be distinctly different from other community members, analyses should be based on the specific group in focus of the policy. This also enables stronger conclusions because information on preferences and trade-offs is based in the relevant socioeconomic and demographic characteristics and social psychological profiles (St. John et al. 2010). Most notably the likely higher risk aversion among a population consisting mainly of non-hunters (i.e. Moro et al. 2012) may explain the marked difference in the effect of command and control measures relative to this study.

This study finds that realistic ranges of fines and patrolling frequencies have very low potential to influence the choice of hunting/trading bushmeat compared to the opportunity costs in terms of daily salary in an alternative available occupation, the potential in owning livestock, and the price of substitute meats. The models suggest that particularly the salary in an available alternative occupation would have the highest effect on the bushmeat trade. This is consistent with other recent studies indicating that hunting rarely is a preferred activity but rather viewed as a means of obtaining regular income when paid employment is unavailable (Coad et al. 2010; Kümple et al. 2010), escalating during periods of economic recession and high unemployment (Endamana et al. 2010; Wittemyer 2011). This suggests that perhaps anti-poaching policies should be directed more at increasing the opportunity cost of poaching by creating better alternative economic opportunities (Poudyal et al. 2009; Gill et al. 2012; Sayer et al. 2012). Specifically this study indicate that if a job was available paying the equivalent of USD 3.37 per day then hunting and trading of bushmeat could be reduced to 10% of the current level. That is, for less than 400,000 USD per year hunting, that appears to be the main reason for significant declines of buffalo, hippopotamus and warthog

and substantial declines of puku and elephant populations (TAWIRI 2009, selected species), could in theory be almost eliminated in the three villages facilitating rebound of wildlife populations. At the same time, the redirection of work effort would produce compensating production values in the new occupations.

However, caution is required in relation to implementing the management recommendations resulting from this study, as our assessments only reflect the choices of individuals at the margin. Large scale implementation of policies will have equilibrium effects not accounted for in studies such as this. Specifically, even in the unlikely event that a major new employment opportunity could be established in the Kilombero Valley, achieving an effect on hunting would require that job opportunities were targeted at both current and potential new hunters and traders of bushmeat taking their place. It would also have to fully occupy their time budgets ensuring they will not pursue hunting activities in any spare time. Finally, the policy need to address the possibility that hunters may simply use this opportunity to purchase firearms themselves instead of renting them from JKT (Jeshi la Kujenga Taifa – national service) army personnel as appears to be common practice now. In addition bushmeat demand is likely to increase with increasing income (Wilkie et al. 2005; Godoy et al. 2010) as well as potential immigration (Poulsen et al. 2009) resulting from establishment of such new income generating opportunities in the Kilombero Valley.

Supporting Information

The questionnaire used (Appendix 1), description of the choice experiment design and contingent valuation question (Appendix 2), analysis of the choice experiment (Appendix 3), and details in relation to comparison between the results of the choice experiment and the contingent valuation WTA question (Appendix 4) are available online. The authors are solely responsible for the content of this material. Queries (other than absence of the material) should be directed to the corresponding author.

Literature Cited

Apaza, L., D. Wilkie, E. Byon, T. Huanca, W. Leonard, E. Pèrez, V. Reyes-Garcia, V. Vadez, and R. Godoy. 2002. Meat prices influence the consumption of wildlife by the Tsimane' Amerindians of Bolivia. Oryx **36:** 382–388.

Bateman, I.J., Carson, R.T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato et al. 2002. Economic Valuation with Stated Preference Techniques. Edward Elgar, Cheltenham, 458 pp.

Bennett, E. L. 2011. Another inconvenient truth: The failure of enforcement systems to save charismatic species. Oryx **45:** 476-479.

Bonnington, C., D. Weaver, and E. Fanning. 2007. Livestock and large wild mammals in the Kilombero Valley, in southern Tanzania. African Journal of Ecology **45:** 658–663.

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

Cavendish, W. 2002. Quantitative methods for estimating the economic value of resource use to rural households. Pages 17–65 in B. Campbell and M. Luckert (editors), Uncovering the hidden harvest. Valuation Methods for Woodland and Forest Resources. People and Plants Conservation Series. Earthscan, London, UK.

Christie, M., N. Hanley, J. Warren, K. Murphy, R. Wright, and T. Hyde. 2006. Valuing diversity of biodiversity. Ecological Economics **58:** 304-317.

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

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

Damiania, R., and J. Hatch. 2005. Protecting Eden: Markets or governments. Ecological Economics **53:** 339–351.

Damania, R., E.J. Milner-Gulland, and D.J. Crookes. 2005. A bioeconomic analysis of bushmeat hunting. Proceedings of the royal society **272:** 259-266.

de Merode, E., K. Homewood, and G. Cowlishaw. 2004. The value of bushmeat and other wild foods to rural households living in extreme poverty in Democratic Republic of Congo. Biological Conservation **118:** 573–581.

