Correlates of Bushmeat Hunting among Remote Rural Households in Gabon, Central Africa

STEFFEN FOERSTER,* † DAVID S. WILKIE,* ‡ GILDA A. MORELLI,* JOSEFIEN DEMMER,§ MALCOLM STARKEY,¶ PAUL TELFER,** MATTHEW STEIL,†† AND ARTHUR LEWBEL‡‡

*Boston College, Office of the Provost and Dean of Faculties, Waul House, 270 Hammond Street, Chestnut Hill, MA 02467, U.S.A.
‡Wildlife Conservation Society, 2300 Southern Boulevard, Bronx, NY 10460, U.S.A.
§Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, P.O. Box 94062, 1090 GB Amsterdam, The Netherlands
¶Wildlife Conservation Society, BP 7847, Libreville, Gabon
∗∗Wildlife Conservation Society, BP14537, Brazzaville, Republic of Congo
††World Resources Institute, 10 G Street NE Suite 800, Washington, DC 20002, U.S.A.
‡‡Boston College, Department of Economics, 140 Commonwealth Avenue, Chestnut Hill, MA 02467, U.S.A.

Abstract: Hunted wild animals (i.e., bushmeat) are a main source of protein for many rural populations in the tropics, and the unsustainable harvest of these animals puts both human food security and ecosystem functioning at risk. To understand the correlates of bushmeat consumption, we surveyed 1219 households in 121 rural villages near three newly established national parks in Gabon. Through the surveys we gathered information on bushmeat consumption, income, and material assets. In addition, we quantified land cover in a 5-km radius around the village center and distance of the village center to the nearest park boundary. Bushmeat was not a source of income for most households, but it was the primary animal protein consumed. Ninety-seven percent of households consumed bushmeat at least once during a survey period of 12 days. Income or wealth, land cover, distance of village to the nearest park boundary, and level of education of the head of the household were among the factors that significantly related to the likelihood of consuming any of the 10 most commonly consumed species of bushmeat. Household size was the predictor most strongly associated with quantities of bushmeat consumed and was negatively related to consumption. Total bushmeat consumption per adult male equivalent increased as household wealth increased and decreased as distance of villages to park boundaries increased. Bushmeat consumption at the household level was not related to unit values (i.e., price estimates for a good that typically does not have a market value; estimates derived from willingness to sell or trade the good for items of known price) of bushmeat or the price of chicken and fish as potential substitutes. The median consumption of bushmeat at the village level, however, was negatively related to village mean unit values of bushmeat across all species. Our results suggest that a lack of alternative protein sources motivated even the wealthiest among surveyed households to consume bushmeat. Providing affordable, alternative protein sources to all households would likely reduce unsustainable levels of bushmeat consumption in rural Gabon.

Keywords: consumption, household economies, household surveys, human welfare, protected areas, wildlife conservation

Correlaciones de la Caza de Carne de Monte en Grupos Familiares Rurales en Áreas Remotas de Gabón, África

Resumen: Los animales silvestres (i.e., carne de monte) son una fuente importante de proteína para muchas poblaciones rurales en los trópicos, y la cosecha no sustentable de esos animales colocan en riesgo tanto a la seguridad alimentaria humana como el funcionamiento del ecosistema. Para comprender las correlaciones del consumo de carne de monte, encuestamos a 1219 grupos familiares en 121 poblados rurales cerca de...
tres parques nacionales recién establecidos en Gabón. Mediante las encuestas recopilamos información sobre el consumo de carne de monte, ingresos y bienes materiales. Adicionalmente, cuantificamos la cobertura de suelo en un radio de 5 km alrededor del poblado y la distancia del centro del poblado al límite del parque más cercano. La carne de monte no fue una fuente de ingreso para la mayoría de los grupos, pero fue la principal proteína animal consumida. Noventa y siete por ciento de los grupos familiares consumieron carne de monte por lo menos una vez durante un periodo de 12 días. El ingreso o riqueza, la cobertura de suelo, la distancia del poblado al límite del parque más cercano y el nivel educativo del jefe de familia fueron algunos de los factores que se relacionaron significativamente con la probabilidad de consumir cualquiera de las 10 especies de carne de monte consumidas más comúnmente. El tamaño de la familia fue el predictor asociado más estrechamente con las cantidades consumidas de carne de monte y se relacionó negativamente con el consumo. El consumo total de carne de monte por macho adulto aumentó con el incremento de la riqueza de la familia y decreció con el incremento de la distancia hasta los límites del parque. El consumo de carne de monte a nivel de familia no se relacionó con las unidades de valor (i.e., estimaciones de precio para un bien que típicamente no tiene un valor de mercado; estimaciones derivadas de la disponibilidad para vender o canjear el bien por productos de precio conocido) de la carne de monte o del valor del pollo o pescado como sustitutos potenciales. Sin embargo, el consumo medio de carne de monte a nivel de poblado se relacionó negativamente con las unidades de valor promedio de carne de monte de todas las especies. Nuestros resultados sugieren que la carencia de fuentes alternativas de proteína motivaron el consumo de carne de monte, aun en las familias más ricas. Proporcionar fuentes alternativas y accesibles de proteína podría reducir los niveles de consumo no sustentable de carne de monte en áreas rurales de Gabón.

