Animal Conservation. Print ISSN 1367-9430

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)

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Keywords
income-elasticity; wildlife consumption; fish; game; birds; demand growth.

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Received 24 February 2009; accepted 21 October 2009

doi:10.1111/j.1469-1795.2009.00330.x

Abstract

Over the last decades, native Amazonians have put increasing pressure on animal wildlife owing to growth in demand. Across societies, household monetary income and wealth shape food consumption; hence, so it is natural to ask what effect might these variables have on the demand for wildlife consumption among native Amazonians, particularly as they gain a stronger foothold in the market economy and increasing *de jure* stewardship over their territories. Prior estimates of the effects of household monetary income and household wealth on wildlife consumption among native Amazonians have relied on cross-sectional data and produced unclear results. The goal of this research was to improve the precision of previous estimates by drawing on a larger sample and on longitudinal data. The analysis draws on a dataset composed of five consecutive annual surveys (2002–2006, inclusive) from 324 households in a native Amazonian society of foragers and farmers in Bolivia (Tsimane'). Multiple regression analysis is used to estimate the association between wildlife consumption and monetary income and wealth. Wildlife consumption bore a positive association with the level of household wealth and no significant association with household monetary income. Among Tsimane', the main internal threat to wildlife conservation in the short run will likely arise from increases in wealth, probably from the enhanced capacity that selected physical assets (e.g. guns) have in the capture of animal wildlife.

Introduction

As part of their subsistence strategy, native Amazonians have relied on animal wildlife for millennia (Redford & Robinson, 1991; Robinson & Redford, 1991; Hill & Hurtado, 1996). Over the last decades, native Amazonians have put increasing pressure on animal wildlife (hereafter wildlife) as a result of two broad forces pushing in the same direction, one force coming from the demand for wildlife and the other one coming from the supply of wildlife (Peres & Palacios, 2007). On the demand side, the quantity of wildlife extracted has risen owing to the growth of human population (Alvard *et al*., 1997; Milner-Gulland, Bennet & the SCB, 2002; McSweeney, 2005) and income (Lunde, Skoufias & Patrinos, 2007) and owing to greater hunter participation in the market economy (Sierra, Rodríguez & Losos, 1999; Naughton-Treves *et al*., 2003; Lu, 2007; Suárez *et al*., 2009). As native Amazonian societies gain greater exposure to the market economy, they export to the rest of the world some of the wildlife they extract from their communities (Redford & Robinson, 1991; Stearman & Redford, 1992; Wilkie & Godoy, 1996; Bodmer, Eisenberg & Redford, 1997; Robinson, Redford & Bennett, 1999; Bennett *et al*., 2007). On the supply side, access to new types of hunting technologies (e.g. guns) have lowered the marginal costs of extracting wildlife, and access to improved forms of transport (e.g. outboard motors) have made it easier to expand the foraging radius of hunters (Hames, 1979; Alvard, 1995; Alvard *et al*., 1997; Sierra *et al*., 1999;

Milner-Gulland *et al.*, 2002; Peres & Lake, 2003). The increasing pressure on wildlife is not unique to Latin America but is also found in Africa and Asia, as researchers have recently documented (Shively, 1997; Auzel & Wilkie, 2000; Fa, Peres & Meeuwig, 2001; Bennet & Rao, 2002; Robinson & Bennet, 2004; Wilkie *et al.*, 2005; LeBreton *et al.*, 2006).

As researchers, we have a general understanding of what drives the extraction of wildlife among native Amazonians but we know much less about how specific socioeconomic variables affect the consumption of wildlife over time. Among socioeconomic variables affecting the consumption of wildlife, household wealth and household monetary income deserves empirical scrutiny. Across societies, household wealth and household monetary income play a dominant role in shaping household food consumption (Bourdieu, 1984; Deaton, 1997; Demmer *et al.*, 2002; De Merode, Homewood & Cowlishaw, 2003; Van der Veen, 2003; Wilkie *et al.*, 2005); hence, it is natural to ask what effect do these variables have on wildlife consumption among native Amazonians. As native Amazonians gain a stronger foothold in the market economy, and as they gain increasing *de jure* stewardship over the management of natural resources in their territories (Redford & Stearman, 1993; Nepstad, Schwartzman & Bamberger, 2006), one would expect their wealth and their monetary income to play an increasingly important role in the household economy, including the consumption of natural resources such as wildlife. The stress on understanding the role of household monetary income and household wealth on household wildlife conservation become even more important when one considers the stress on poverty alleviation (Shively, 1997; Brown, 2007). Throughout Latin America and other low-income nations, one finds a growing interest in implementing projects to increase real per capita income; yet, we know little about the direct effects of such efforts on conservation.