Endamana, D., A. K. Boedhihartono, B. Bokoto, L. Defo, A. Eyebe, C. Ndikumagenge, Z. Nzooh, M. Ruiz-Perez, and A. Sayer. 2010. A framework for assessing conservation and development in a Congo Basin forest landscape. Tropical Conservation Science **3:** 262–281.

Geldman, J., M. Barnes, L. Coad, I. D. Craigie, M. Hockings, and N. D. Burgess. 2013. Effectiveness of terrestrial protected areas in reducing habitat loss and population decline. Biological Conservation **161:** 230–238.

Gill, D. J. C., J. S. Fa, J. M. Rowcliffe, and N. F. Kümpel. 2012. Drivers of change in hunter off-take and hunting strategies in Sendje, Equatorial Guinea. Conservation Biology **26:** 1052–1060.

Godoy, R., E. A. Undurraga, D. Wilkie, V. Reyes-García, T. Huanca, W. R. Leonard, T. McDade, S. Tanner, V. Vadez, TAPS Bolivia Study Team. 2010. The effect of wealth and real income on wildlife consumption among native Amazonians in Bolivia: Estimates of annual trends with longitudinal household data (2002-2006). Animal Conservation **13:** 265–274.

Harrison, R. 2011. Emptying the forest: Hunting and the extirpation of wildlife from tropical nature reserves. BioScience **61:** 919–924.

Jachmann, H. 2008. Monitoring law-enforcement performance in nine protected areas in Ghana. Biological Conservation **141:** 89–99.

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.

Kümpel, N. F., E. J. Milner-Gulland, G. Cowlishaw, and J. M. Rowcliffe. 2010. Incentives for hunting: The role of bushmeat in the household economy in rural Equatorial Guinea. Human Ecology **38:** 252–264.

Laurence, W. F., D. C. Useche, J. Rendeiro, M. Kalka, J. A. Bradshaw, S. P. Sloan, S. G. Laurance, M. Campbell, K. Abernethy et al. 2012. Averting biodiversity collapse in tropical forest protected areas. Nature **489:** 290–294.

List, J. A. 2005. Scientific numerology, preference anomalies, and environmental policymaking. Environmental and Resource Economics **32:** 35-53

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

Milner-Gulland, E. J. 2001. Assessing sustainability of hunting: Insights from bioeconomic modelling. Pages 113–152 in M. I. Bakarr, G. A. B. da Fonseca, R. Mittermeier, A B. Rylands and K.W. Painemilla (editors), Hunting and Bushmeat Utilization in the African Rain Forest:

Perspectives Towards a Blueprint for Conservation Action. Advances in Applied Biodiversity science number 2, Conservation International, Washington DC, USA.

Milner-Gulland, E. J., and L. Clayton. 2002. The trade in babirusas and wild pigs in North Sulawesi, Indonesia. Ecological Economics **42:** 165–183.

Mockrin, M. H, E. L Bennett, and D. T. La Bruna. 2005. Wildlife farming: A viable alternative to hunting in tropical forests? WCS Working Paper No. 23. Wildlife Conservation Society, New York.

Moro, M., A. Fisher, M. Czajkowski, D. Brennan, A. Lowassa, L. C. Naiman, and N. Hanley. 2012. An investigation using the choice experiment method into options for reducing illegal bushmeat hunting in western Serengeti. Conservation Letters DOI: 10.1111/j.1755-263X.2012.00284.x/.

Olsen, S. B., T. H. Lundhede, J. B. Jacobsen, and B. J. Thorsen. 2011. Tough and easy choices: Testing the influence of utility balance and other design issues on self-reported certainty levels. Environmental and Resource Economics **49:** 491-510

Patton, M. 1990. Qualitative evaluation and research methods. Sage Publications. Newbury Park, California, USA, pp. 532.

Poudyal, M., K. Rothley, and D. Knowler. 2009. Ecological and economic analysis of poaching of the greater one-horned rhinoceros (*Rhinoceros unicornis*) in Nepal. Ecological Applications **19:** 1693–1707.

Sayer, J. A., D. Endamana, M. Ruiz-Perez, A. K. Boedhihartono, Z. Nzooh, A. Eyebe, A. Awono, and L. Usongo. 2012. Global financial crisis impacts forest conservation in Cameroon. International Forestry Review **14:** 90–98.

Síren, A. H., J. C. Cardenas, and J. D. Machoa. 2006. The relation between income and hunting in tropical forests: An economic experiment in the field. Ecology and Society **11**(1): 44 available online at: http://www.ecologyandsociety.org/vol11/iss1/art44/.