**Palabras Clave:** áreas protegidas, bienestar humano, conservación de vida silvestre, consumo, economía doméstica, encuestas a grupos familiares

**Introduction**

Wild animals are a primary source of protein for many rural populations in poor countries, particularly for people living in or near tropical forests (Redford 1993; Fa et al. 2002b). Both subsistence hunting and the trade in bushmeat are often unsustainable (Fitzgibbon et al. 1995; Noss 1998; Brugiere & Magassouba 2009) and can result in dramatic declines of local populations of wild animals (Brashares et al. 2004; Fa & Brown 2009). The unsustainable harvest of mammals and birds can have negative effects on forest structure and regeneration (Stoner et al. 2007; Brodie et al. 2009), ecosystem functioning (Cullen et al. 2001), and species diversity (Redford 1992; Wilkie & Carpenter 1999; Robinson & Bennett 2000).

Identifying factors that correlate with the consumption of bushmeat lead to a better understanding of how hunting of wild animals could be reduced to sustainable levels. Bushmeat consumption may be associated with factors such as taste preferences (Njiforti 1996; Schenck et al. 2006; Ndibalema & Songorwa 2008); availability of hunting equipment (Damania et al. 2005; van Vliet & Nasi 2008; Coad et al. 2010); market price of bushmeat (Wilkie & Godoy 2001; Cowlishaw et al. 2005; Wilkie et al. 2005); availability and price of goods that may act as substitutes for or complements to bushmeat (Wilkie & Godoy 2001; Nyahongo et al. 2009); and household income or wealth (Wilkie & Godoy 2001; Albrechtsen et al. 2005; Fa et al. 2009).

In addition to identifying economic and social predictors of bushmeat consumption, identifying positive and negative correlations between bushmeat consumption and income or wealth may help one predict the effect economic development may have on bushmeat consumption. If consumption of bushmeat increases as income or wealth increase, then economic development that increases household wealth may do little, alone, to reduce hunting. A decrease in bushmeat consumption may only be achieved through the enforcement of restricted spatial or temporal access to animal habitats or by making acceptable alternative protein sources available. If, however, bushmeat were an inferior good consumed only by households that lack access to better (and typically more expensive) alternatives, then its consumption would decrease as income or wealth increase (Wilkie & Godoy 2001) and economic development would presumably have positive effects on conservation of wild animals.

Comprehensive empirical assessments of the correlates of bushmeat consumption are still relatively scarce and often have had contrasting results. Among Amerindian societies of Central and South America, for example, bushmeat appears to be a necessity for low-income households, but is considered an inferior good by members of high-income households (Wilkie & Godoy 2001). Consumption of bushmeat increases as income among the poorest people increases, but bushmeat is replaced by other, more preferred goods among wealthier households. In studies of urban and rural households in Gabon (Wilkie et al. 2005) and Equatorial Guinea (East et al. 2005; Fa et al. 2009), however, bushmeat consumption increases monotonically as income increases. In contrast, a study on the island of Bioko in Equatorial Guinea showed that bushmeat consumption decreases as income increases (Albrechtsen et al. 2005), which indicates wealthier households replace bushmeat with more preferred sources of protein. These contrary
findings likely result from local ecological, social, and historical differences (Fa et al. 2009). For example, bushmeat consumption and hunting practices vary among ethnic groups (East et al. 2005), either in response to cultural traditions and food preferences (Fa et al. 2002a; Ndibalema & Songorwa 2008) or variability in access to wild animals and to markets where wild meat and meat of livestock are sold (Wilcox & Nambu 2007).

We investigated the correlates of bushmeat consumption among rural households of Gabon. We assessed social and economic household-level variables, village attributes, prices of major sources of protein, and land cover around villages. Identifying the correlates of bushmeat consumption may help predict future consumption patterns and identify how management practices of protected areas may affect human welfare.

Methods

Study Sites and Village Selection

This study is part of a longitudinal study that aims to assess the effects of protected areas on human welfare through a before-after-control-impact (BACI) study (Wilkie et al. 2006; Foerster et al. 2011). We gathered data on household patterns of bushmeat consumption and livelihood variables in the vicinity of three newly established national parks in rural Gabon: Biringou, Ivindo, and Monts de Cristal. We selected 121 villages in which to conduct extensive surveys (Supporting Information). We gathered information on household composition (number, age, and sex of all household members), education, income, and wealth from 1219 households. Subsequently, we conducted an intensive survey in a subset of villages (56) and households (928) in the vicinity of each park (169 households in 14 villages near Biringou, 371 households in 15 villages near Ivindo, and 388 households in 27 villages near Monts de Cristal) to gather information on food consumption. This sample was composed primarily of remote villages, few of which were close to urban centers, and represented about 7% of all villages in Gabon. On average villages had 17 (SE 1) households and 125 (SE 9) inhabitants. To account for seasonal changes in bushmeat consumption, we split this survey into two periods: February–May 2006 (dry season) and September–December 2006 (wet season). Two researchers spent 1 week in each village, where they surveyed and interviewed each household three times. Half of the households were interviewed on days 1, 3, and 5 and half were interviewed on days 2, 4, and 6.