Nevertheless, obtaining reliable estimates of the effect of a household's wealth and monetary income on the consumption of wildlife has been hard because the relation might vary across years; estimates from cross-sectional studies might give an inaccurate portrait of the true relation between household wildlife consumption and socioeconomic variables if there was something special about the year in which the measures occurred. Cross-sectional data refer to data collected at only one point in time; in contrast, panel or longitudinal data refer to data collected from the same unit (e.g. household) at different times.

With only one exception known to us (Vickers, 1988), most of the socioeconomic studies of wildlife consumption among native Amazonians rely on cross-sectional data (Sierra *et al.*, 1999; Wilkie & Godoy, 2001; Apaza *et al.*, 2002). These studies show a variety of associations between household monetary income or household wealth and household consumption of wildlife. Drawing on a comparative study carried out during 1997–1998, among 443 households from 42 villages in four lowland Amerindian societies of Bolivia (Yuracaré, Mojeño, Chiquitano, Tsimane'), Wilkie & Godoy (2001) found that income bore a negative association with fish consumption but bore no association with game consumption. To estimate the effect that a change in household income has on wildlife consumption by households, the authors used the concept of household elasticity of consumption, defined as the percentage change in the quantity of wildlife consumed by a household from a 1% change in household income or a 1% change in another variable (e.g. price of substitutes for wildlife). The elasticity of the demand for wildlife might be affected by the availability of substitutes (e.g. beef, chicken), or by an increase in income available to acquire the good. Wilkie & Godoy found that the elasticity of wildlife consumption of a household with respect to household income was −0.15 and statistically significant ($P = 0.05$) for fish consumption, and was +0.05 and indistinguishable from zero ($P = 0.72$) for game consumption. They did not include a measure of wealth, a serious shortcoming as food consumption typically reflects the role of both income and wealth, or temporary and permanent income (Friedman, 1957; Deaton, 1997). In a later study (2000) with a sample of 285 Tsimane' households in the Bolivian Amazon, Apaza *et al.* (2002) found statistically insignificant income and wealth elasticities of game and fish consumption. They found household income elasticities of game and fish consumption of −0.01 ($P = 0.85$) and +0.003 ($P = 0.94$), and they found wealth elasticities of game and fish consumption of +0.061 ($P = 0.60$) and +0.13 ($P = 0.27$). The finding of Apaza and colleagues that neither income nor wealth bore a significant association with wildlife consumption is at odds with a vast empirical literature suggesting that food consumption typically responds to income, wealth or both (Bourdieu, 1984; Godoy, Brokaw & Wilkie, 1995; Deaton, 1997; Shively, 1997; Demmer *et al.*, 2002; De Merode *et al.*, 2003; Van der Veen, 2003; Wilkie *et al.*, 2005). Apaza and colleagues did not test whether their findings of no significant relation could have resulted from insufficient statistical power to detect true magnitudes. In a study spanning almost a decade (1973–1981/1982), Vickers (1988) measured village population size and hunting yields ($kg\,h^{-1}$ of hunting) from an 8% sample of a population in one native Amazonian community in north-east Ecuador (Siona Secoya). After aggregating data to the community level ($n = 6$), he regressed the mean annual hunting yield per hour of effort (outcome variable) against mean annual population size (explanatory variable) and found no change over time in hunting yields.

Prior research has produced suggestive but inconclusive results, and has left several unanswered questions. First, the data from Bolivia suggest that the income elasticity of fish consumption is sensitive to the year of measurement. In their comparative study with data from 1997 to 1998, Wilkie & Godoy (2001) found a statistically significant negative association between fish consumption and monetary income but the later study by Apaza *et al.* (2002) carried out in 2000 among the Tsimane' found no such association. Second, the study of Vickers (1988) aside, none of the studies on wildlife consumption provide estimates of changes over time in wildlife consumption, and even Vickers relied on a small sample of observations ($n = 6$) and did not control for the role of income or other third variables.

Here, we draw on a longitudinal or panel dataset composed of five consecutive annual surveys (2002–2006, inclusive) from 324 households in one native Amazonian society of foragers and farmers in Bolivia, the Tsimane', to achieve two goals: (1) improve the precision of prior estimates of income and wealth elasticities of wildlife consumption by controlling for year effects and by using a large sample of observations; (2) estimate the annual rate of change in household consumption of wildlife while statistically controlling for confounders. Data on wildlife consumption were collected at the household level. Some of the household surveys of prior studies are the same as the ones used in the 2002–2006 panel dataset but in this article we do not include data from the prior studies because of changes in the definition of variables.

