Patricia Carignano Torres

Caça e consumo de carne silvestre na Amazônia Oriental: determinantes e efeitos na percepção do valor da floresta

Bushmeat hunting and consumption in Eastern Amazonia: drivers and effects on the perception of forest value

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Orientadora: Renata Pardini

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Índice

Resumo

A extração de produtos florestais é uma estratégia de sustento importante para populações que vivem próximas a remanescentes de florestas tropicais. Entre estes produtos, a carne silvestre é fonte importante de proteína e renda monetária. A sobreçaca, no entanto, pode levar à extinção local de espécies, comprometendo a integridade das florestas tropicais e o sustento de populações humanas. Como consequência, pode também levar à diminuição do valor atribuído às florestas pelos moradores, incentivando a sua conversão a outras formas de uso da terra. Sabe-se que fatores econômicos, como renda monetária e riqueza, são determinantes importantes da caça e do consumo de carne silvestre. Porém, tem sido sugerido que o efeito destes indicadores econômicos dependa do contexto ambiental – em especial, a cobertura florestal, associada à disponibilidade de animais para caça e a distância ao centro urbano, associada ao acesso a outras fontes de renda e proteína – e do contexto cultural, em particular, a região de origem dos moradores. No entanto, estudos prévios não consideraram todos estes fatores simultaneamente. Além disso, pouco ainda se sabe sobre qual o valor atribuído às florestas por populações rurais e sua relação com a caça e o consumo de carne silvestre. Através de questionários estruturados aplicados por meio de entrevista à população rural de uma região extensa e heterogênea na Amazônia oriental, esta tese teve como objetivos investigar: (i) o efeito de fatores ambientais em maior escala como determinantes da caça e do consumo de carne silvestre (Capítulo 1); (ii) a importância relativa e as interações entre fatores em escalas distintas – econômicos, culturais e ambientais - na determinação da caça e do consumo de carne silvestre (Capítulo 2) e; (iii) se a caça e o consumo de carne silvestre, bem como o desmatamento, que pode comprometer esse recurso, estão associados à percepção do valor das florestas (Capítulo 3). No Capítulo 1, os resultados indicam que fatores ambientais são determinantes mais importantes da caça do que do consumo de carne silvestre, que é mais frequente que a caça, sugerindo a relevância do compartilhamento e/ou comércio como formas de obtenção de carne silvestre. Enquanto o consumo de carne de silvestre foi um pouco mais frequente em áreas remotas e mais florestadas, a

caça foi mais frequente em áreas mais florestadas, mas também em áreas mais próximas a centros urbanos. Assim, os resultados sugerem que é improvável que a pressão de caça diminua com a crescente migração para áreas urbanas que hoje se observa na Amazônia. O Capítulo 2 traz evidências de que o consumo de carne silvestre, e principalmente a caça, dependem não só do contexto ambiental, mas também do cultural, e que os efeitos de indicadores econômicos dependem de fatores ambientais. A caça e o consumo de carne silvestre foram mais frequentes nas famílias de origem na região Amazônica, entre aqueles que dependem mais de atividades de subsistência, e ambos aumentaram com a renda monetária em áreas próximas a centros urbanos e/ou menos florestadas, mas diminuíram com a renda monetária em áreas remotas e/ou florestadas. Isto sugere que o sucesso de intervenções econômicas que visem tanto à redução da pobreza quanto à conservação da biodiversidade depende do contexto ambiental, e é muito mais provável em áreas mais florestadas e remotas. Os resultados do Capítulo 3 indicam que a quantidade de carne silvestre consumida influencia positivamente a percepção do valor utilitário da floresta, enquanto que a quantidade de florestas remanescentes no entorno influencia positivamente a percepção de seu valor intrínseco. Assim, para além de estratégias que visem o bem-estar humano via incentivos econômicos, há oportunidade para iniciativas que considerem outros aspectos do bem-estar associados aos serviços providos pela floresta - sejam recursos como a carne silvestre ou benefícios culturais e estéticos. Ao mesmo tempo, os resultados apontam o potencial de um perigoso ciclo de desvalorização da floresta, em que o desmatamento leva a diminuição da percepção do seu valor, que, por sua vez, pode agravar o desmatamento, indicando a urgência de investimentos em iniciativas de conservação nas paisagens mais alteradas.

Abstract

The extraction of forest products is an important livelihood strategy for human populations living in and around tropical forest remnants. Among these products, bushmeat is an important source of protein and monetary income. However, overhunting can lead to local species extinction, compromising the integrity of tropical forests and the livelihoods of human populations. As a consequence, it can also lead to a decrease in the value local people attribute to forests, further promoting land conversion. It is well known that economic factors, such as monetary income and asset-wealth, are important drivers of bushmeat hunting and consumption. However, it has been suggested that the effect of economic factors depend on the environmental context – especially forest cover, associated with game availability, and distance to urban centers, associated with alternative sources of protein and income – and on the cultural context, particularly the region of origin of residents. Nevertheless, previous studies did not consider all these factors simultaneously. In addition, little is known about the value attributed to forests by rural populations and its association with bushmeat hunting and consumption. Using questionnaire-based interviews with the rural population of a wide heterogeneous region in eastern Amazonia, this thesis aimed at investigating (i) the effects of large-scale environmental factors as drivers of bushmeat hunting and consumption (Chapter 1); (ii) the relative importance and interactions between factors at different scales – economic, cultural and environmental – in driving bushmeat hunting and consumption (Chapter 2) and; (iii) whether bushmeat hunting and consumption, as well as deforestation, which may compromise this resource, are associated with the perception of forest values (Chapter 3). In Chapter 1, the results indicate that environmental factors are more important drivers of hunting than of bushmeat consumption, which is widespread, suggesting significant bushmeat sharing and/ or trading. While bushmeat consumption was slightly more likely in remote and more forested areas, hunting was more likely in more forested areas but also in areas closer to urban centers. These results suggest that hunting pressure is unlikely to decrease with the increasing migration to urban areas nowadays observed in the Amazon. Chapter 2

brings evidences that bushmeat consumption, and especially hunting, depend not only on the environmental context but also on the cultural context, and that the effects of economic variables depend on environmental factors. Bushmeat hunting and consumption were more likely in households with Amazonian origin, with greater reliance on subsistence activities and both increased with monetary income in less remote and/or less forested areas, but decreased with monetary income in more remote and/or more forested areas. This result suggests that the success of economic interventions aiming at both poverty alleviation and biodiversity conservation depend on the environmental context, and is more likely in more forested and remote areas. The results of Chapter 3 indicate that the amount of consumed bushmeat positively influences the perception of forest instrumental value, while forest cover in the surroundings positively influences the perception of forest intrinsic value. These results suggest that, beyond strategies that aim at human well-being through economic incentives, there is opportunity for initiatives that consider other aspects of well-being associated with services provided by forests – whether resources such as bushmeat or cultural and aesthetic benefits. At the same time, the results suggest the potential for a dangerous reinforcing cycle of forest depreciation, in which deforestation erodes perceptions of forest values, which may in turn facilitate further deforestation, indicating the urgent need to invest in conservation initiatives in more altered landscapes.

Introdução geral

A extração de produtos florestais é uma estratégia de sustento importante para populações que vivem próximas a remanescentes de florestas tropicais (Stoian 2005, Angelsen et al. 2014). A importância desses recursos para as populações locais pode influenciar as percepções das pessoas sobre o valor das florestas e da sua conservação (Gillingham & Lee 1999). Entre esses produtos, a carne silvestre representa uma fonte importante de proteína e renda monetária (Milner-Gulland et al. 2003, de Merode et al. 2004) e a caça de vertebrados é uma atividade extremamente comum, que requer contato e conhecimento da floresta e sua fauna (Alves et al. 2009). A sobreçaca, no entanto, pode levar à redução populacional e mesmo à extinção local de espécies mais vulneráveis, especialmente aves e mamíferos de maior porte (Peres & Palacios 2007), comprometendo a integridade das florestas tropicais, a persistência da biodiversidade no longo prazo e o sustento de populações humanas (Milner-Gulland et al. 2003, Stoner et al. 2007, Jorge et al. 2013). Como consequência, pode também levar à diminuição do valor atribuído às florestas pelos moradores locais, o que pode incentivar a sua conversão para outras formas de uso da terra (Allendorf et al. 2006), desencadeando um processo de retroalimentação e degradação.

As decisões relativas à caça e ao consumo de carne silvestre são em parte determinadas pelo retorno que o caçador ou consumidor tem comparado a outras atividades ou fontes de alimentação (Behrens 1992, Ling & Milner-Gulland 2006). Este retorno deve ser extremamente variável espacialmente, dependendo do contexto ambiental em que a pessoa vive, uma vez que o acesso a animais silvestres e outras

fontes de carne depende da disponibilidade desses recursos. Assim, é de se esperar que as condições ecológicas e geográficas tenham papel fundamental em determinar a caça e o consumo de carne silvestre. Apesar disso, apenas recentemente pesquisadores começaram a examinar a importância de fatores como cobertura florestal, indicativo da disponibilidade de caça (Foerster et al. 2012), e distância a centros urbanos, indicativo da disponibilidade de fontes alternativas de renda e proteína (Brashares et al. 2011, Foerster et al. 2012, Mgawe et al. 2012), como determinantes da caça e do consumo de carne silvestre. Grande parte dos trabalhos sobre esse assunto ainda tem como foco fatores na escala da unidade doméstica, em especial os econômicos (e.g. Godoy et al. 2010, Rentsch & Damon 2013), enquanto fatores culturais também são menos estudados.

O fato destes fatores ambientais frequentemente não serem considerados pode estar por trás dos resultados aparentemente contraditórios na literatura sobre a relação entre fatores econômicos e a caça e consumo de carne silvestre. Os diversos estudos focados na importância da riqueza e renda monetária, por exemplo, encontraram resultados divergentes (Wilkie & Godoy 2001, de Merode et al. 2004, Wilkie et al. 2005, Albrechtsen et al. 2006, Fa et al. 2009, Godoy et al. 2010). Contextos ambientais distintos podem definir diferenças no benefício líquido do consumo de carne silvestre, e secundariamente, da caça. Em regiões mais remotas e florestadas, não só a disponibilidade de animais silvestres é maior, mas também o acesso a outros tipos de carne é menor. Estas diferenças no benefício líquido devem fazer com que a carne silvestre seja considerada um bem inferior (ou seja, cuja demanda diminui com o aumento do poder aquisitivo do consumidor) em áreas remotas e florestadas, e um bem normal (ou seja, cuja demanda aumenta com o aumento do poder aquisitivo do consumidor) em áreas mais desmatadas próximas a centros urbanos. Além disso, é

provável que fatores econômicos também interajam com fatores culturais, podendo levar, por exemplo, a efeitos opostos da renda e da riqueza sobre o consumo de carne silvestre em povos de diferentes culturas (Mgawe et al. 2012). Assim, é provável que a caça e o consumo de carne silvestre resultem da interação de fatores econômicos, culturais e ambientais.