Starkey, M., N. Birnie, A. Cameron, R.A. Daffa, L. Haddelsey and L. Hood. 2002. The Kilombero Valley Wildlife Project: An ecological and social survey in the Kilombero Valley, Tanzania. The Kilombero Valley Wildlife Project, Edinburgh, UK.

Starkey, M. 2004. Commerce and subsistence: The hunting, sale and consumption of bushmeat in Gabon. PhD thesis (pp. 305). University of Cambridge, Cambridge, United Kingdom.

St. John, F. A. V., G. Edwards-Jones, and J. P. G. Jones. 2010a. Conservation and human behavior: Lessons from social psychology. Wildlife Research **37:** 658–667.

TAWIRI 2009. Kilombero Ramsar site project, KVRSP: Wet season 2009 aerial census in the Kilombero Valley flodplains Ramsar site. Tanzania Wildlife Research Institute, Conservation Information and Monitoring Unit in collaboration with Tanzanía National Parks and Wildlife Division.

Whittington D. 2010. What have we learned from 20 years of stated preference research in less-developed countries? Annual Review of Resource Economics **2:** 2:209–236.

Wittemyer, G. 2011. Effects of economic downturns on mortality of wild African elephants. Conservation Biology **25:** 1002–1009.

Wilkie, D. S., and R. A. Godoy. 2001. Income and price elasticities of bushmeat demand in lowland Amerindian societies. Conservation Biology **15:** 761–769.

Wilkie, D., M. Starkey, K. Abernethy, E. Effa Nsame, P. Telfer, and R. Godoy. 2005. Role of prices

and wealth in consumer demand for bushmeat in Gabon, Central Africa. Conservation Biology **19:**

268–274.

Figure legend

Figure 1. Sketched map of Kilombero valley based on sheet SC-37-1 and SC-36-4 in scale

1:250.000, Series Y 503, edition 1 TSD 1961, published by the survey division, ministry of lands,

forests and wildlife, Tanganyika 1962.

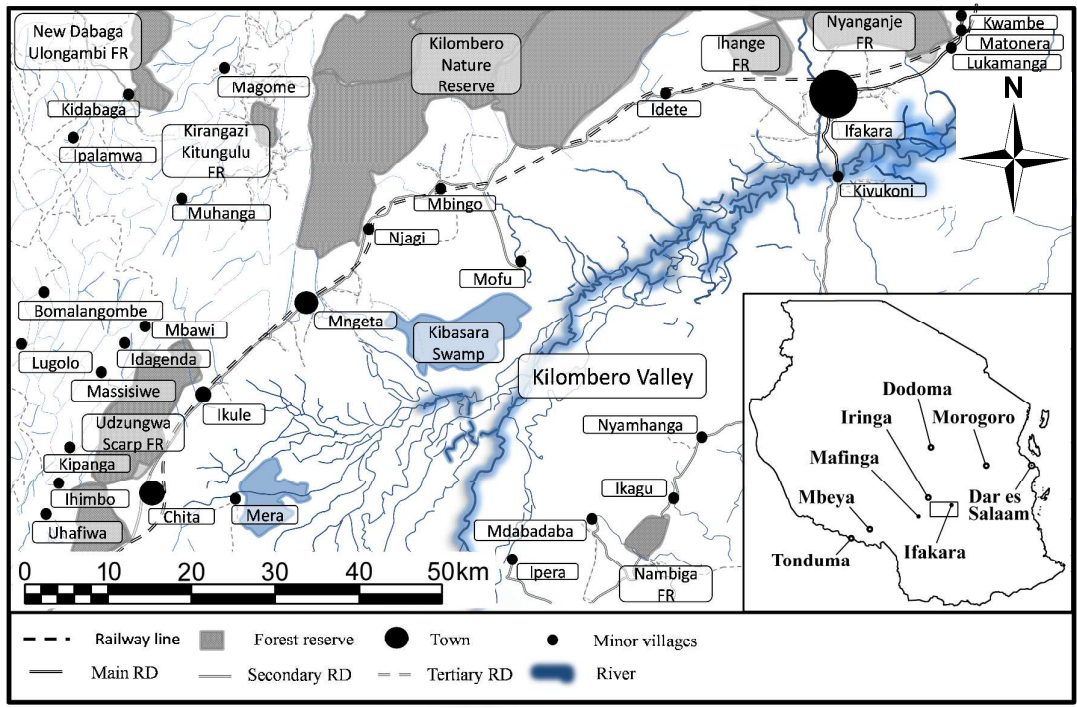Figure 1

Table 1. Attributes, their levels and hypothesis about their effects on the choice to hunt/trade bushmeat or accept the salary job option. Hypotheses were largely based on bio-economic equilibrium theory as outlined in Milner-Gulland (2001) (see also Supporting Information, Appendix 1).