Background and study site

The Tsimane' number ~8000 people and live in ~100 villages, mostly along the Maniqui and the Apere rivers in the department of Beni. The Tsimane' economy centers on hunting, fishing, plant foraging and on slash-and-burn farming.

Several studies have described Tsimane' use of game, fish and birds (Chicchón, 1992; Apaza, 2001; Pérez, 2001; Wilkie & Godoy, 2001; Apaza *et al*., 2002, 2003; Gutíerrez, 2005). Besides analyzing the relation between: (1) household monetary income or household wealth; (2) wildlife consumption, the prior studies just cited make the following points that bear on this article: (a) Tsimane' use wildlife mainly for food rather than for other ends (e.g. medicines); (b) market exposure makes it easier to acquire modern hunting technologies; (c) consumption of wildlife responds to changes in the price of wildlife substitutes (e.g. lower beef or chicken prices are associated with lower wildlife consumption). Tsimane' are growth stunted (Foster *et al*., 2005), defined as being ≤ -2 standard deviations relative to peers of the same sex and age in industrial nations but we do not know whether stunting results from deficiencies in consumption of animal proteins and key micronutrients, from widespread parasitic infections common in the area (McDade *et al*., 2005; Tanner, 2005), or from both of these or other causes.

Current sources of monetary income among the Tsimane' include: (1) sale of farm crops, principally rice, and also plantains, maize, manioc and fruits; (2) sale of forest products, principally thatch palm and timber, and also honey, firewood and wildlife; (3) wage labor in logging camps, cattle ranches and in the homestead of colonist farmers; (4) salaried work as school teachers or as employees of local institutions; (5) sale of domesticated animals and animal products (e.g. eggs) (Godoy *et al*., 2007). Despite their participation in the market economy, Tsimane' retain a high degree of economic self-sufficiency. For example, among people over 16 years of age, 74.88% reported no earnings from wage labor and 56.40% reported no earnings from the sale of farm or forest goods for the 14 days before the day of the interview. Across the 5 years of the study, 16% of all household-level observations had zero values for total monetary earnings (total monetary earnings = wage earnings + earnings from sale of goods).

Materials and methods

Survey data

We draw on survey data from a panel study composed of five consecutive annual surveys (2002–2006) (Leonard & Godoy, 2008). We gathered data annually during June–September from all Tsimane' in 13 villages along the Maniqui river, department of Beni (Fig. 1). The panel included a total of about 1500 people in 324 households (household's size mean = 6.15, SD = 2.80). Villages differed in their proximity to the market town of San Borja (mean = 25.96 km; SD = 16.70), the only town along the Maniqui river. Four Tsimane' who worked in the study from its inception worked as translators. The complete data and its documentation, along with publications from the project, are available for public use at the following address: http://people.brandeis.edu/~rgodoy/.

Measure of household wildlife consumption, monetary income and wealth

Household wildlife consumption

To measure wildlife consumption, we asked the female head of the household – or, in her absence, the male head of the household – to list all sources of wild animals that entered the household during the 7 days before the day of the interview, and to indicate for each item the amount consumed in kilograms. As we collected wildlife data at the level of the entire household and we needed measures of wildlife consumption expressed at the individual level, we had to transform the raw measures of wildlife consumption. We estimated the amount of wildlife consumed per person (or per capita) by dividing the kilograms of wildlife consumed by the entire household by the number of people in the household during the survey year. To estimate per capita values, each member of the household was counted as one, as it is the most widely accepted deflation procedure (Deaton & Zaidi, 2002) but in the sensitivity analysis presented later, we also use other deflators besides the head count to ensure the results of the analysis do not hinge on how we defined and estimated consumption. When people reported answers in units (e.g. one bird), we used conversion factors for average usable edible portions of animals to transform information reported in units into kilograms. We developed the conversion factors from our fieldwork among the Tsimane' (Apaza, 2001; Pérez, 2001). We limit the recall period to 7 days before the day of the interview because we found that food recalls beyond that period produced unreliable information. We have no convincing way to correct for random or systematic measurement error in data for the