Entender quais são estes determinantes e suas interações pode ajudar a identificar quais são e em que contexto vivem os atores que contribuem mais para a pressão de caça, ou que são mais dependentes de carne silvestre e, portanto, mais vulneráveis à diminuição deste recurso. Dessa forma, pode ajudar na elaboração de intervenções que reduzam a caça não sustentável e evitem efeitos negativos no bem-estar da população que depende desse recurso para subsistência. Além disso, esse conhecimento é fundamental para propor intervenções adequadas em diferentes contextos ambientais e culturais, identificando as inter-relações entre redução de pobreza, mudanças em estratégias de sustento, uso de recursos e conservação da biodiversidade (Billé et al. 2012) e assim evitando efeitos não desejados de mudanças em condições econômicas das populações (Damania et al. 2005).

Adicionalmente, entender como o uso deste recurso florestal influencia a percepção do valor das florestas é importante para a elaboração de intervenções que sejam aceitas e apoiadas pelas populações locais, aumentando sua chance de sucesso. A percepção de valores ambientais tem sido associada a atitudes e comportamentos pró-ambientais (Stern et al. 1995, Schultz & Zelezny 1999, Schultz 2001). Se a carne silvestre é um recurso importante, que leva à valorização da floresta, então, garantir a utilização sustentável deste recurso pode favorecer a conservação de florestas.

Nesta tese, pretendi investigar (i) o efeito de fatores ambientais (ecológicos e geográficos) em maior escala – cobertura florestal, densidade demográfica e distância aos centros urbanos – sobre a caça e o consumo de carne silvestre (Capítulo 1); (ii) a importância relativa e as interações entre fatores em escalas distintas – econômicos, culturais, ambientais - na determinação da caça e do consumo de carne silvestre (Capítulo 2); e por fim, (iii) se a caça e o consumo de carne silvestre, bem como o desmatamento, que pode comprometer esse recurso, estão associados à percepção do valor das florestas (Capítulo 3).

O estudo foi realizado em uma região de fronteira agrícola recentemente consolidada, de aproximadamente um milhão de hectares, na Amazônia oriental, abrangendo os municípios de Santarém, Belterra e Mojuí dos Campos, no Pará. Como consequência do desenvolvimento agrícola, a região apresenta um gradiente de cobertura florestal associado à distância ao maior centro urbano, a cidade de Santarém. A região é ocupada desde a época pré-colombiana, mas a partir do final do século XIX tem recebido diversos fluxos migratórios por conta de diferentes ciclos econômicos (Fonseca 1996). A partir da década de 60, projetos de desenvolvimento do governo federal, promoveram novo influxo de migrantes, vindos de todas as regiões do país e de diferentes condições econômicas (Castro et al. 2004, Nepstad et al. 2006). Ambas essas características, ambiental e socioeconômica, fazem da região uma área particularmente apropriada para investigar a importância e interação entre fatores ambientais em escala mais ampla e fatores econômicos e culturais na escala das unidades domésticas na determinação da caça e do consumo de carne silvestre. Embora seja improvável que os moradores desta região dependam fundamentalmente de produtos florestais para seu sustento (Futemma & Brondízio 2003), o suprimento de produtos para alimentação, especialmente a carne silvestre, que está disponível durante todo o ano, deve representar

um recurso importante. Assim, a região também é apropriada para o estudo da relação entre o uso deste recurso e a percepção dos moradores em relação ao valor da floresta.

Esta tese está dividida em três capítulos, uma introdução geral e considerações finais. Os três capítulos estão apresentados na forma de artigo científico em inglês. O primeiro artigo foi submetido para a revista Journal of Applied Ecoloy em agosto de 2014 e no momento está em revisão.

O primeiro capítulo é fruto da parceria com uma rede de pesquisa internacional – Rede Amazônia Sustentável – RAS (Embrapa, INCT-CNPq, Museu Paraense Emílio Goeldi - MPEG, University of Cambridge, Lancaster University e Darwin Initiative). A rede tem por objetivo avaliar a biodiversidade, o fornecimento de serviços ecossistêmicos, as atividades econômicas e o bem-estar das populações humanas associados com diferentes tipos de usos da terra em duas regiões na Amazônia oriental brasileira, nos municípios de Santarém e Paragominas, no Pará. Neste primeiro capítulo, analisei os dados referentes à caça e ao consumo de carne silvestre, coletados pela rede de pesquisa através de questionários socioeconômicos aplicados em 2010 e início de 2011. A parte do questionário utilizada nesse trabalho foi elaborada por mim em colaboração com pesquisadores da rede de pesquisa antes do meu ingresso no programa de Pós-graduação. Por ser parte de um questionário socioeconômico bastante extenso, as informações sobre caça e consumo de carne silvestre coletadas foram mais simples, se comparadas aos dados utilizados nos dois capítulos posteriores. O capítulo contou com a colaboração dos pesquisadores, coordenadores da rede de pesquisa RAS - Luke Parry, Toby Gardner, Jos Barlow e Joice Ferreira. A análise desses dados também possibilitou o aprimoramento do delineamento amostral e do questionário para a coleta

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Nos segundo e terceiro capítulos analisei os dados coletados por mim em trabalho de campo realizado com financiamento da FAPESP através de auxílio à pesquisa regular (FAPESP 2011/19108-0). O delineamento amostral foi um pouco modificado para ampliar as paisagens de estudo, de modo a incluir maior número de unidades domésticas, bem como abranger áreas não contempladas no delineamento da rede de pesquisa e que eram importantes para os objetivos desta pesquisa.

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Capítulo 1

Large-scale drivers of bushmeat consumption and hunting in post-frontier tropical landscapes

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Abstract

Identifying the factors that influence bushmeat consumption and hunting is important for informing conservation strategies and identifying challenges to human food security. However, current understanding is still largely limited to household-scale socio-economic drivers, with studies often neglecting large-scale determinants of bushmeat supply (e.g. game availability) and demand (e.g. access to alternative sources of animal protein and of cash income). We examine bushmeat consumption and hunting in 292 households across 16 landscapes in a heterogeneous post-frontier region in eastern Amazonia. We test the hypotheses that bushmeat consumption and hunting are positively associated with forest cover (as a proxy of game availability) and remoteness from urban centers (as a proxy of access of alternative sources of animal protein). Bushmeat had been consumed by 79 % of households within the past 12 months and was slightly more common in remote and less deforested landscapes, as expected. In contrast, whilst hunting was more likely in more forested landscapes, when controlling

for forest cover, it was more common near urban centers. Our findings demonstrate that large-scale factors are important determinants of bushmeat consumption and hunting, even in economically and culturally diverse rural areas, and that bushmeat consumption makes an important contribution to food security and well-being in post frontier tropical landscapes. Although people living in remote, forested areas are likely to be the most dependent on bushmeat for subsistence, rural people living in more populous areas near to urban centers are the actors contributing most to hunting pressure, due to higher per capita probability of hunting combined with higher population densities. This finding undermines the assumption that urbanization in the forested tropics will deliver a much needed reprieve for many overhunted species. Ensuring the persistence and recovery of game populations in post-frontier regions requires greater efforts to reduce hunting activity by people travelling from peri-urban areas.

Keywords: accessibility, alternative source of protein, deforestation, forest products, game availability, livelihoods, urban center, wild meat

Introduction

The extraction of forest products is an important livelihood strategy in developing countries (Stoian 2005, Angelsen et al. 2014), where hunting forest vertebrates is widespread and bushmeat is an important source of both animal protein and cash income (Milner-Gulland et al. 2003, de Merode et al. 2004). Despite its importance for the livelihoods of many people, hunting can threaten the population viability of game species, particularly large-bodied mammals and birds, driving widespread depletion and local and regional extinctions of the most vulnerable taxa (Peres & Palacios 2007). Since these animals play key roles in ecological processes, including seed dispersal and herbivory, overhunting can compromise not only the livelihoods of local people but also affect the integrity of tropical forests, and the long-term persistence of non-hunted biodiversity (Stoner et al. 2007, Jorge et al. 2013). Understanding the drivers of both hunting and bushmeat consumption can help identify interventions to reduce unsustainable hunting whilst also seeking to avoid negative impacts on the well-being of those most dependent on bushmeat for nutrition.

Bushmeat consumption and hunting decisions are in part determined by the perceived returns compared to other activities or alternatives (Behrens 1992, Ling & Milner-Gulland 2006), both of which can be highly variable across space. However, only recently researchers have begun to examine the importance of large-scale factors on hunting and bushmeat consumption (Brashares et al. 2011, Foerster et al. 2012, Mgawe et al. 2012). In contrast, most studies have focused on individual consumer and hunter preferences or the interplay of demographic, socioeconomic and cultural factors at the household scale (e.g. Godoy et al. 2010, Rentsch & Damon 2013). Yet the availability of bushmeat and alternative sources of animal protein at the landscape level

may be at least as important drivers of bushmeat consumption and hunting as household socioeconomic or cultural characteristics (Nyahongo et al. 2009, Brashares et al. 2011). A failure to account for these large-scale factors may help explain the apparently inconsistent role of some household factors (e.g. wealth and income) reported by some studies on bushmeat consumption and hunting (Wilkie & Godoy 2001, Wilkie et al. 2005, Fa et al. 2009).

Large-scale factors are likely to be particularly important in dynamic and heterogeneous regions such as those found along deforestation frontiers and in relatively recent post-frontier landscapes in the tropics. In this study we evaluate the importance of large-scale factors in determining bushmeat consumption and hunting in a heterogeneous post-frontier tropical region in eastern Amazonia. Game availability, which should influence both bushmeat consumption and hunting decisions (Fa et al. 2009, Brashares et al. 2011, Foerster et al. 2012), is likely reduced by deforestation (Michalski & Peres 2007) and high levels of hunting pressure (associated with older settlements, higher human population density and increased road access) (Poulsen et al. 2009, Suarez et al. 2009). Limited access to alternative sources of animal protein, which is related to remoteness from urban centers, should also influence both bushmeat consumption and hunting (Wilkie & Godoy 2001). People in more remote areas are also likely to have lower monetary income (Zenteno et al. 2013) and make less frequent trips to urban centers (Parry et al. 2010a). We therefore hypothesize that both bushmeat consumption and hunting are less common in landscapes that (i) have lower forest cover (either due to deforestation and/or high human population density) and therefore lower game abundance, (ii) close to urban centers where the availability of alternative sources of animal protein and of cash income is higher than in remote areas (Fig. 1).