Notation	Attribute	Levels	Hypothesis
Cd	Cows donated	0 and 4	Higher number of cows reduces the inclination to choose to hunt/trade bushmeat illegally because it supplies meat and products for own use and income generation
Dp	Price of domestic animal meat in general	1.000, 3.000, 4.000 and 6.000 (TZS/kg)	Higher price provide incentives to hunt/trade bushmeat in order to cover own protein needs and profit from potential positive spill-over to the price of bushmeat
S	Daily salary in an alternative occupation of similar strenuousness and risk	1.000, 2.000, 3.000, 4.000, 5.000 and 7.000 (TZS/day)	Higher wages reduce the propensity to choose the hunting/trading bushmeat option.
Interaction = PF	Patrolling frequency by law enforcement staff	Once per year, twice per year, once every month and once every week	The product of patrolling frequency and magnitude of fine is the expected costs of enforcement. Therefore higher frequency and higher fines reduce the utility from hunting/trading bushmeat.
	Magnitude of the fine	30.000, 50.000, 100.000 and 300.000 (TZS/arrest)	

Note: In addition the following continuous socio-economic variables were included, *Av* = value of selected household assets per AEU, *Lc* = acre land cultivated per AEU and *I* = total annual household income per AEU.

Table 2. First column is the random effect binary logistical regression on the choice to hunt/trade bushmeat or do salary work (base group). Second column is the marginal effects for the logistic probability function averaged over observations. First numbers represent the regression coefficient and numbers in brackets are robust std errors.

	Logit model	**Marginal effect**
Donated cows	-0.94474 (0.16881)***	-0.09168 (0.01542)***
Price of domestic animal meat (1,000 TZS/kg)	0.12150 (0.03401)***	0.01179 (0.00316)***
Salary (1,000 TZS/day)	-1.15293 (0.03900)***	-0.11188 (0.00189)***
Patrol-fine interaction (10,000)	-0.00045 (0.00018)**	-0.00004 (0.00002)**
Household assets value (1,000,000 TZS/AEU)	2.83627 (1.45153)*	0.27524 (0.14008)*
Land cultivated (acre/AEU)	-0.39948 (0.16221)**	-0.03877 (0.01571)**
Total income (1,000,000 year/AEU)	1.22790 (0.34971)***	0.11916 (0.03354)***
Constant	3.58091 (0.28996)***	
Sigma	2.40894 (0.14065)***	
Model properties		
Observations	2593	
Groups (i.e. individuals)	325	
Log-likelihood	-942.81755	
McFadden's pseudo R^2	0.5590	
AIC/n	0.734	

*, ** and *** signify statistical significance at 0.1, 0.05 and 0.01 levels, respectively.

Table 3. Random effect binary logistical regression on the choice to hunt/trade bushmeat or do salary work (base group) incorporating interactions between actor groups and the attributes and socioeconomic variables. First number represents the regression coefficient and numbers in brackets are robust standard error terms.

	Logit model
Donated cows	-1.63934 (0.33907)***
Donated cows*hunter	1.22359 (0.46955)***
Donated cows*trader	0.65751 (0.41990)
Price of domestic animal meat (1,000 TZS /kg)	0.14813 (0.05802)**
Price of domestic animal meat*hunter	-0.00793 (0.08515)
Price of domestic animal meat*trader	-0.01856 (0.07283)
Salary (1,000 TZS/day)	-1.19758 (0.09930)***
Salary*hunter	0.17490 (0.11276)
Salary*trader	-0.06747 (0.10303)
Patrol-fine interaction (10,000)	-0.00093 (0.00038)**
Patrol-fine interaction*hunter	0.00051 (0. 00051)
Patrol-fine interaction*trader	0.00072 (0.00044)
Household assets value (1,000,000 TZS/AEU)	5.14175 (5.40045)**
Household assets value*hunter	-3.55845 (5.59533)
Household assets value*trader	0. 94900 (6.03015)
Land cultivated (acre/AEU)	0.30757 (0.28909)
Land cultivated*hunter	-1.01517 (0.46696)**
Land cultivated*trader	-1.03919 (0.37803)***

Total income (1,000,000 year/AEU)	-0.40373 (0.85974)
Total income*hunter	2.42498 (1.17844)**
Total income*trader	1.89691 (1.09309)*
Constant	3.56330 (0.36609)***
Sigma	2.40127 (0.18414)***
Model properties	
Observations	2593
Groups (i.e. individuals)	325
Log-likelihood	-925.77892
McFadden's pseudo R^2	0.4337
AIC/n	0.7318

*, ** and *** signify statistical significance at 0.1, 0.05 and 0.01 levels, respectively.