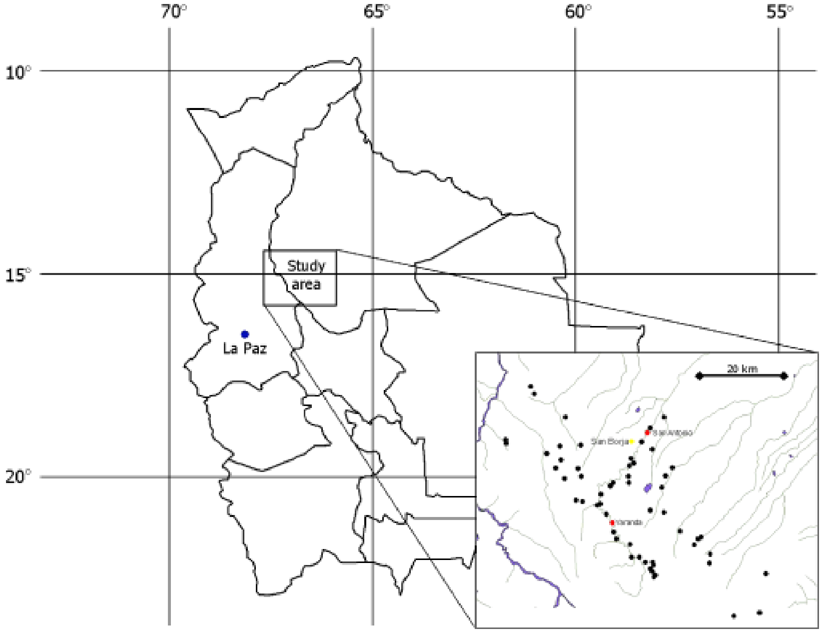

Figure 1 Map showing Tsimane' Amazonian Panel Study area and the distribution of Tsimane' villages in the department of Beni, Bolivia.

wildlife consumed. A shorter recall period (e.g. 1 day) might have produced more accuracy, but it would have also produced lower variance. Diaries would have been impractical as they do not fit easily into an annual panel study. Furthermore, most Tsimane' adults are functionally illiterate, and thus would have found it hard to keep diaries. Measurement errors in the outcome variable should increase standard errors and the likelihood of accepting the null hypothesis of no effect.

Our measure of wildlife consumption refers only to the amounts consumed at home but it likely contains measurement error for at least two reasons. First, at any one time, a household might have had visitors, and thus might have shared wildlife with them. If so, then the amount of wildlife entering the household (which we measured) would overstate the actual amount of wildlife consumed by the members of the household measured. If, on the other hand, the people in the measured household were served wildlife while visiting other households, then our measure of wildlife consumption would understate the true amount of wildlife consumed. Second, Tsimane' villages have no restaurants or bars; hence, all food consumption occurs in households. This said, some Tsimane' may have traveled to nearby towns and in those towns consumed wildlife; we did not measure the amount of wildlife consumed in towns. In short, our impression is that the omission of wildlife consumed outside of the home is likely small, and downward biases from eating out are likely canceled by upward biases from sharing food.

Monetary income

To measure household monetary income we asked all people over 16 years of age (or younger if they headed a household) to report all their monetary earnings from wage labor and from the sale of goods for the 14 days before the day of the interview. For the analysis, we added data on monetary earnings from all adults (>16 unless they were household heads) in a household in a year, and we then divided the total amount of monetary income by the total head count of the household to arrive at an estimate of an annual income for each person. Monetary income changes across seasons. Unfortunately, the panel surveys occurred during June–-September, hence, we have no way of correcting for the seasonality of income.

Wealth

We measured the inflation-adjusted monetary value of a household's wealth in 22 modern and traditional physical assets. The word 'real' refers to the value of a good (or income) after adjusting for inflation, and the word 'nominal' refers to the value of a good (or income) without adjustments for inflation. We added the nominal monetary value of five traditional physical assets (e.g. canoes, bows), 13 modern physical assets (e.g. radios, cutlasses) and four domesticated animals (e.g. chickens, ducks) owned by all people in the household. Based on ethnographic knowledge of the Tsimane' (Reyes-García, 2001; Huanca, 2006; Martínez-Rodríguez, 2009), we selected a range of physical assets to capture wealth differences in the entire sample and between women and men. For instance, the poorest people own bows, arrows and small animals (e.g. chickens) but better-off people are more likely to own large domesticated animals (e.g. cattle) and expensive industrial goods (e.g. guns). Among the assets we measured, we included assets that women generally own (e.g. bags, pots, small animals), and assets that men generally own (e.g. cattle, guns). To