To test these hypotheses we focused on a heterogeneous ~1 million ha area south of the city of Santarém in the Brazilian Amazon, and conducted interviews at 292 households across 16 hydrological catchments or 'landscapes' (c. 5000 ha). The landscapes capture high variation in forest cover, human population and remoteness from urban centers as a result of rapid agricultural expansion and urban development (Moran 1993, Fearnside 2005), and are therefore well suited to teasing apart the relative importance of large-scale correlates of bushmeat consumption and hunting activity. Specifically, we examine the association of bushmeat consumption and hunting with three large-scale drivers: (1) forest cover as a proxy of game availability both at the property scale (the immediate surroundings of the household) and at the landscape scale, (2) the amount of forest cover per household as a proxy of game availability that takes into account human population size and associated hunting pressure, and (3) the remoteness from urban centers, as a proxy of the access to alternative source of protein and of cash income.

Methods

Study region

We conducted this study in the eastern Brazilian Amazonia, Pará state, in a region of approximately 1 million ha, bordered by the Amazon, Tapajós and Curuá-Una Rivers (Fig. 2). It encompasses the rural areas of the municipalities of Santarém (78,790 inhabitants living in rural areas from a total of 294,580), Belterra (6,852 of 16,318) and Mojuí dos Campos, a recently established municipality with no data on rural population size (total of 15,232) (IBGE 2010).

Santarém was founded in 1661, but the region has been inhabited since pre-Colombian times and has received different migratory influxes associated with various economic cycles (D'Antona et al. 2006). Starting around 1958, road construction and government-led colonization and land reform initiatives promoted the influx of low income immigrants from the arid northeast, and from the southern part of the country (Castro et al. 2004, Nepstad et al. 2006). Agriculture mechanization began at the end of the 1990s, with a new migratory wave of farmers from south and midwest Brazil (Nepstad et al. 2006). Large-scale, mechanized agriculture has rapidly expanded in the region in recent years (SAGRI 2013a), as well as cattle ranching, with a 50% increase in the number of cattle between 2002 and 2012 (SAGRI 2013b). The study region is therefore home to both recent and long-term in-migrants from various regions of Brazil, and rural properties that range from small-scale farms based on subsistence agriculture to large-scale soy farms and cattle ranches.

Sampling design

This study is part of the Sustainable Amazon Network (*Rede Amazônia Sustentável*, RAS), which aims to assess social and ecological dimensions of land-use sustainability in Eastern Brazilian Amazonia (Gardner et al. 2013). The sampling design was hierarchical, first selecting landscapes (catchments) that captured the variability in forest loss within the study region, and then a stratified random selection of rural properties (and households) within them. In total, we sampled 16 hydrological catchments of third or fourth order (c. 5000 ha) (hereafter landscapes), distributed across a gradient of current forest cover (24 to 98 %), population density (0.25 to 34 households/ km^2) and straight-line distance from the nearest urban center (5 to 92 km) (Fig. 2).

Within each landscape, we sampled only households in rural properties ≥ 1 ha that were active rural agricultural producers in 2009. We first mapped all such properties in each landscape, and selected a random sample, stratified by the number of properties per road branch (to ensure a reasonable spatial spread across the entire landscape). For those properties that had more than one household (i.e., with workers or multiple groups of relatives), we sampled additional households according to the total number of households (two when 2-3, three when 4-6, and four when ≥ 7). We skipped individual households if the household head declined to take part in the study, or if after three visits no resident was encountered. In total we sampled 292 households, with 4 to 30 households per landscape. Large soy farms and cattle ranches were scattered across landscapes and smaller properties were usually < 50 ha while larger ones were usually > 400 ha within landscapes, so that in each landscape there was variation in socioeconomic characteristics.

Bushmeat consumption and hunting

We used an interview-based survey with the household heads (when possible both household heads were interviewed), applied by a team of six trained assistants who conducted the interviews between August 2010 and March 2011. We asked (1) the month when bushmeat was last consumed in the household and (2) if there was at least one hunter in the household (even if only occasionally). Bushmeat consumption and hunting were equal to 1 when, respectively, bushmeat was consumed at least once in the previous 12 months and there was at least one hunter in the household. The recall period of 12 months for bushmeat consumption aimed at avoiding variation associated with seasonality in hunting activity.

Large-scale drivers of bushmeat consumption and hunting

As proxies of game availability, we used the percentage of forest cover (Sampaio et al. 2010), as well as forest cover per household (percentage of forest cover divided by the number of households) to account for hunting pressure from local residents. Both variables were quantified considering either: only non-degraded primary forest, all primary forests (degraded and non-degraded), or both primary forests and secondary forest older than 10 years. Forest cover was calculated at three spatial scales: (1) a smaller scale of 500-m radius buffer (0.78 km^2) around each household, representing game availability in the immediate surroundings of the household within the property and neighboring properties (median of property size in the region was 0.25 km^2), and at two wider, landscape scales of (2) 5-km radius (78.5 km^2) and (3) a 10-km radius (314 km^2) buffers around each household, since local species persistence and abundance is known to depend on the wider landscape context (Andrén 1994) (Fig. 2). Forest cover per household was calculated only at the two landscape scales, because human population density varied little at the property scale. We calculated the cover of each type of forest through a time-series of Landsat images from 1990 to 2010, using a decision tree classification procedure that separated primary and secondary forest, as well as primary forest with a signal of degradation from past logging and fire (Gardner et al. 2013). To calculate the number of households we used 2010 census data from the Brazilian Institute of Geography and Statistics (IBGE). In this census, each municipality is divided into census sectors and, in the majority of cases IBGE provides the coordinates for all rural households. We estimated the number of households with no coordinate data by assuming that they had a regular distribution in the census sector, and that their number in each buffer was proportional to the percentage of the area of the census sector that overlapped the buffer.

As a proxy of access to alternative sources of animal protein and of cash income, we calculated the remoteness from urban centers. Remoteness was estimated using five different measures: straight-line distance of households to the (1) largest, (2) nearest and (3) most visited urban center (the latter being reported in the interviews), and time spent to get from the household to the most visited urban center in the (4) dry season and (5) in the wet season (both reported in the interviews).

Data analysis

Our analyses considered four predictors: forest cover at the property scale (different forest types at 500-m radius buffer), forest cover at the landscape scale (different forest types at 5-km and 10-km radius buffers), forest cover per household (different forest types at 5-km and 10-km radius buffers divided by the number of households in the buffer) and remoteness from urban centers (straight-line distance to the largest, nearest and most visited urban center, and time spent to get to the most visited urban center in the dry and wet seasons). Our first step was to select the measure of each of the four predictors that best explained bushmeat consumption and hunting, using a model selection approach based on the Akaike's Information Criterion modified for small samples (AICc). For each dependent variable (*bushmeat consumption* [0/1] and *hunting* [0/1]), we compared a candidate set of simple models each containing a different measure for a given predictor, and selected the measure contained in the first-ranked model (Supporting Information Table S1). To account for the hierarchical nature of the sampling design, we used generalized linear mixed-effects models (GLMM), with dependent variables modeled as binary variables using logit as the link function, the different measures of each predictor as fixed factors, and landscapes as a random factor.

Fixed factors were standardized so that each had a mean of zero and a standard deviation of one (Zuur et al. 2009).

After selecting the best measure for each predictor, we compared a set of candidate GLMM models of each dependent variable (modeled as a binary variable) as a function (logit link) of different combinations of the four predictors (standardized, fixed factors, with landscapes as a random factor). Each set of candidate models included eight models: an intercept-only model for reference (that does not include any fixed factors), four simple models with each of the four predictors on their own, and models combining one of the three predictors of game availability with the predictor remoteness from urban centers. Alternative models in each set were compared using the difference in their AICc values in relation to the first-ranked model (ΔAICc) (Burnham & Anderson 2002). A value of ΔAICc $\leq$ 2 indicates equally plausible models. All analyses were implemented in R 3.0.3 (R Core Team 2014) using the lme4 package (Bates et al. 2011).

Results

Bushmeat consumption was far more common than hunting. In the majority of households (78.8% of sampled households, range = 20 to 100%, mean = 77.5, and SD = 19.4 across landscapes), members reported having consumed bushmeat at least once in the previous 12 months (Fig. 2). By contrast, the presence of a hunter in the household was reported in 38.4% of the sampled households, and varied between 0 and 100% (mean = 37.9, SD = 26.4) across landscapes (Fig. 2). Amongst bushmeat-consuming households, the majority (59 %) stated that the last bushmeat they ate was a gift, 34%

that it was hunted by one of the members of the household and 7% that it was purchased. In seventy eight percent of households that consumed bushmeat in the last year, interviewees reported having last consumed either paca or armadillos (Fig. 3).

Large-scale drivers of bushmeat consumption and hunting

For bushmeat consumption, the best measures for all the three proxies of game availability were those that included all forest types together, and a 10-km radius buffer was the best buffer size for the two proxies quantified at the landscape scale (Supporting Information Table S1). The best measure for the remoteness from urban centers was the time spent to get to the most visited urban center in the wet season (Supporting Information Table S1). These predictors were then included in the model selection procedure for analyzing the large-scale drivers of bushmeat consumption. Five models were selected including the reference model (Table 1). The model including only the remoteness from urban centers was the first-ranked model, followed by the model including only forest cover at the landscape scale, the models including remoteness from urban centers and either forest cover at the landscape scale or forest cover at the property scale, and the reference model.

As expected, living farther from urban centers was associated with increased probability of bushmeat consumption (Table 1). Within 60 minutes of urban centers (1st quintile of the data), 74% of households had consumed bushmeat, whereas for the most remote households (travel time = 180 to 300 minutes, 5th quintile) 93% had consumed bushmeat (Fig. 4a). Higher total forest cover at the landscape scale was also positively associated with bushmeat consumption, as expected (Table 1). In heavily deforested areas (1st quintile, ≤ 27% forest cover in surrounding landscape), 71% of households consumed bushmeat compared to 88 % of households within more forested landscapes

(5th quintile, 71 - 94% forest cover) (Fig. 4b). When controlling for remoteness from urban centers, higher forest cover both at the landscape and at the property scale was associated with an increase in bushmeat consumption probability (Table 1). The association between bushmeat consumption and the large-scale drivers, however, was not strong, since the reference model was included among selected models, albeit as the last-ranked (Table 1).