Income and Wealth

We assessed household wealth (permanent income) on the basis of the total value of a collection of 22 assets owned by any household member. We included assets that span a broad range of values and thus were likely to be owned by households that differ widely in wealth (e.g., cooking equipment, guns, beds, mattresses, lamps, watches, clocks, refrigerators, music players, televisions, mobile phones, electric fans, air conditioners, vehicles). We recorded the value of all assets in local currency (African Financial Community franc [XAF]) and reported them in purchasing power parity (PPP) in U.S. dollars to facilitate comparison with other locations. We used the PPP conversion factor for private consumption in 2005, which was 443.7 XAF per PPP (World Bank 2008). Thus, 443.7 XAF had approximately the same purchasing power in Gabon as US$1 in 2005.

To estimate transitory income, we asked all working household residents to recall the amount of income during the previous month from salaries, wages, bonuses, pensions, donations, commercial enterprises, sale of forest goods, gifts, and remittances. In addition, we asked them to recall their earnings from annual crops. We divided income into categories that reflected different income ranges (Supporting Information) and in private had each subject point to the category their income fell into.

Measuring Consumption

We asked heads of households to recall all produce, natural resources, and manufactured goods consumed (purchased, hunted, caught, or otherwise obtained) during the 48 h prior to the survey by all members of the household. For each consumed item, heads of households provided an actual or estimated value in XAF and the number of units of that good consumed. We estimated the value of items produced by the household by having interviewees estimate the price they would have sold an item for or the quantity of a good with a known price that they would trade it for.

To obtain an adequate measure of animal protein consumption that would not be affected by variation in market value across villages, we transformed all protein consumption (except tinned fish) into kilograms. Because the majority of proteins is measured in units other than kilograms (e.g., piece, leg, head, pile, cup), we estimated the weight for each item in one of the following ways. For some frequently used units (e.g., leg, pile, cup), we use weights provided in Wilkie et al. (2005). We used the unit value (i.e., price estimates for a good that typically does not have a market value; estimates derived from willingness to sell or trade the good for items of known price) of a whole animal of the species to estimate weight consumed: value consumed × mean weight whole/mean unit value whole. When unit-value data for whole animals were not available for the village in which they were consumed (15% of all cases), we used the average unit value for the whole animal calculated across all villages. If the mean weight of the whole animal could not be obtained from our records, we used average adult weight of the animal reported in the literature, if available.
The 62 consumption records for which animal weight could not be calculated were excluded from analyses. An additional 60 records were excluded because the respective households were surveyed on <3 days. The final data set included 3633 consumption records (terrestrial wildlife, 1825; wild-caught fish, 1788; chicken, 319; other livestock [e.g., cattle, pig, goat, sheep], 111). Only 20 households (2.6%) stated they did not consume bushmeat at any time during the survey.

Land Cover

The presence of animal habitat near villages varies and affects the quantity and kind of animals humans can hunt. To control for this effect, we analyzed land cover in a 5-km radius around each village measured from the village centroid. We observed that hunters rarely went farther than 5 km away from villages during hunting trips, and our findings did not change when we extended the land-cover analysis to a 10-km radius around each village.

To calculate the percent area of different land-cover types, we used GlobCover (version 2.2, ESA GlobCover Project, MEDIAS-France, Toulouse), which provides gridded global land-cover data at a resolution of 300 m (MERIS Full Resolution Level 1B product) for December 2004–June 2006. Land-cover classes are defined on the basis of the United Nations Land Cover Classification System. The classes we used were forest (>50–70% area cover) and cropland (20–50% area cover) mosaic; closed (>40% canopy cover) broadleaf evergreen or semideciduous forest (>5 m tall); and closed to open (>15% canopy cover) broadleaf evergreen or semideciduous forest (>5 m tall). We refer to these classes as forest-cropland mosaic, closed forest, and closed to open forest, respectively. We excluded three additional land cover classes from analysis because they covered <5% of the total area surveyed across all villages. We carried out all analyses with ArcGIS 9.3.1 (ESRI, Redlands, California).