Table 1 Definition of variables measured annually, 2002–2006 (inclusive), used in the regressions

Name of variable in Table 2	Definition
Dependent variables (natural logarithms or log)	
A. Game[a]	Four dependent variables: kilogram of game, fish, birds or total wildlife (game + fish + birds) consumed by household during the 7 days before the day of the interview. The total amount divided by total household head count to arrive at an estimate of mean wildlife consumption per person in household
B. Fish[a]	
C. Birds[a]	
D. Total (A + B + C)	
Explanatory variables	
Log household real monetary income per person[a,b]	Log of mean, real (i.e. inflation-adjusted) monetary income per person in household earned during the 2 weeks before the day of the interview. Income sources include sales of forest and farm goods plus earnings from wage labor and collected only for people ≥16 years of age (or younger if they headed a household). Total household income divided by head count in household
Log household real monetary wealth per person[a,b]	Log of real monetary value of household's wealth measured with five traditional physical assets (e.g. canoes, bows), 13 modern physical assets (e.g. radios, cutlasses, guns), and four domesticated animals (pigs, cattle, chickens, ducks) owned by the household. Value divided by household head count to arrive at an estimate of the mean value of wealth per person in the household
Schooling	Mean maximum school grade achieved by female and male heads of the household
Bed-ridden days	Total number of bed-ridden days by all members of the household during the 14 days before the day of the interview
Household size	Total number of people in the household
Survey year	Year of survey
Village dummies	A full set of 12 village dummy variables, one for each village, included in the regression to control for village fixed effects

[a] +1 added before taking natural logarithms.

[b] To obtain real values, we used the deflators come from the Unidad de Análisis de Políticas Sociales y Económicas (n.d.), a policy analysis bureau of the Bolivian government. (Table 1.1.5, Deflactores implícitos del PIB por rama de actividad económica). The deflators (base = 1990) were: 2002 = 222.23, 2003 = 231.50, 2004 = 257.70, 2005 = 235.14, and 2006 = 247.85.

estimate the nominal value of an asset, we multiplied the quantity by its price in the village, and we added the value of the different assets to arrive at a monetary measure of total nominal wealth for the household. We did not correct for the quality or for the age of the asset. Current nominal values for wealth were transformed into real values using the consumer price index for agricultural and natural resources of Bolivia. Table 1 contains the definition of the variables used in the regression analysis and the notes to it contain a description of the deflators used to obtain inflation-adjusted values for wealth and monetary income.

Estimation strategy

We used the following linear panel approximation to estimate the effect of household monetary real income and household real wealth on average per capita consumption of wildlife in the household:

$$\ln\ Y_{whvt} = \alpha + \gamma \ln I_{hvt} + \zeta \ln W_{hvt} + \eta C_{hvt} + \beta V_t + \varepsilon_{hvt} \quad (1)$$

In equation (1), $\ln Y$ stands for the natural logarithm (hereafter log) of the mean amount of kilograms of wildlife type w consumed per capita during the 7 days before the day of the interview in household h in village v at time (or year) t. We split wildlife (w) into the following four types: game, fish, birds and total (sum of game, fish and birds). Explanatory variables include the following: (1) $\ln I$ stands for the log of the monetary real income in a household earned by all people over 16 years of age from the sale of goods and wage labor during the 14 days before the day of the interview divided by the number of people in the household each year; (2) $\ln W$ stands for the log of real wealth in physical assets owned by the household each year; (3) C stands for a vector of control variables measured at the household level (e.g. household size, mean schooling of household heads, total days ill by all people in the household), which might change across years and affect both wildlife consumption and income or wealth; (4) V, which stands for a full set of 12 dummy variables for villages ($n = 13-1 = 12$) to control for villages' attributes that remain fixed during the study period but that may affect household wildlife consumption and household monetary income or wealth (e.g. proximity to town, prices, stocks of wildlife). We do not include prices as separate explanatory variables because (1) the stress here lies on the potential role of income, wealth and time trends; (2) because we do not have village prices for wildlife or wildlife substitutes for all years. Some prices and all other fixed attributes of villages that may have remained fixed during the study are swept away in the dummy variables for villages and, in the sensitivity analysis, by a full set of year–village variables (described later). We estimated the parameters of expression (1) using a household fixed-effect linear panel regression.