For bushmeat hunting, the best measure for forest cover at the property scale was the total primary forest cover (degraded plus non-degraded), while total forest cover (total primary and secondary forest) in a 10-km radius buffer was the best measure for the two proxies of game availability quantified at the landscape scale (Supporting Information table S1). The best measure for the remoteness from urban centers was the distance to the largest urban center (Supporting Information table S1). These predictors were then included in model selection procedure for analyzing the large-scale drivers of hunting. Two models were selected (Table 1). The model including only forest cover at the landscape scale was the first-ranked model, followed by the model including forest cover at the landscape scale and remoteness from urban centers.

As expected, higher forest cover at the landscape scale was positively associated with hunting (Table 1). Only 20% of the households in heavily deforested areas (1st quintile, ≤ 27% forest cover in surrounding landscape) had at least one hunter, compared to 64 % of household within more forested landscapes (5th quintile, 71 - 94% forest cover) (Fig. 4c). When controlling for forest cover at the landscape scale, in contrast to our observations for bushmeat consumption, households near urban centers were more likely to have a hunter (Table 1).

Discussion

By investigating both bushmeat consumption and hunting, our findings demonstrate that large-scale factors are important determinants of these activities. Forest cover and remoteness from urban centers strongly affected hunting decision, but were less important in determining bushmeat consumption, which was widespread and more prevalent than hunting, indicating significant bushmeat sharing and/ or trading. Our findings thus suggest that bushmeat is an important forest resource even in altered landscapes of post-frontier regions. In the following paragraphs we discuss in detail the effects of these large-scale factors and their implications for wildlife conservation and rural livelihoods.

Our results support the idea that bushmeat consumption is widespread in post-frontier tropical regions, even in deforested, densely populated landscapes near urban centers. Hunting was less common than consumption and may be under-reported, although subsistence hunting in Brazil is not illegal. Gifts and trade certainly provide important means of acquiring bushmeat other than hunting, and many killed animals are therefore eventually consumed in households other than those of the hunters (de Merode et al. 2004). Although game populations seem heavily depleted, since the species consumed were mostly those with high reproductive rates (e.g. paca and armadillos, Redford & Robinson1987, Parry et al. 2009) our results support assertions that bushmeat can continue to play an important role in rural livelihoods in altered areas (Schulte-Herbrüggen et al. 2013). Moreover, although consumption was slightly more likely in remote, forested landscapes, total demand for bushmeat is certainly higher in less remote, deforested landscapes, given the higher human population densities in these areas.

We found that bushmeat consumption was slightly more likely in more remote and forested areas, as expected, with landscape-scale forest cover and remoteness from urban centers being similarly important drivers. This is presumably related to people having less access to domestic marketed meat and to higher game availability, making bushmeat more important for household food security in more remote and forested areas. Indeed, studies in Africa have shown that poor access to other types of meat can drive bushmeat consumption (Brashares et al. 2011), which is also more common in places close to game sources (Brashares et al. 2011, Foerster et al. 2012, Mgawe et al. 2012). Remoteness has also been linked to greater dependence on hunting for subsistence (Pangau-Adams et al. 2012). Importantly, levels of bushmeat consumption may be more variable and strongly related to large-scale drivers, especially remoteness, within still intact pre-frontier landscapes, where it can take many days for a riverine household to reach an urban center (Parry et al. 2010a). Moreover, it is possible that a stronger variation in consumption would be observed among landscapes if the frequency or quantity (instead of the occurrence) of bushmeat consumption was measured.

Hunting, while less prevalent than consumption, was more strongly associated with large-scale factors. In contrast to the observed for consumption, landscape-scale forest cover was the main driver of hunting, with remoteness from urban centers only appearing important after controlling for variability in forest cover. Indeed, the proximity of game sources (such as protected areas) has been associated with higher hunting rates (Brashares et al. 2011, Nuno et al. 2013). When controlling for forest cover, however, households far from urban centers were less likely to hunt. This may be due to co-linearity between remoteness and socioeconomic factors. On the other hand, it may also be associated with the concentration of bushmeat market and trade near urban

centers, stimulating hunting. Although our dataset in not adequate for testing hypotheses on bushmeat trade and commercial hunting, the literature suggests that the higher human population density and thus higher demand on bushmeat near urban centers may support a stronger informal bushmeat trade. Bushmeat trade is frequently reported as supporting higher profits near urban centers, especially in Africa, where trade is well developed (Brashares et al. 2011). People living closer to major markets are often reported as engaging more in commercial bushmeat trade (Espinoza 2009, Pangau-Adams et al. 2012) and higher purchasing was associated with greater monetary power by urban consumers (Fa et al. 2009). Although there are few studies on bushmeat trade in the Brazilian Amazon (Nasi et al. 2011), it has already been reported even in open markets (Chaves Baía Junior et al. 2010), indicating that it might be important.

By considering different measures of game availability and access to alternative sources of animal protein, our study also contributes to the identification of the best proxies of the large-scale drivers of bushmeat consumption and hunting. Forest cover per household was not associated with either bushmeat consumption or hunting, confirming that human population density is not always important in determining local hunting pressure (sensu Urquiza-Haas et al. 2009) and forest cover alone is a better predictor of game abundance. Importantly, our results highlight that forest cover should be accessed at the landscape scale rather than at the property scale since persistence and local abundance of game species depend on ecological processes that occur at the landscape scale (Andrén 1994). In addition, in post-frontier regions such as our study area, degraded and secondary forests are prevalent and probably important determinants of game availability. Within relatively ‘pristine’ pre-frontier regions, however, wildlife abundance within non-degraded primary forest is probably a more important determinant of bushmeat consumption and hunting (Parry et al. 2009). In contrast,

different measures of remoteness were effective predictors of bushmeat consumption and hunting, indicating that distinct measures may capture different aspects of remoteness. While distance to the largest urban center may have a stronger association with bushmeat trade affecting hunting probability, the time spend to reach an urban center may be a better proxy of access to alternative sources of protein and income affecting bushmeat consumption.

Implications for conservation and rural livelihoods

Our study demonstrates that bushmeat consumption is prevalent even in heavily disturbed post-frontier landscapes. Plausibly, hunters living near urban centers are exerting impacts on game populations across a much broader area, if they are using the well-developed road network - characteristic of post-frontier regions - to travel far and target game in more remote areas. In any case, our results indicate that hunting pressure is unlikely to decrease with urbanization (Parry et al. 2010b, Wilkie et al. 2011), and that the rapid agricultural expansion occurring in many areas of Amazonia, associated with increased in-migration to cities, may not result in reduced pressure on game species in more preserved areas. While people from remote, forested areas are likely to be the most dependent on bushmeat for subsistence and thus the most vulnerable to law-enforcement policies on hunting, people living near urban centers might be the actors contributing the most to bushmeat hunting, since the probability of hunting was higher near urban centers, where human population density is also higher.

We have presented strong evidence that large-scale factors are important determinants of bushmeat consumption and hunting in heterogeneous post-frontier regions. These factors should therefore be considered when developing strategies and policies to conserve biodiversity and maintain food security within these regions. In

particular, it is important to ensure that the food security and livelihoods of forest-dependent peoples in remote areas are not compromised by incursions from hunters from peri-urban areas, as was frequently reported by interviewees in this study.

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Table 1. Model selection results for bushmeat consumption and hunting as a function of large-scale drivers.

	Models	K	logLik	AICc	ΔAICc	ωi	Coefficient 1	Coefficient2
Bushmeat consumption	**Remoteness from the urban center**	**3**	**-147.43**	**300.86**	**0.00**	**0.24**	**0.37(0.17)**	
	Forest cover at landscape-scale	**3**	**-147.85**	**301.70**	**0.84**	**0.16**	**0.36(0.18)**	
	Forest cover at landscape-scale + remoteness from the urban center	**4**	**-146.85**	**301.69**	**0.89**	**0.15**	**0.22(0.20)**	**0.27(0.19)**
	Forest cover at property-scale + remoteness from the urban center	**4**	**-146.88**	**301.75**	**0.95**	**0.15**	**0.19(0.18)**	**0.33(0.17)**
	Reference model	**2**	**-149.41**	**302.81**	**1.91**	**0.09**		
	Forest cover per household + remoteness from the urban center	4	-147.43	302.85	2.05	0.09	-0.02(0.20)	0.38(0.20)
	Forest cover at property-scale	3	-148.49	302.98	2.12	0.08	0.26(0.19)	
	Forest cover per household	3	-149.19	304.37	3.51	0.04	0.15(0.20)	
Hunting	**Forest cover at landscape-scale**	**3**	**-179.53**	**365.05**	**0.00**	**0.59**	**0.68(0.13)**	
	Forest cover at landscape-scale + remoteness from the urban center	**4**	**-179.11**	**366.21**	**1.22**	**0.32**	**0.84(0.22)**	**-0.19(0.21)**
	Forest cover at property-scale + remoteness from the urban center	4	-180.71	369.41	4.41	0.07	0.48(0.14)	0.34(0.13)
	Forest cover at property-scale	3	-183.80	373.60	8.55	0.01	0.45(0.16)	
	Remoteness from the urban center	3	-184.22	374.43	9.38	0.01	0.43(0.21)	
	Forest cover per household	3	-184.62	375.25	10.20	0.00	0.38(0.20)	
	Reference model	2	-185.89	375.78	10.69	0.00		
	Forest cover per household + remoteness from the urban center	4	-184.21	376.43	11.43	0.00	-0.04(0.49)	0.47(0.51)

Selected models (ΔAICc<2) in bold. K: number of parameters, logLik: log-Likelihood of the model, AICc: AICc value, ΔAICc: difference in AICc value compared to the first-ranked model, ωi: Akaike weight, Coefficient 1: coefficient for the first variable in the model, Coefficient 2: coefficient for the second variable in the model when the model has two variables. In parenthesis: standard errors for the coefficients.