Statistical Analyses

We expressed consumption and income measures per adult male equivalent (AME) to control for different demographic compositions of households (Deaton 1997). We based conversion of household size to AME on estimated daily food requirements (kilocalories per day) for different ages and genders (James & Schofield 1990). We used generalized estimating equations to model the relation between consumption of bushmeat (kilograms per AME per month) and the following independent variables: household wealth, household income, number of household members, number of years of education completed by the household head, land cover, distance from nearest park boundary (measured from the village center), bushmeat price (as assessed by unit value), and the price of potential substitutes of bushmeat (i.e., fish, chicken, other livestock). Because household members themselves caught much of the bushmeat they consumed and because we did not collect information on actual market prices, we used average unit values per village to estimate demand elasticities in our models (Deaton 1997). Variation in bushmeat quality (i.e., fresh, dried, smoked) was low; fresh meat accounted for approximately 96% of all bushmeat consumed.

To account for the clustering of households in villages near different national parks, we entered park and village as subject variables (random effects) in the model and independent variables as covariates. Because we were interested in variables associated with the decision of households to consume bushmeat and those that were correlated with the quantity of bushmeat eaten, we used a two-step modeling process. First, we used a binary logistic (logit) model to investigate what factors were associated with whether a household consumed a given species. Second, we used a linear model and a log-link function to model the correlates of consumption quantity only among those households that consumed that species. We considered these second-step models conditional demand functions (i.e., they were conditional on the choice to consume that type of bushmeat). For all models we applied a robust estimating method to account for potential misspecification of models. We assessed model fit with a quasi likelihood under independence model criterion (QIC) and model effects with Wald chi-square statistics. We report only the results of the best model for any given data set (lowest QIC). We considered results with a 5% or lower probability of type I error significant, but included results here if p values were between 0.05 and 0.10 because our sample sizes were relatively low for some models and hence power of statistical tests was low. All tests were performed with PASW Statistics 17 (SPSS) for Windows.

Validation Studies

With our two-step approach, we could not control for selection bias in the estimation of the demand function because we estimated the demand function (quantity consumed) for only those households that consumed bushmeat. To identify variables associated with consumption across both consumers and nonconsumers of bushmeat, it may be beneficial to estimate demand with a conventional Heckman selection model (Heckman 1976). In such a model, a probit regression is fitted on a binary consumption variable to calculate the inverse Mill’s ratio (lambda), which is then used as an additional predictor in an ordinary least squares regression on quantity consumed. To test whether accounting for selection bias would change our results, we re-ran all of our models with the Heckman procedure with maximum likelihood estimation of coefficients and village as the cluster variable for the estimation of standard errors. Efficient Heckman estimation depends on the use of
exclusion restrictions (i.e., variables that affect selection but not quantity consumed). We used the predictors of our generalized logistic models for this purpose. We used the variables identified by our generalized linear models as predictors of the demand function. Analyses were performed in STATA 11.0 for Windows (procedure heckman). Results of this validation approach indicated weak to moderate selection bias. The direction of effects for the predictors of our demand function was largely identical to our prior modeling approach, however. Because the Heckman coefficient estimation may perform poorly (i.e., be associated with unusually large standard errors [Vermeulen 2001]), particularly in the context of estimating elasticities (Lazaridis 2004), we believe the unconditional demand function coefficient estimates derived from this procedure are less reliable than the conditional demand function coefficients; thus, we present only the latter.

We also assessed whether the exclusion of households with commercial hunters would change the magnitude or direction of associations with predictor variables. For this purpose, we re-ran our models excluding all households that obtained >50% of their total income from the sale of bushmeat (n = 35). The direction of all significant effects remained the same, although additional predictors were associated with consumption of some species. Similar to the full data set, no significant own-price elasticities (changes in demand for a particular consumer good on the basis of its price) emerged from these analyses.

Results

Bushmeat was hunted primarily for household consumption. For all surveyed households, sales from bushmeat accounted for >90% of total monthly income for 3% of households (n = 36). For 85% of households it provided no income. The median consumption of bushmeat among households included in the consumption surveys was 3.9 kg/AME/month (0.1 kg/person/day, 750 households), but varied widely across households (0–267.9 kg/AME/month) and villages (1–35.8 kg/AME/month, n = 56). When we excluded households that derived income from the sale of bushmeat (n = 83), median consumption was 3.6 kg/AME/month. The five most commonly consumed species accounted for 63% of all consumption (blue [Phialantomba monticola], red [Cephalophus callipygus, nigrifrons, or ogilbyi], and unidentified duikers [Cephalophus spp.], sitatunga [tragelaphus spekii], and brush-tailed porcupine [Atelerix africanus]). More than 95% of all bushmeat consumption was of 20 species (Table 1).