Table 2 Trends in per capita wildlife consumption among Tsimane' households, Bolivia, 2002–2006 (inclusive) ($n=1098$), results of household fixed-effect panel linear regressions

	Dependent variables – natural log of mean (kg)/person of wildlife consumed per household per year			
Explanatory variables	A. Game	B. Fish	C. Birds	D. Total (A+B+C)
A. Log household monetary real income per person	0.002 (0.88)	0.001 (0.90)	0.010 (0.039)	0.006 (0.69)
B. Log household monetary real wealth per person	0.527 (0.010)	0.509 (0.000)	0.388 (0.000)	0.383 (0.011)
C. Schooling	−0.004 (0.916)	−0.082 (0.043)	0.004 (0.723)	−0.045 (0.204)
D. Bed-ridden days	−0.003 (0.833)	0.016 (0.169)	0.003 (0.425)	0.006 (0.543)
E. Household size	−0.032 (0.590)	−0.136 (0.000)	−0.121 (0.000)	−0.098 (0.016)
F. Survey year	0.031 (0.267)	0.064 (0.001)	0.008 (0.192)	0.050 (0.026)
Constant	−64.572 (0.262)	−128.764 (0.001)	−18.528 (0.165)	−99.397 (0.028)
Overall R^2	0.08	0.15	0.71	0.12

Regression results shown include the coefficient (or constant) and, below and in parentheses, the *P* values. Regressions include clustering by household, robust standard errors, and full set of dummy variables for communities (not shown).

Because our estimates for the parameters of income and wealth could reflect the role of omitted variables and because of random and systematic measurement errors with these variables, our estimates of elasticities of wildlife consumption are likely biased. As we have no convincing instrumental variable for income or wealth, the elasticities we estimate must be read as associations. Finding reliable instrumental variables for income or wealth is difficult because native Amazonian societies are highly autarkic or economically self-sufficient, and in such economies the demand and supply framework operates poorly.

Main results

Table 2 contains the main regression results. Two main results stand out. First, wealth (row B) bore a strong positive association with wildlife consumption. As both wildlife consumption and wealth are expressed in natural logarithms, the coefficients of the wealth variables in row B imply that doubling household wealth would be associated with an increase in wildlife consumption of about 52.7% for game, 50.9% for fish, 38.8% for birds and 38.3% for all forms of wildlife. Second, total household size bore a negative association with wildlife consumption. Row E suggests that the addition of one extra person in the household was associated with 13.6% lower consumption of fish, 12.1% lower consumption of birds, and with 9.8% lower consumption of all forms of wildlife.

Monetary income (row A) bore no statistically significant association with wildlife consumption, and we also found no statistically significant year-to-year change in wildlife consumption (row F), except for fish, as per capita consumption of fish grew by 6.4% per year.

Sensitivity analysis

To ensure that the two main results were not sensitive to the type of regression used, we re-estimated the regressions using all the same outcome and explanatory variables but using: (1) ordinary least squares and given the heterogeneity of prices, weather and ecological conditions across villages and years, we also used; (2) village–year fixed effects. To achieve (2), we added dummy variables that contained the interaction of the village dummy variable with the year variable. These regressions results produced even larger and statistically more significant coefficients (Table 3). Wealth bore continued to bear a positive and significant relation with all types of wildlife consumption, while household size was negatively and significantly associated with wildlife consumption.

Next, we explored whether our main results were sensitive to differences in consumption patterns across households that may result from the gender and age composition of households. For instance, children typically consume less than adults. We repeated the regressions in Table 2 using equivalence scales. The equivalence scales were defined considering equivalent food and energy requirement for Tsimane', based on ethnographic work and using the FAO–WHO protocol (Godoy *et al.*, 2007). The regressions using equivalence scales produced similar results (Table 4). Household wealth still bore a positive and significant relation with all forms of wildlife consumption, and household size (expressed in equivalence units) was still negatively associated with all wildlife consumption but was not statistically significant for game ($P = 0.573$).

Finally, given that the dummies used to control for village fixed effects might also capture other village-specific characteristics (such as number of households, access to roads, or acculturation), we repeated the regressions of Table 2 controlling for village-to-town distance, measured in hours, instead of controlling for the full set of village dummy variables. The main results of Table 2 were robust to this change (not shown).

Last, we did a power analysis to rule out the possibility that the insignificant findings did not result from insufficient observations. We found that for a power of 0.80, an α of 0.05 and 18 explanatory variables, the critical sample size was about 152 observations; thus, the absence of a significant association probably has to do with other factors (e.g. omitted variables) as our regressions include >152 observations.