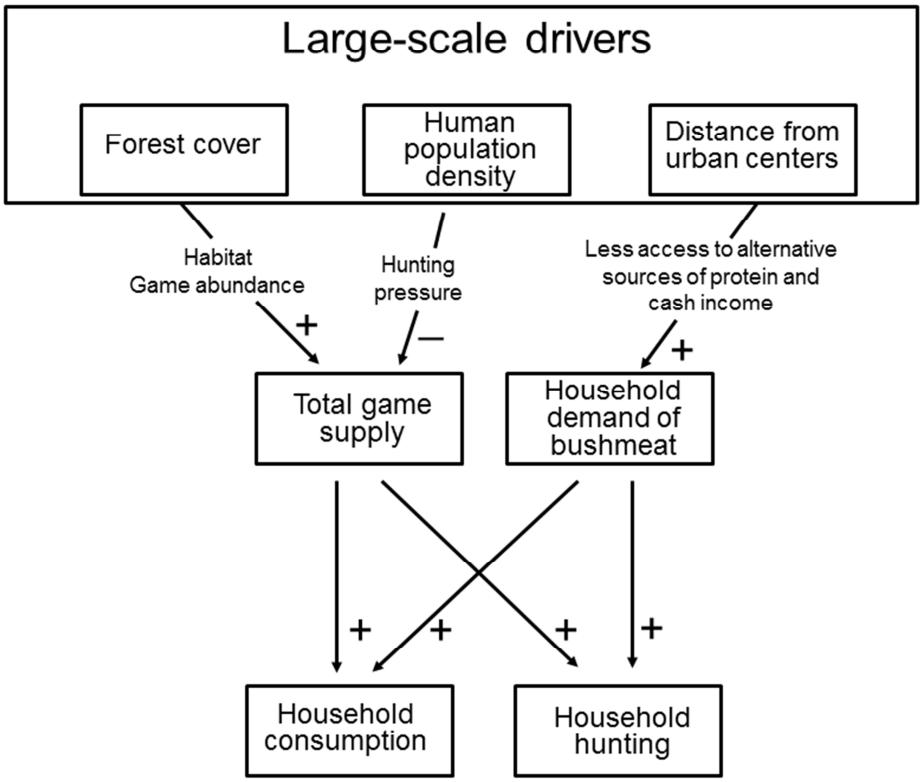

Figure 1. Expected relationships of large-scale drivers and bushmeat consumption and hunting.

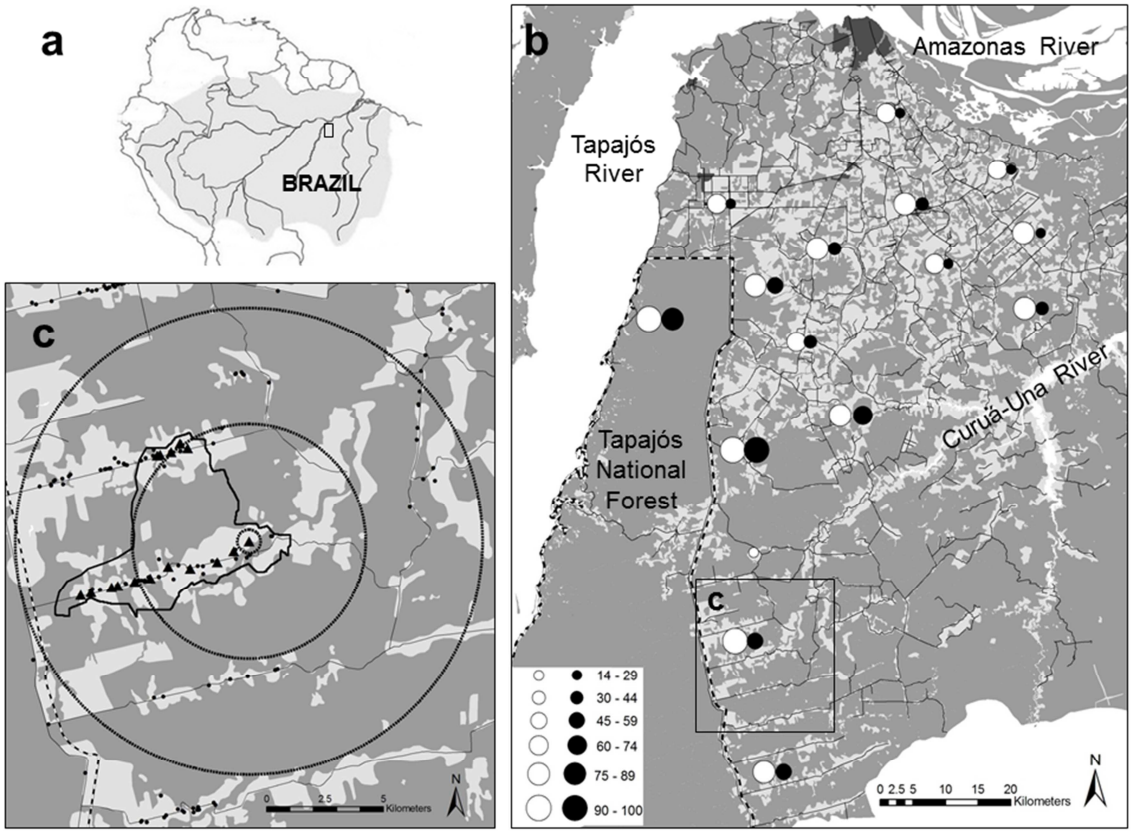

Figure 2. Land cover map of the study region, with percentage of households where bushmeat was consumed and that had a hunter. (a) Location of the study region in Amazonia. (b) Land-cover map of the study region indicating the location of the centroids of the 16 sampled landscapes (circles). Size of circles is proportional to the percentage of sampled households in a landscape where bushmeat was consumed (white) and that had a hunter (black). Urban areas in dark grey, forests in grey, converted land in light grey, and water bodies in white. (c) Distribution of households (sampled – triangles, not-sampled - dots) within a landscape (solid black line), and the indication of the three buffers for calculating forest cover for a given household. Solid grey lines are roads.

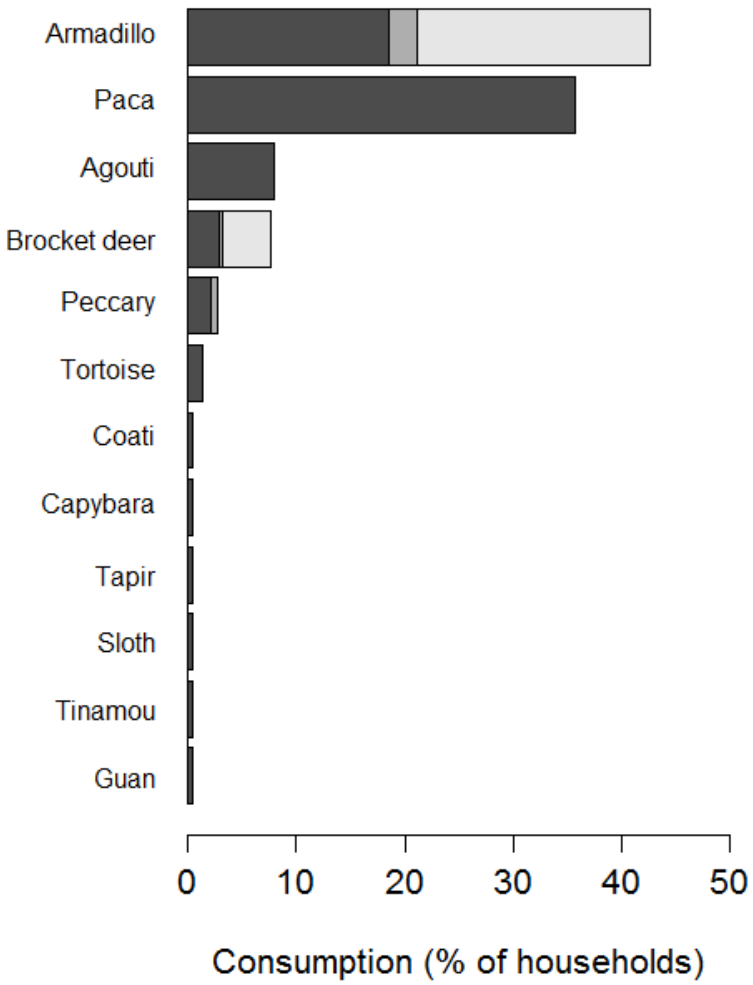

Figure 3. Game species reported to be the last consumed across households where bushmeat was consumed in the last year. For armadillos, dark grey indicates *Dasypus novemcinctus*, grey *Cabassous unicintus* and light grey non-identified species. For brocket deer, dark grey indicates *Mazama gouazoubira*, grey *Mazama americana* and light grey non-identified species. For peccaries, dark grey indicates collared peccary *Pecari tajacu* and grey non-identified species. For tortoises (*Chelonoids* spp.) and sloth, the species were not identified, with two slot species from different genus occurring in the region. For Tinamou (*Tinamus* sp.) and guan (*Penelope* sp.) species were not identified. For the remaining game animals the species were *Cuniculus paca* (paca), *Dasyprocta leporina* (agouti), *Nasua nasua* (coati), *Hydrochoerus hydrochaeris* (capybara) and *Tapirus terrestris* (tapir).

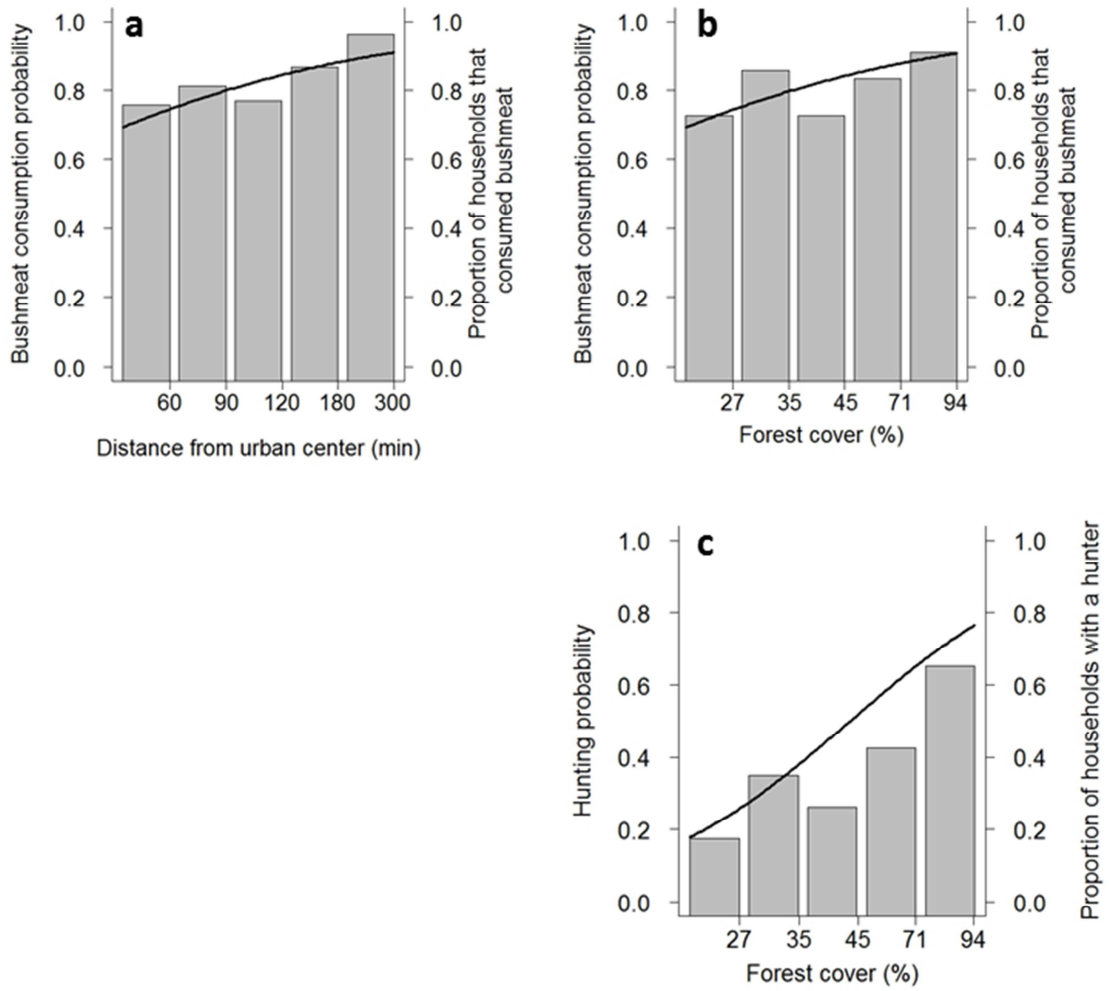

Figure 4. Relationships between large-scale drivers and bushmeat consumption and hunting. Probability of bushmeat consumption as a function of (a) the remoteness from urban centers and (b) forest cover within a 10-km radius buffer, as predicted by the first- and second-ranked models in Table 1. (c) Probability of hunting as a function of forest cover within a 10-km radius buffer as predicted by the first-ranked model in Table 1. Bars represent the proportion of households where bushmeat was consumed in the last 12 months, or that harbor at least one hunter.