The median unit value for bushmeat varied between 303 and 1340 XAF/kg across villages (mean = 671 XAF/kg, n = 56 villages). Across species for which we had data on unit values from at least five villages, unit values varied from 234 XAF/kg (golden cat [Profelis aurata]) to 4940 XAF/kg (brush-tailed porcupine) (median = 629 XAF/kg; n = 21 species). Within species, variation in unit value across villages was considerable; coefficients of variation ranged from 16% to 202% (mean = 52%; Table 2). Prices for alternative protein sources ranged from 433 XAF/kg to 1850 XAF/kg for fish (n = 45 village means) and between 400 and 3000 XAF/kg for chicken (n = 42 village means).

Species-Specific Consumption

The odds that a household consumed any of the 10 most commonly consumed bushmeat species were significantly associated with income or wealth, proportion of land covered by different forest types, distance to nearest park boundary, and education of the household head (Table 3). For example, a 10-fold increase in income or wealth (measured in XAF) was associated with 1.6–1.9 times greater odds of consumption of red duikers and unidentified duikers, whereas a 10% change in type of land cover was associated with a change in odds of 30–110% in four species. The range of factors that was most closely associated with the quantity of consumption among those households that consumed a given species was similar to the variables that were associated with the odds of consumption (Table 4), but household size appeared as an additional factor that was generally associated with a decrease in consumption. After household size, distance to park boundary had the most consistent (negative) association with consumption (four species). Land cover was significantly associated with consumption for four species, and education and income had inconsistent associations with consumption of different species (Table 4). Neither the average bushmeat unit value nor the price of alternative protein sources, such as fish and chicken, were associated with consumption of any particular species.

Total Bushmeat Consumption

Three factors were significantly associated with overall bushmeat consumption across households on the basis of our multivariate log-linear model. Consumption per AME decreased as household size increased (b = −0.24, p < 0.001), increased as wealth increased (b = 0.48, p = 0.05), and decreased as distance to the nearest national park boundary increased (b = −0.004, p = 0.04). Total bushmeat consumption showed a negative own-price elasticity of demand when its unit value was entered into the model as the sole predictor variable (b = −0.73, p < 0.01), but its unit value had no effect on consumption when combined with the main predictors (b = 0.002, p = 0.99). Neither chicken nor fish prices were related to total bushmeat consumption.

To further investigate the price elasticity of bushmeat consumption, we conducted post hoc analyses in which...
Table 1. Mean household consumption of bushmeat (in kilogram/adult male equivalent/month) by species, calculated across all households in the vicinity of Biringou, Ivindo, and Monts de Cristal National Parks, Gabon (*n* = 751).

| Species                              | Mean consumption (kg)* | SD      | Percent consumption *b* |
|--------------------------------------|------------------------|---------|-------------------------|
| Blue duiker (*Philantomba monticola*)| 1.88                   | 4.35    | 21.1                    |
| Red duikers (*Cephalophus callipygus*, *nigrifrons*, or *ogilbyi*) | 1.06                   | 4.37    | 11.9                    |
| Unidentified duikers (*Cephalophus* spp.) | 1.00                   | 4.65    | 11.2                    |
| Sitatunga (*Tragelaphus spekit*)      | 0.89                   | 8.00    | 10.0                    |
| Brush-tailed porcupine (*Atherurus africanus*) | 0.84                   | 2.69    | 9.5                     |
| Red river hog (*Potamochoerus porcus*) | 0.59                   | 3.54    | 6.7                     |
| Monkeys (*Cercoptithecus* spp.)       | 0.45                   | 1.82    | 5.0                     |
| Water chevrotain (*Hyemoschus aquaticus*) | 0.35                   | 4.36    | 3.9                     |
| Bay duiker (*Cephalophus dorsalis*)   | 0.28                   | 4.77    | 3.1                     |
| Mandrill (*Mandrillus sphinx*)        | 0.28                   | 1.90    | 3.1                     |
| Gambian rat (*Cricetomys gambianus*)  | 0.16                   | 0.66    | 1.8                     |
| African palm civet (*Nandinia binotata*) | 0.13                   | 1.27    | 1.5                     |
| Cane rat (*Thryonomys swinderianus*)  | 0.12                   | 0.71    | 1.4                     |
| Golden cat (*Profelis aurata*)       | 0.11                   | 1.51    | 1.2                     |
| Long-tailed pangolin (*Manis tetradactyla*) | 0.10                   | 0.65    | 1.2                     |
| Leopard (*Panthera pardus*)          | 0.08                   | 1.52    | 0.9                     |
| Gabon viper (*Bitis gabonica*)       | 0.07                   | 1.34    | 0.8                     |
| Western lowland gorilla (*Gorilla g. gorilla*) | 0.07                   | 1.60    | 0.8                     |
| Bushbuck (*Tragelaphus scriptus*)     | 0.06                   | 1.51    | 0.7                     |
| Sun-tailed guenon (*Cercopithecus solatus*) | 0.06                   | 0.59    | 0.7                     |

*a* Kilograms per adult male equivalent per month (i.e., total household consumption adjusted for the typical energetic needs of its members measured against the energy requirements of a typical 18- to 30-year-old male).