Discussion

Earlier studies had found that monetary income did not affect game consumption. Drawing on better data,

Table 3 Trends in per capita wildlife consumption among Tsimane' households, Bolivia, 2002–2006 (inclusive) ($n = 1098$)

Explanatory variables	(i) Ordinary least square (OLS) A. Game	B. Fish	C. Birds	D. Total (A+B+C)	(ii) FEPLR with village–year fixed effects A. Game	B. Fish	C. Birds	D. Total (A+B+C)
A. Log household monetary real income per person	0.020	0.004	0.009	0.015	0.003	−0.003	0.012	0.0001
	(0.223)	(0.760)	(0.039)	(0.269)	(0.871)	(0.812)	(0.017)	(0.993)
B. Log household monetary real wealth per person	0.558	0.626	0.469	0.544	0.680	0.515	0.358	0.501
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
C. Schooling	−0.086	−0.024	−0.010	−0.072	0.013	−0.074	−0.002	−0.037
	(0.000)	(0.132)	(0.010)	(0.000)	(0.813)	(0.087)	(0.796)	(0.309)
D. Bed-ridden days	0.003	0.018	0.003	0.009	−0.010	0.012	−0.002	−0.002
	(0.798)	(0.109)	(0.302)	(0.336)	(0.535)	(0.299)	(0.672)	(0.823)
E. Household size	−0.071	−0.079	−0.116	−0.062	0.009	−0.157	−0.126	−0.090
	(0.004)	(0.000)	(0.000)	(0.000)	(0.861)	(0.000)	(0.000)	(0.012)
F. Survey year	0.059	0.052	0.019	0.060	−0.303	−0.179	0.050	−0.257
	(0.021)	(0.005)	(0.003)	(0.003)	(0.044)	(0.040)	(0.412)	(0.043)
Constant	−120.112	−105.639	−39.267	−119.806	607.689	361.198	−101.379	517.121
	(0.021)	(0.005)	(0.002)	(0.003)	(0.044)	(0.040)	(0.407)	(0.043)
R^2	0.12	0.20	0.72	0.16	0.188	0.270	0.438	0.190

Notes same as Table 2.

Table 4 Trends in per capita wildlife consumption among Tsimane' households, Bolivia, 2002–2006 (inclusive) ($n = 1098$), results of household fixed-effect panel linear regressions adjusting for equivalent consumption scales

Explanatory variables	Dependent variables – natural log of mean (kg)/person of wildlife consumed per household per year A. Game	B. Fish	C. Birds	D. Total (A+B+C)
A. Log household monetary real income per person	0.005	0.005	0.011	0.009
	(0.808)	(0.744)	(0.019)	(0.574)
B. Log household monetary real wealth per person	0.511	0.673	0.439	0.475
	(0.0108)	(0.000)	(0.000)	(0.000)
C. Schooling	−0.005	−0.079[a]	0.002	−0.045
	(0.896)	(0.0486)	(0.818)	(0.205)
D. Bed-ridden days	−0.002	0.011	0.001	0.004
	(0.863)	(0.328)	(0.609)	(0.684)
E. Equivalent-consumption adjusted household size	−0.049	−0.135	−0.173	−0.109
	(0.573)	(0.013)	(0.000)	(0.071)
F. Survey year	0.031	0.065	0.010	0.050
	(0.283)	(0.001)	(0.126)	(0.026)
Constant	−63.299	−130.574	−22.296	−101.063
	(0.278)	(0.001)	(0.106)	(0.027)
R^2	0.014	0.063	0.360	0.036

Notes same as Table 2.
Summary of results using (i) ordinary least squares, and (ii) fixed-effect panel linear regressions (FEPLR) with village–year fixed effects.

longitudinal observations, and on a more sophisticated estimation strategy that controls for a wide range of confounders, we too found that levels of monetary real income bore no significant association with the level of per capita game consumption in a household. For game consumption, we found monetary real income elasticities of consumption of $+0.002$ ($P = 0.88$) (column A, Table 2), and prior researchers had found income elasticities of $+0.05$ ($P = 0.72$) (Wilkie & Godoy, 2001) and -0.01 ($P = 0.85$) (Godoy, 2000). Thus, the bulk of the evidence until now all point to the same general conclusion that monetary income has a negligible effect on household game consumption. Why might this be? One possible reason might have to do with the low levels and small variance in monetary income among native Amazonians. A second possible reason has to do with possible reverse causality; that is, commercial hunting influencing the amount of monetary income earned, and not the other way around. Unfortunately, we do not have instrumental variables to resolve the biases from possible two-way causality. Bearing this caveat in mind, our results tentatively imply that there is no income effect in the short run; hence, there may be no conflict between standard approaches to alleviate poverty by increasing monetary income and wildlife conservation. However, as native Amazonians societies gain a stronger foothold in the market economy, and as monetary income rises by large amounts, monetary income might begin to exert a stronger influence on the consumption of animal wildlife, as they may acquire goods such as outboard motors or firearms.