Supporting Information

Table S1. Results of the model selection for identifying the best measures of each of four large-scale predictors for bushmeat consumption and hunting.

	Model	logLik	AICc	wAICc
Bushmeat consumption				
Forest cover at the property scale	All forest types	-148.5	303.1	0.54
	Degraded and non-degraded primary forest	-149.3	304.7	0.24
	Non-degraded primary forest	-149.4	304.9	0.22
Forest cover at the landscape scale	All forest types at 10-km	-147.9	301.8	0.27
	Non-degraded primary forest at 10-km	-148.1	302.4	0.20
	Degraded and non-degraded primary forest at 10-km	-148.2	302.5	0.19
	All forest types at 5-km	-148.6	303.3	0.13
	Degraded and non-degraded primary forest at 5-km	-148.7	303.5	0.11
	Non-degraded primary forest at 5-km	-148.8	303.6	0.11
Forest cover per household at the landscape scale	All forest types at 10-km	-149.2	304.5	0.18
	Non-degraded primary forest at 10-km	-149.2	304.5	0.18
	Degraded and non-degraded primary forest at 10-km	-149.2	304.5	0.18
	All forest types at 5-km	-149.4	304.9	0.15
	Degraded and non-degraded primary forest at 5-km	-149.4	304.9	0.15
	Non-degraded primary forest at 5-km	-149.4	304.9	0.15
Remoteness from urban center	Time spent to get to the most visited urban center in wet season	-147.4	300.9	0.38
	Time spent to get to the most visited urban center in dry season	-147.8	301.6	0.27
	Largest urban center	-148.3	302.8	0.15
	Most visited urban center	-148.7	303.5	0.11
	Nearest urban center	-148.8	303.6	0.10
Hunting				
Forest cover at the property scale	Total primary forest	-183.8	373.7	0.57
	Non-degraded primary forest	-184.5	375.1	0.29
	All forest types	-185.2	376.5	0.14
Forest cover at the landscape scale	All forest types at 10-km	-179.6	365.3	0.35
	All forest types at 5-km	-180.1	366.3	0.20
	Non-degraded primary forest at 10-km	-180.3	366.7	0.16
	Degraded and non-degraded primary forest at 10-km	-180.5	367.1	0.13
	Non-degraded primary forest at 5-km	-181.0	368.0	0.08
	Degraded and non-degraded primary forest at 5-km	-181.0	368.1	0.08
Forest cover per household at the	All forest types at 10-km	-184.6	375.4	0.20
	Non-degraded primary forest at 10-km	-184.7	375.4	0.19

landscape scale	Degraded and non-degradedprimary forest at 10-km	-184.7	375.6	0.18
	Non-degraded primary forest at 5-km	-184.9	376.0	0.14
	All forest types at 5-km	-185.0	376.0	0.14
	Degraded and non-degradedprimary forest at 5-km	-185.0	376.0	0.14
Remoteness from urban center	Largest urban center	-184.2	374.5	0.47
	Nearest urban center	-185.1	376.3	0.19
	Most visited urban center	-185.5	377.0	0.13
	Time spent to get to the most visited urban center in wet season	-185.7	377.6	0.10
	Time spent to get to the most visited urban center in dry season	-185.8	377.7	0.10

Capítulo 2

Interactions between economic, cultural and environmental drivers of hunting and bushmeat consumption in the Amazon

Abstract

Identifying economic drivers of hunting and bushmeat consumption is essential for developing coherent strategies that at the same time produce positive outcomes for poverty alleviation, sustainable resource use and biodiversity conservation. However, the findings of empirical assessments have been inconsistent, possibly due to interactions between economic, cultural and environmental drivers. We investigated hunting and bushmeat consumption in 240 households across 20 landscapes in a heterogeneous region in eastern Amazonia, addressing three inter-related questions: (i) Which of the three types of drivers (economic, cultural and environmental) and (ii) which indicator among each of them are more strongly associated with hunting and bushmeat consumption?; and (ii) Do the effects of economic variables depend on cultural and environmental factors? We found that all three types of factors are needed to understand hunting. In contrast, economic or cultural factors explain bushmeat consumption, even without considering environmental drivers. Moreover, economic-environmental interactions were strong for hunting, while less important for bushmeat consumption. Hunting and bushmeat consumption increased with monetary income near urban centers and/or in less forested areas, but decreased with monetary income in

remote and/or more forested areas. Importantly, reliance on subsistence activities and being from the Amazon had strong and positive effects on both hunting and bushmeat consumption. We show that bushmeat can be a different type of economic good in different environmental contexts - a normal good close to urban contexts but an inferior good in more remote and forested areas. Win-win solutions for both poverty alleviation and biodiversity conservation thus depend on the environmental context. Consequently, poverty reduction is important also for conserving game species in more remote and forested areas, whereas economic development should be accompanied by stricter forms of hunting control in deforested areas close to urban centers.

Keywords: animal protein, deforestation, game availability, livelihoods, monetary income, non-monetary income, poverty, urbanization, wealth, wild meat

Introduction

The importance of different economic factors in driving bushmeat consumption has been widely discussed in the literature (e.g. Wilkie & Godoy 2001, Godoy et al. 2010, Foerster et al. 2012). Identifying these factors improves our understanding of the effects of market expansion, market integration, development projects and cash transfer programs on the interplay between poverty alleviation, livelihood strategies, resource use and biodiversity conservation (Milner-Gulland et al. 2003, Kumpel et al. 2010, Brashares et al. 2011). Because some recommendations for reducing hunting and bushmeat consumption focus on promoting economic development (e.g. investments in agriculture – Milner-Gulland et al. 2003), it is crucial to determine whether poverty alleviation and wealth creation inadvertently increase hunting and bushmeat consumption (Damania et al. 2005).

Competing hypotheses that seek economic explanations for wildlife consumption make divergent predictions (Milner-Gulland et al. 2003). On the one hand, when bushmeat is considered an inferior good, consumption should be driven by poverty and therefore poorer, and typically rural households, should consume more bushmeat than richer households because it is a cheaper and more accessible source of protein (de Merode et al. 2004, Wilkie et al. 2005, Fa et al. 2009, Godoy et al. 2010). On the other hand, when bushmeat is a normal good wealth would lead to greater consumption (East et al. 2005, Wilkie et al. 2005, Fa et al. 2009, Godoy et al, 2010). Although hunting may be influenced by factors other than the demand for bushmeat in the household, such as the available time and resources for hunting and economic opportunities in trading bushmeat, these economic hypotheses on bushmeat consumption should also affect hunting. When bushmeat is an inferior good, poorer

households should be more engaged in hunting (Nielsen 2006), whereas when bushmeat is a normal good, increases in income and asset-wealth should lead to higher hunting activity (Damania et al. 2005).

Indeed empirical assessments of economic drivers of bushmeat consumption and hunting commonly resulted in contrasting conclusions. Most studies address asset-wealth and monetary income and disagree over which is the most important economic driver and also the direction of its relationship with hunting and consumption (e.g. Wilkie & Godoy 2001, Albrechtsen et al. 2006, Fa et al. 2009, Godoy et al. 2010). Some authors suggest that these contradictions result from environmental (ecological and geographical contexts) (e.g., Brashares et al. 2011, Foerster et al. 2012) and cultural differences among studies (East et al. 2005, Mgawe et al. 2012), which would interact with economic drivers.

Geographical factors, such as the distance to urban centers, affect the availability of alternative sources of protein so that in remote areas bushmeat may be an inferior good replaced when other types of meat become available or when income or asset-wealth rises. Indeed Brashares and colleagues (2011) found that in more remote contexts, poorer households consume more bushmeat than wealthier households. In contrast, they found that near urban centers, wealth increased bushmeat consumption, indicating that bushmeat is a normal good close to urban contexts. More remote locations are more likely to maintain large tracts of primary forest, and therefore not only the availability of alternative sources of protein should be lower but also the abundance of many game species should be higher. Remote areas with high forest cover should therefore offer greater net benefits of hunting and bushmeat consumption. Both environmental factors – distance to urban centers and habitat cover - should thus

influence the net benefits of hunting and consuming bushmeat, influencing the effect of economic drivers.

Cultural differences have received less attention by conservation scientists but could also alter the effects of economic drivers of hunting and bushmeat consumption. For instance, Mgawe and collegues (2012) found that bushmeat consumption was more likely in wealthier than in poorer indigenous households, whereas the opposite pattern was observed among in-migrant households. Interaction between cultural and economic factors may result from culturally-determined taste preferences among ethnic groups (Njiforti 1996, Schenck et al. 2006) or simply food habits (Mbete et al. 2011). Higher income or asset-wealth would thus lead to more bushmeat consumption only among those subgroups preferring bushmeat over other types of meat (East et al. 2005).

Recent studies on the effects of economic drivers on bushmeat consumption and/ or hunting have incorporated ecological and geographical variables (herein environmental variables) into their research design (e.g. Brashares et al. 2011, Foester et al. 2012, Mgawe et al. 2012). However, only Brashares and colleagues (2011) explicitly investigated the interactions between environmental and economic factors by addressing the effects of wealth depending on the distance to urban centers and the proximity to the nearest consistent source of bushmeat (reported by hunters). Moreover, the available evidence concerns mainly bushmeat consumption rather than hunting with examples mainly from central and West Africa, where markets for bushmeat are common and large. In addition, although studies have found differences in hunting and consumption patterns among different cultural groups, and an interaction between origin and wealth has been suggested (Mgawe et al. 2012), this interaction has not yet been tested.