*b* Percentage of all consumed bushmeat across all households.

We associated village mean total bushmeat consumption with the weighted mean unit value per kilogram of bushmeat (weighted by total consumption for each species in a given village) across all species consumed. When we grouped villages according to their weighted mean unit value of 1 kg of bushmeat, mean total household consumption of bushmeat declined consistently as the unit value increased (Fig. 1). Results of a Spearman rank correlation between total bushmeat consumption and weighted village unit value of bushmeat were consistent (*r* < −0.35, *p* < 0.01, *n* = 56). Correlations between mean bushmeat consumption and the mean unit values of either chicken or fish were not significant or nonlinear.

Table 2. Variability in price (African Financial Community Franc per kilogram) of each bushmeat species and alternative protein sources across villages in the vicinity of Biringou, Ivindo, and Monts de Cristal National Parks, Gabon.

| Species a | Mean | SE | Median | Range       | Number of villages | CV b |
|-----------|------|----|--------|-------------|--------------------|------|
| Bushmeat  |      |    |        |             |                    |      |
| Blue duiker | 629  | 14 | 626    | 410-839     | 54                 | 16.4 |
| Brush-tailed porcupine | 739  | 20 | 738    | 451-1107    | 47                 | 18.6 |
| Red duikers | 420  | 31 | 426    | 170-682     | 43                 | 48.4 |
| Gambian rat | 810  | 45 | 833    | 417-1667    | 39                 | 35.2 |
| Monkeys | 699  | 31 | 651    | 434-1128    | 37                 | 27.0 |
| Long-tailed pangolin | 1472 | 77 | 1354   | 1000-2667   | 32                 | 29.6 |
| Unidentified duikers | 307  | 31 | 326    | 118-527     | 27                 | 52.5 |
| Cane rat | 876  | 58 | 910    | 317-1905    | 27                 | 34.4 |
| Red river hog | 456  | 170| 284    | 148-1234    | 26                 | 190.1|
| Mandrill | 758  | 143| 600    | 200-1750    | 24                 | 92.4 |
| Sitatunga | 259  | 117| 155    | 90-955      | 20                 | 202.0|
| Water chevrotain | 530  | 40 | 593    | 130-667     | 18                 | 32.0 |
| African palm civet | 416  | 21 | 444    | 222-593     | 16                 | 20.2 |
| Bay duiker | 527  | 57 | 532    | 298-783     | 13                 | 39.0 |
| Pygmy antelope | 2480 | 265| 2667   | 1867-3200   | 11                 | 35.4 |
| Forest tortoise (unidentified) | 724  | 95 | 690    | 345-1379    | 10                 | 41.5 |
| Bushmeat alternatives |      |    |        |             |                    |      |
| Wild-caught fish | 1253 | 39 | 1265   | 433-1850    | 45                 | 20.9 |
| Chicken | 1465 | 60 | 1346   | 400-3000    | 42                 | 26.5 |
| Other livestock | 1473 | 95 | 1400   | 200-2500    | 25                 | 32.2 |

*a* Species for which unit values were available from at least 10 villages.

*b* Coefficient of variation.
Table 3. Variables associated with the likelihood that households consumed the 10 most commonly consumed bushmeat species.

| Species       | Variable                  | ΔQICC  | Odds ratio | p     |
|---------------|---------------------------|--------|------------|-------|
| Red duikers   | wealth (log)              | 23.2   | 1.87       | 0.003 |
|               | income (log)              | 19.3   | 1.55       | < 0.001 |
| Unidentified  | forest and cropland mosaic| 0.93   |            | 0.02  |
| Sitatunga     | closed forest             | 7.3    | 0.97       | 0.004 |
| Brush-tailed  | closed forest             | 17.8   | 0.97       | < 0.001 |
| porcupine     | education                 |        |            |       |
| Red river hog | wealth (log)              | 23.6   | 2.73       | 0.01  |
| Monkeys       | distance to park          | 3.7    | 1.01       | 0.01  |
| Water chevrotain | distance to park      | 4.8    | 1.02       | 0.03  |
| Bay duiker    | income (log)              | 5.4    | 0.46       | 0.02  |
| Mandrill      | education                 | 4.4    | 1.54       | 0.01  |

a No variables could be identified for blue duiker.

b Variables included in the best models as identified by the quasi likelihood under independence criterion corrected for model complexity (QICC). Variables considered in the model-building process: household size in adult male equivalents (total household consumption adjusted for the typical energetic needs of its members, measured against the energy requirements of a typical 18- to 30-year-old male), income, wealth, level of education of the household head, the species' unit value (in XAF), distance to nearest park boundary (in kilometer from village center), and the percentage of area in a 5-km radius from the village center covered by forest-cropland mosaic, closed forest, and closed to open forest (see Methods for definition of land-cover types).

c Difference in QICC between the best model and the intercept-only (null) model indicates the magnitude of improvement of model fit when the given predictors are included in the model. The larger the difference, the greater the improvement in model fit.

d We set the reference category to zero (household did not consume the species). Thus, odds ratios of < 1 indicate that an increase in the value of the predictor variable by one unit decreases the odds of consuming the species. Odds ratios can be interpreted as the relative change in odds when changing the value of the predictor variable by one unit.