A second result that meshes with prior research has to do with the absence of a secular or time-trend in wildlife consumption. Drawing on a much larger sample size and on a more sophisticated estimation strategy than that used by Vickers (1988), we too found no significant year-to-year change in wildlife consumption. This result suggests that – after conditioning for prices, income and wealth – at least over the 5 years of observations, we see no significant changes in tastes or preferences for animal wildlife. This might have happened from small changes in levels of acculturation to Bolivian society during the study period. Had tastes or preferences changed during the 5 years of observation, then we might have detected changes over time in patterns of wildlife consumption. In both Vicker's study and in our study, the absence of a clear time trend also suggests that the populations under study have remained relatively isolated from national society. Again, as native Amazonian societies gain a stronger toehold in the market economy, we might begin to see a time trend in the consumption of animal wildlife, particularly if these societies begin to export wildlife to the rest of the world.

On the other hand, at least one result contrasts with findings from previous research. In the previous study by Apaza *et al.* (2002), researchers found that wealth bore no statistically significant relation with either game consumption (elasticity = +0.061, $P = 0.60$) or with fish consumption (elasticity = +0.13, $P = 0.27$). In contrast, row B of Table 2 suggests large, positive and highly significant wealth elasticities of wildlife consumption that range from 0.38 ($P = 0.001$) for birds to 0.50 for fish ($P = 0.001$) and 0.52 for game ($P = 0.01$). This result is in accord with Friedman's (1957) permanent income hypothesis, which postulates that consumption tends to reflect the role of permanent income more than the role of temporary or monetary income. Researchers typically proxy permanent income with variables such as wealth or assets. Temporary monetary income becomes permanent income at the moment Tsimane' purchase productive physical assets (e.g. outboard motors or firearms). It is nearly impossible to tell whether children are permanent or temporary income because children leave their homes at an early stage, and although they contribute to foraging activities since their childhood, they also represent a cost in terms of food consumption. Why might wealth bear such a strong positive association with wildlife consumption? One reason is that our measure of wealth includes rifles, guns, canoes and fishing nets, and thus higher levels of wealth might imply improved access to foraging technologies. Several articles cited in the introduction (Hames, 1979; Alvard, 1995; Alvard *et al.*, 1997; Auzel & Wilkie, 2000) have also found that improved foraging technologies tend to be positively associated with increases in wildlife consumption.

Finally, we found that total household size bore a negative association with wildlife consumption. This finding might be explained by the age composition of bigger households, as children eat less food than adults, and contribute less than adults to hunting and fishing. In a bivariate analysis (not shown), we found that the addition of one more person in the household was associated with a 0.16 ($P < 0.001$) increase in the dependency ratio, defined as the ratio of children to adults. Another possible explanation is that bigger households eat all edible portions of animals, producing fewer leftovers, which cannot be stored or refrigerated. The finding that as household size increases the per capita demand for food decreases, holding constant per capita income, is known as the 'Deaton–Paxson paradox' (Deaton & Paxson 1998, 2003). This paradox has been addressed by several authors in the last years (Gan & Vernon, 2003; Gibson & Kim, 2007; Perali, 2008) but so far no satisfactory answer has been found.

Conclusion

In sum, our results suggest that at least among the Tsimane', the internal threat to wildlife conservation in the short run will not likely come from an increase in monetary income nor from an increase in household size. Nor will the threat to conservation likely come from changes in tastes and preferences. Rather, the main internal threat to wildlife conservation will likely arise in the long run. As the Tsimane' gain a stronger foothold in the market economy, they will likely increase their wealth in physical assets, and some of these assets (e.g. guns, fishing nets) will enhance their ability to capture wild animals.

Acknowledgements

The Cultural and Physical Anthropology Programs of NSF, USA, provided funding for the research. The Institutional Review Board for research with human subjects of Northwestern University, Brandeis University and the Great Tsimane' Council approved the study. Before enrollment in the study, we obtained assent from participants. We are also grateful to two anonymous reviewers and to the editor, Dr Matthew Gompper, for their comments on the earlier drafts.

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