In this paper we seek to advance current understanding on the importance of, and interactions between economic, cultural and environmental drivers of bushmeat consumption and hunting. Specifically, we examine whether the effects of economic factors are dependent on cultural and environmental contexts. To do so, we conducted this study in a recent post-frontier region in eastern Brazilian Amazonia, a former agricultural frontier where deforestation has been consolidated. Following agricultural development, the region now has a gradient of current forest cover correlated with distance from the main city, Santarem. In recent decades of agricultural transition, the study region has received different migratory waves from all Brazilian regions, including in-migrants with different economic and cultural backgrounds (Castro et al. 2004, Nepstad et al. 2006). These characteristics make the region particularly appropriate to investigate the interactions of cultural and environmental factors with economic drivers. By surveying 240 households distributed in 20 7,850 ha landscapes across a rural region of approximately 1 million ha, we addressed three inter-related questions: (i) Which of the three types of drivers (economic, cultural and environmental) and (ii) which indicators among economic, cultural and environmental drivers, are more strongly associated with hunting and bushmeat consumption?; and (ii) Do the effects of economic variables on hunting and bushmeat consumption depend on environmental and cultural factors?

Drawing on economic theory and previous empirical studies, we expect that both cultural and environmental factors need to be considered together with economic drivers to understand the patterns of hunting and bushmeat consumption, and that there are strong interactions between both factors and economic drivers. In more remote and forested areas, wealth (whether assets or monetary income) should decrease the likelihood of hunting and bushmeat consumption, since both have higher net benefits in

those areas given the lower access to alternatives and higher game availability. In less remote and less forested areas, there is easier access to alternative sources of animal protein, and higher costs of hunting due to lower availability of game, therefore wealth should increase the likelihood of hunting and bushmeat consumption. The effects of wealth on hunting and bushmeat consumption may also differ in strength or direction among people from the Amazon compared to in-migrants, due to differences in culturally-determined taste preferences.

Methods

Study region

Our study was carried out in rural areas of the municipalities of Santarém (78,790 inhabitants living in rural areas from a total population of 294,580), Belterra (6,852 of 16,318) and Mojuí dos Campos, a recently established municipality with no data on rural population size (total of 15,232) (IBGE 2010). The study region encompasses approximately 1 million ha in eastern Brazilian Amazonia and is bordered by the Amazon, Tapajós and Curuá-Una Rivers (Fig. 1).

The region has been inhabited since pre-Colombian times, but since the end of the nineteenth century has received many fluxes of migrants due to various economic cycles. A wave of migration from northeast Brazil arrived in 1877 to work in the forests, tapping rubber (Fonseca 1996). In the mid-twentieth century road construction and government-led colonization and land reform initiatives promoted another influx of low income in-migrants from the arid northeast, and also from the southern part of the country (Castro et al. 2004, Nepstad et al. 2006). In the 1990's, agricultural

mechanization began and cattle ranching expanded, with a new migratory wave of more capitalized farmers (including soy-farmers) from states in South and Mid-west Brazil (Nepstad et al. 2006). More recently, there have been changes in the spatial arrangement of the rural population and land properties, with some areas under-going urbanization, and the development of larger rural settlements, which generally enjoy better infrastructure and public service provision (Côrtes 2012). Therefore, in the study region there are both recent and long-term in-migrants from diverse regions of Brazil, and rural properties that range from small-scale farms based on subsistence agriculture to large-scale soy farms and cattle ranches, as well as more and less dense-populated communities.

Government policies on colonization and the recent expansion of mechanized agriculture and cattle ranching increased deforestation in the region (Nepstad et al. 2006). Yet, more than half of the study region is still covered by primary or secondary forest, with larger tracks of continuous forest mostly further from urban centers (Fig. 1).

Sampling design

We used a hierarchical sampling design. We first selected 20 7,850-ha areas (5-km radius circumferences), hereafter landscapes, that captured the variability in forest cover (from 33 to 93%) and road distance from the largest city (Santarém, from 10 to 140 km) within the study region. Within each landscape we randomly selected 12 households, resulting in a total of 240 sampled households (Fig. 1).

For selecting households, we first mapped roads, rivers and households within each landscape in the field and with help of GOOGLE EARTH images. We then established in ArcGis 9.3 a set of points every 10 m in each stretch of road and river

with at least one household (a stretch was defined as the section between two vertices). From those we randomly drew 12 points per landscape at least 400 m a part from each other (the maximum possible distance in all landscapes) to ensure a good spatial distribution of sampled households within landscapes. The selected households were those nearest to the 12 points. When the same household was the nearest to more than one of these points, the second point was excluded and another one was randomly drawn. When one point was at the same distance to more than one household, we randomly selected one of these household. We skipped individual households if the household heads declined to take part in the study (n=3), or if after three visits no resident was encountered (n=4).

Hunting and bushmeat consumption

We conducted an interview-based survey, with household heads (when possible both heads were interviewed) between July and November 2013. The survey was coordinated by P.C.T and conducted together with a team of three trained assistants, two of them from the region. To estimate the dependent variables, we asked (1) if any household member had gone hunting in the last 30 days and (2) if bushmeat was consumed in the household in the last 15 days. We reduced the recall period of bushmeat consumption to 15 days because it was more frequent than hunting and the respondents would have difficulties in answering with accuracy for the previous 30 days.

Economic and cultural drivers

The data on economic and cultural variables were collected through the same interview-based survey. The economic variables included in this study were per capita monetary income, reliance on non-monetary income (as a proportion of total income) in the

household and per capita asset-wealth; while the cultural variable was region of origin of the household head. Although not frequently considered in studies about the effects of economic variables on bushmeat consumption and hunting, the reliance on non-monetary income in the household was quantified as a proxy of how much the household economy is dependent on subsistence rather than on commercial activities and wage labor.

To measure monetary income, we asked about all the monetary earnings in the household in the previous 30 days, which included wage labor, sales of goods (agricultural, non-timber forest products and any other products), rents, remittances, pensions and cash transfer programs). We then divided the total monetary income by the total number of household residents to estimate monthly per capita monetary income, the variable used in the analyses.

To estimate the reliance on non-monetary income, we summed the monetary value of all own-produced goods, extracted forest products and gifts received, which were consumed by the household members in the 30 days prior to the interview. The value for each product was the commercial value each respondent declared (own-reported values). When the respondent was unable to inform the commercial value, we adopted the mean value declared to the same good by other respondents living in the same landscape or in the closest landscape. When no one was able to attribute a commercial value to the good, as frequently occurs with untraded forest products, we assigned a value based on the closest substitute which had a commercial value (Cavendish 2002). We then summed the monetary and non-monetary income to calculate the total income, and then divided the non-monetary income by the total income to get the reliance on non-monetary income in each household.

To estimate asset-wealth, we calculated the monetary value of 51 assets (ranging from pans to vehicles), including also livestock owned by all people in the household. The monetary value of the assets was accessed in markets in the largest city (Santarém), where most people purchase their goods. In the case of livestock, however, we relied on the values reported by interviewees. After summing the total value of asset-wealth, we divided it by the total number of household members to get a per capita estimate, which was then adopted in the analyses. All economic variables were measured in reais (the Brazilian currency), with a conversion rate at the time of 1 real = 0.45 US dollars.

To estimate the variable "origin", we asked where the male head of the household was born (state and municipality) and then considered if he was born in the Amazon, following the classification by the Brazilian Ministry of Environmental (MMA 2006). We considered the male head because only men were responsible for hunting in the region. Households were classified as having an Amazonian origin or a non-Amazonian origin.

Environmental drivers

The environmental variables considered where forest cover and distance to urban center. Forest cover was measured as a proxy of game availability and was the amount of total forest cover (in km^2), i.e. non-degraded and degraded primary plus secondary forest older than 10 years, at 10-km radius buffer (31,400 ha) around each household location of residence. We considered a large-scale measure of forest cover because local species persistence and abundance is known to depend on the wider landscape context (Andrén 1994). Moreover, previous work showed that a 10-km buffer was the best scale, and total forest was the best measure, to explain the variation in hunting and bushmeat consumption in the study region (Chapter 1). Yet, we also run the analyses considering

only non-degraded primary forest and total primary forest (degraded and non-degraded) and the results did not change. We calculated the cover of each type of forest through a time-series of Landsat images from 1990 to 2010, using a decision tree classification procedure that separated primary and secondary forest, as well as primary forest with a signal of degradation from past logging and fire (Gardner et al. 2013).

Distance to urban center was calculated as the road distances from each household location of residence and the largest urban center (Santarém city) using ArcGis 9.3. We considered the largest urban center because it is the most important economic center, being much larger than the other two urban centers in the study region and most people purchase their goods, sell their production and receive their pensions and payments from cash transfer programs there.

Data analysis

To investigate the association between hunting and bushmeat consumption and the economic, cultural and environmental factors we used generalized linear mixed-effects models (GLMM) to account for the hierarchical nature of the sampling design, with landscapes as random factors (Zuur et al. 2009). We run a set of candidate models for each of the two dependent variables - hunting and bushmeat consumption. We modeled the dependent variables as binary variables using logit as the link function. Hunting and bushmeat consumption were equal to 1 when, respectively, at least one household member have gone hunting in the previous 30 days and bushmeat was consumed at least once in the previous 15 days in the household.

For each model selection we considered six independent variables (three economic, one cultural and two environmental variables) as fixed factors. All fixed

factors, besides “origin” (which was a categorical variable), were standardized so that each had a mean of zero and a standard deviation of one, a procedure adopted to help improving convergence of the fitting algorithm (Zuur et al. 2009). Both sets of candidate models contained: an intercept-only model for reference (that does not include any fixed factors), simple models with each of the six independent variables on their own as fixed factors, models with all possible combinations between the six independent variables as fixed factors, without accounting for interactions between them, and all possible combination between the six independent variables with two-way interactions between the economic variables and either cultural or environmental variables. Only the two environmental variables were strongly correlated ($r = 0.89$; $p < 0.01$) as expected (remote areas are also more forested); the remaining pairwise correlations between the six independent variables were small, with the correlation between monetary income and asset-wealth being the highest ($r = 0.33$; $p < 0.01$) and the remaining very low ($r < 0.15$; $p > 0.04$).