Discussion

Our results indicate bushmeat consumption was associated with a complex interaction of variables that varied among species consumed. First, the likelihood of a species being consumed by households was correlated with the distance to the nearest park boundary and with land-cover type. Second, overall bushmeat consumption was not related to its own unit value. These results differ from those of previous studies (Wilkie et al. 2005). These

Table 4. Variables associated with household consumption of the most common bushmeat species.

| Species          | Number of households | Variable                  | ΔQICC  | Coefficient | p     |
|------------------|----------------------|---------------------------|--------|-------------|-------|
| Blue duiker      | 361                  | Household size            | 2948   | -0.268      | < 0.001 |
|                  |                      | Distance to park          |        | -0.004      | 0.06  |
|                  |                      | Forest and cropland mosaic|        |             |       |
| Red duikers      | 153                  | Household size            | 1972   | -0.181      | 0.001 |
|                  |                      | Distance to park          |        | -0.008      | 0.02  |
|                  |                      | Forest and cropland mosaic|        |             |       |
| Unidentified duikers | 109              | Household size            | 725    | -0.117      | 0.03  |
| Sitatunga        | 48                   | Household size            | 3685   | -0.139      | 0.10  |
| Brush-tailed porcupine | 200              | Household size            | 1824   | -0.516      | < 0.001 |
|                  |                      | Distance to park          |        | -0.013      | 0.002 |
|                  |                      | Education                 |        | -0.415      | 0.002 |
| Red river hog    | 68                   | Distance to park          | 247    | -0.014      | 0.01  |
| Monkeys          | 100                  | Household size            | 1061   | -0.546      | < 0.001 |
| Water chevrotain | 30                   | Household size            | 11,111 | -3.878      | < 0.001 |
| Bay duiker       | 23                   | Household size            | 15,029 | -0.117      | 0.001 |
|                  |                      | Wealth (log)              |        | -0.779      | 0.02  |
|                  |                      | Closed forest             |        | -0.051      | < 0.001 |
|                  |                      | Household size            | 1008   | -0.425      | < 0.001 |
|                  |                      | Distance to park          |        | -0.090      | 0.004 |
| Mandrill         | 45                   | Household size            |        | -0.549      | 0.02  |

a Variables that were included in the best models as identified by the quasi likelihood under independence criterion corrected for model complexity (QICC). For variables considered in the model-building process, see footnote to Table 3.

b Difference in QICC between the best model and the intercept-only (null) model indicates the magnitude of improvement of model fit when the given variables are included in the model. The larger the difference, the greater the improvement in model fit.
Bushmeat Consumption in Rural Gabon

Figure 1. Mean (SE 2) total household consumption of bushmeat (kilogram per adult male equivalent [total household consumption adjusted for the typical energetic needs of its members measured against the energy requirements of a typical 18- to 30-year-old male]) per village per month relative to the weighted mean unit value (value estimate on the basis of willingness to sell or the willingness to trade for a good of known price) of bushmeat (African Financial Community Franc [XAF] per kilogram). Unit-value classes are delineated by the mean and 1 SD around the mean.

Figure 1

differences may be related to the fact that most of the surveyed households obtained bushmeat directly from the forest and not from markets. Although conventional price elasticities may be difficult to assess accurately in this nonmarket economy, labor is valued in rural households. Thus the unit value of bushmeat, as indicated by the willingness to accept payment in the form of other goods of known price, should provide a reasonable approximation of price elasticity of demand (Deaton 1975, 1987, 1990).

That unit values did not correlate with bushmeat consumption as reported previously (Wilkie & Godoy 2001; Apaza et al. 2002) suggests that protein sources other than bushmeat may have been unavailable or too expensive for many households. This lack of own-price elasticity may have been at least in part related to the low availability of domesticated animals in the densely forested areas. However, when we estimated demand functions for chicken and fish (i.e., used the consumption of these potential bushmeat alternatives as a dependent variable in our models), the mean unit value of bushmeat was related positively to the consumption of these bushmeat alternatives. Nevertheless, unit values for chicken and fish were not associated with bushmeat consumption. A possible cause of nonsignificant cross-price elasticities in our bushmeat models could be that unit-value variation within bushmeat alternatives was insufficient to accurately estimate elasticity coefficients. To address this possibility, we used model specifications as in our bushmeat-demand models that estimated quantity consumed per AME per month to determine the association between bushmeat unit values (expressed as weighted village means) and the consumption of bushmeat alternatives. Bushmeat unit values were not related to the consumption of bushmeat alternatives. Assuming symmetry of cross-price elasticities, these results suggest that fish, chicken, or livestock were not adequate substitutes for bushmeat.

Although our results showed no consistent relation between income or wealth and household-level consumption of different bushmeat species, when consumption data for individual species were aggregated wealth was positively associated with consumption. This finding differs from results of studies that show an overall negative relation between income and consumption (Wilkie & Godoy 2001; Albrechtsen et al. 2005; Nielsen 2006), but is consistent with the results of studies that show positive associations of wealth or income with bushmeat consumption among rural households (Wilkie & Godoy 2001; Godoy et al. 2010). The cause of this positive relation is unclear.

Coad et al. (2010) found that households with guns are significantly wealthier than households without guns, and it is reasonable to assume there might be a relation between access to hunting equipment and bushmeat consumption. In our study, households with guns were more than twice as wealthy as households without guns (mean [SD] = 1060 PPP [117] versus 2353 PPP [153], t = 6.8, p < 0.001, N = 713). However, only about 42% of bushmeat-consuming households in our study possessed guns (see also Starkey 2004), and possession of guns was not associated with bushmeat consumption across households after accounting for the main effects of wealth, household size, and distance to the nearest park boundary (p = 0.82).

Given that most households derived no income from the sale of bushmeat, it is likely that bushmeat consumption was a consequence rather than a cause of greater wealth. That wealthier households did not switch to alternative protein sources was likely due to the low availability of bushmeat alternatives in the remote rural villages. In addition, households may not have reached a threshold in income or wealth at which they would begin substituting bushmeat with alternative protein sources, even if available, as indicated by very low income and wealth levels compared with urban Gabonese households (respectively, income, 57 PPP/AME/month versus 192 PPP/AME/month; wealth, 347 PPP/AME/month versus 1552 PPP/AME/month [Wilkie et al. 2005]).
In contrast to our finding that suggested no effect of bushmeat prices on individual household consumption, we also found that on average, less bushmeat was consumed in villages where it had a higher value and that variation in bushmeat consumption across villages did not coincide with changes in the consumption of domesticated animals or fish. It is possible that the relation between bushmeat unit values and consumption emerged because village averages reduced random household variation and reflected average consumption more accurately than household averages. However, it is also possible that village-level analyses were less reliable because they did not account for the simultaneous effects of supply functions and other demand predictors. Thus, the results of these analyses should be interpreted with caution.

Among households that consumed at least some bushmeat, household size was the variable most strongly and consistently associated with consumption; as household size increased, consumption per AME decreased. Theory predicts the opposite; that is, at any given per capita income, the sharing of public goods makes larger households more efficient and leaves more resources to increase per capita consumption of private goods such as food (Deaton & Paxson 1998; Perali 2008). Empirical research shows, however, that this prediction is often inaccurate and that larger households often consume less food per capita than smaller households. It is possible that consumption of bushmeat per capita is being more than offset by consumption of other foods as household size increases, perhaps because effects of price or income or tastes differ across different food types. An alternative explanation could be that the marginal productivity of hunters decreased as household size increased, perhaps because limits to hunting success were independent of household size (hunting restrictions, possession of a limited number of traps, density of animals) or because hunters shared their catch when hunting in groups, leaving hunters with larger families with less bushmeat per capita.

Overall, our results suggest that consumption of bushmeat among rural households in Gabon not only varies by species, but also correlates with proximity to different land cover types. Local variation in land cover can determine the composition and quantity of bushmeat consumed, yet such localized patterns of bushmeat consumption are generally overlooked in studies conducted at larger spatial scales (Andam et al. 2010). The gradient of social and economic conditions included in any sample of households may affect associations with bushmeat consumption that can be detected with statistical analyses, especially if these associations vary across income groups (Wilkie & Godoy 2001). For example, an examination of consumption of bushmeat in a more diverse set of Gabonese households that spanned a greater range of income and wealth suggested that constraining supply and raising the price of bushmeat would likely decrease the demand for bushmeat (Wilkie et al. 2005). For our study of strictly rural households, we could not make such a general prediction. Increased household income and wealth appeared to increase the probability that households would consume certain species, but did not have clear effects on the aggregate level of consumption across all species. Only when much of the variation among households within a village was removed by averaging across households was there a negative price elasticity of demand on bushmeat. If this assessment of a negative price elasticity is accurate, then policy measures aimed at increasing opportunity costs of hunting may reduce bushmeat consumption. Increased opportunity costs may come about through the enforcement of regulations governing the use of natural resources in protected areas or through increasing the costs of hunting equipment (Coad et al. 2010). Given the high reliance of all households on bushmeat as a source of nutrition, however, any attempts at reducing hunting pressure on wild animals through such measures will decrease human welfare unless alternative sources of protein are accessible and affordable to all households.

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Supporting Information

Survey data sheets and protocols are available online for both the extensive (Appendix S1) and consumption (Appendix S2) surveys. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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