Alternative models in each set were compared using the difference in their AICc values in relation to the first-ranked model (ΔAICc) (Burnham & Anderson 2002). A value of ΔAICc ≤ 2 indicates equally plausible models. All analyses were implemented in R 3.0.3 (R Core Team 2014) using the lme4 package (Bates et al. 2011).

Results

Hunting was carried out at least once in the previous 30 days by members of nearly a third (31%) of the households. Bushmeat had been consumed in 33% of the households within the previous 15 days. In total, respondents declared 188 hunting events (mean =

2.5, SD = 1.6 across households where hunting was carried out), from which only 88 were successful (hunters caught at least one individual), and declared 208 meals containing bushmeat (mean = 2.6, SD = 2.5 across households where bushmeat was consumed). From those meals, in 45% of the cases bushmeat was hunted by a household member and in the remaining 55% the bushmeat consumed was a gift. Paca (*Cuniculus paca*) and nine-banded armadillo (*Dasypus novemcinctus*) were the most frequently hunted and consumed species in the region (Fig. 2).

Hunting was strongly associated with four factors – monetary income, reliance on non-monetary income, forest cover and origin of the household head, as all four selected models contained these variables (Table 1). This indicates that all three types of factors – economic, cultural and environmental- are needed to understand the variation in hunting probability across the region. The interaction between monetary income and forest cover was also important and included in all four selected models. It indicates that hunting probability is positively associated with monetary income in less forested areas but negatively associated with it in more forested areas (Fig. 3a). Moreover, in households with a greater reliance on non-monetary income and with Amazonian origin hunting was more likely.

There is some evidence that asset-wealth and distance to urban center may also be associated with hunting after controlling for the effects of monetary income, reliance on non-monetary income, forest cover and origin, as each was included in one of the selected models (Table 1). Residents in less asset-wealthy households and in those nearer to the urban center were more likely to hunt. Similarly, the interaction between the reliance on non-monetary income and origin was included in one of the selected models. This interaction indicates that hunting probability is positively associated with

reliance on non-monetary income among households with non-Amazonian origins, whereas it is only slightly and negatively associated with reliance on non-monetary income among households with Amazonian origin (Fig.3b).

In contrast to hunting, models containing only economic (one model) or cultural (one model) factors, only cultural factors and environmental (two models), only economic and cultural factors (three models), or the three types of factors together (11 models) were equally plausible to explain the variation in bushmeat consumption (Table 3). Moreover, only three of the 18 selected models included interactions, all of which were between environmental (either distance to urban center or forest cover) and economic variables (in all cases monetary income).

Origin, the only cultural factor considered, was the most important driver of bushmeat consumption, being present in 17 of the 18 selected models, including the simple model containing just this factor (Table 2). Households with Amazonian origin were more likely to consume bushmeat (Fig. 4a), as also observed for hunting. The reliance on non-monetary income was the most important economic variable, present in 12 selected models including the simple model with this variable alone (Table 2). In households with a greater reliance on non-monetary income bushmeat consumption was more likely (Fig. 4b), as also observed for hunting. However, monetary income and asset-wealth were also included in seven and four of the selected models, respectively (Table 2). In contrast to the observed for hunting, both variables had a negative association with bushmeat consumption. Moreover, three of the seven selected models containing monetary income included also the interaction of this variable with environmental variables (Table 2). These interactions indicate that the probability of bushmeat consumption was positively associated with monetary income in less forested

areas and near urban center (similar to the observed for hunting), whereas it was only slightly and negatively associated with monetary income in more forested and remote areas (Fig. 3c and 3d).

Differently from the observed for hunting, both distance to urban center and forest cover were associated with bushmeat consumption, as eight and five selected models contained these variables, respectively (Table 2). Bushmeat was more likely to be consumed in more remote households and those located in more forested areas.

Discussion

Previous studies have not considered economic, cultural and environmental drivers together for understanding hunting and bushmeat consumption. Yet we found that all three types of drivers are necessary to understand variation in hunting patterns in our Amazonian study region. In contrast economic or cultural factors explained bushmeat consumption patterns, even without considering environmental drivers. Supporting our hypotheses, we found strong evidence that economic and environmental factors interact to determine hunting probability, while these economic-environmental interactions were less important in explaining bushmeat consumption probability. The observed environmental-economic interactions were congruent with our hypotheses, but were much more drastic for hunting than for bushmeat consumption. For hunting, forest cover was a more important environmental driver than distance to urban center, and monetary income a more important economic driver than asset-wealth. Conversely, the reliance on non-monetary income (a proxy for subsistence in the household economy) and origin were major drivers for both hunting and bushmeat consumption. In contrast

to previous assertions (Mgawe et al. 2012), we did not find evidence of interactions between cultural factors (origin) and commonly studied economic variables (economic income and asset-wealth) for determining either bushmeat hunting or consumption.

We discuss next our findings on the drivers of hunting and bushmeat consumption, as well as their implications for rural livelihoods and biodiversity conservation.

Drivers of hunting

Our results indicate that two economic variables (monetary income and reliance on non-monetary income), a cultural factor (origin) and an environmental factor (forest cover) were major drivers of hunting probability. However, the economic variables interacted with the environmental or the cultural factor.

The effect of monetary income on hunting probability depended on forest cover. The proximity of game sources or forest cover as proxies of game availability has already been associated with higher hunting rates (Brashares et al. 2011, Nuno et al. 2013, Chapter 1). Nevertheless, we found that in areas with low forest cover, and thus presumably lower game availability, hunting probability increased with monetary income, while it decreased with monetary income in more forested areas. This interaction has not been suggested in the literature so far, as studies involving economic factors and hunting patterns were carried out in more environmentally homogenous contexts (e.g. Coomes et al. 2004, Nielsen 2006, Coad et al. 2010, Kümpel et al. 2010), and those including both economic and environmental drivers focused mainly on bushmeat consumption instead of hunting (Brashares et al. 2011, Foerster et al. 2012). However, this result was as expected by our hypotheses and similar to studies that

focused on bushmeat consumption. In more forested areas bushmeat should be an inferior good, so that members from poorer households would be more likely to hunt than those from richer households. As the cost of hunting in more forested areas is low (due to more game availability), the net benefits of hunting should be higher, increasing hunting probability among poor households as they are be less able to afford other types of meat due to economic constraint. In less forested areas, game should be less available and thus hunting should have a higher cost, making bushmeat less affordable to poorer households.

We also found that hunting was more likely in households that rely more on subsistence and have an Amazonian origin. However, we found some evidence that this positive effect of subsistence reliance on hunting might be observed only among people with a non-Amazonian origin. Although there is no study that investigated the effects of subsistence reliance on hunting or bushmeat consumption, our results add to the evidence that households less involved in cash-income activities may depend on hunting to acquire food (Loibooki et al. 2002, de Merode et al. 2004, Nielsen 2006, Kümpel et al. 2010). Differences in geographic origin have also been found to influence hunting patterns. For instance, Mgawe and colleagues (2012) found higher hunting offtake in indigenous villages compared to in-migrants in Africa, where bushmeat was apparently preferred by indigenous people compared to in-migrants. Our results suggest that either people from the Amazon have better knowledge on the forest or have a stronger culture of hunting than people from other parts of the country. Thus the probability of hunting among in-migrants seems to be higher for those relying more on subsistence, i.e. in-migrants may hunt more only for necessity, whereas people from the Amazon hunt regardless of the level of subsistence reliance.

Finally, we found weaker evidence for negative associations between both distance to urban center and asset-wealth with hunting, but only after controlling for forest cover, origin, monetary income and reliance on non-monetary income. The probability of hunting was higher in households nearer the urban center (see also Chapter 1). Although some studies in Africa found the opposite relationship between hunting and distance to urban centers, they did not control for other major drivers (Loibooki et al. 2002, Coad et al. 2010). Our results are consistent with studies that found that people living closer to major markets are often more engaged in commercial bushmeat trade (Espinoza 2009, Pangau-Adams et al. 2012), which would bring higher returns for hunters compared to more remote areas (Brashares et al. 2011). This suggests that interviewees may not have reported bushmeat trade in our study because bushmeat trade is illegal in Brazil. The probability of hunting was also lower among wealthier households. Previous studies in rural Africa found incongruent effects of asset-wealth on hunting patterns (Loibooki et al. 2002, Coad et al. 2013). We did not find evidence that asset-wealth interacts with environmental or cultural factors to determine hunting in the Amazon, but we have shown that monetary income is a more important predictor of hunting patterns than asset-wealth in this region.

Drivers of bushmeat consumption

Our results indicate that economic and cultural factors alone are more important in explaining bushmeat consumption than in explaining hunting, which seems much more dependent on environmental factors. This may be due to the fact that in many households where bushmeat was consumed it was not obtained through hunting, which should be strongly dependent on game availability. Rather, they received bushmeat as a gift in 55% of the consumption events, and bushmeat sharing is known to be related to

economic and cultural factors (Behrens 1992, Henrich et al. 2005, Gurven et al. 2008). Moreover, although none of the interviewees reported the purchase of bushmeat many people may disguise it because bushmeat trade is illegal in Brazil, as stated above. Part of the bushmeat consumed in these events may have been purchased and this form of acquiring meat is strongly determined by economic factors (Godoy et al. 2010, Brashares et al. 2011). Thus the high percentage of consumption events that are not associated with hunting may explain why bushmeat consumption is less dependent than hunting on environmental factors.

On the other hand, although the reliance on non-monetary income, a proxy of dependence on subsistence activities, and origin were extremely important for both hunting and bushmeat consumption, for the later these two variables may explain consumption patterns alone, irrespective of other economic or of environmental factors. These major drivers are either not included in previous bushmeat studies (reliance on subsistence) or less frequently so (origin). People from the Amazon were more likely to consume bushmeat, perhaps because they prefer bushmeat over other types of meat. A similar pattern was also found in a logging concession in rural Congo (Poulsen et al. 2009), where bushmeat was more frequent in meals of indigenous households than in in-migrants and foreigners households. Moreover, in households with a greater reliance on non-monetary income bushmeat consumption was more likely, consistent with the idea that households less involved in cash-income activities may depend more on bushmeat (Loibooki et al. 2002, de Merode et al. 2004, Nielsen 2006, Kümpel et al. 2010). There was, however, no evidence of interaction of these two factors, as we observed for hunting, meaning that although people from the Amazon are more likely to hunt irrespective of the level of subsistence reliance, similarly to in-migrants they also are more likely to consume bushmeat when depending more on subsistence.

Although less important than certain economic and cultural variables, both distance to urban center and forest cover were associated with bushmeat consumption, regardless of the interactions with economic and cultural factors. Bushmeat was more likely to be consumed in more remote households and those located in more forested areas, suggesting that bushmeat is more important for household food security in these contexts. Indeed, studies in Africa have shown that poor access to other types of meat can drive bushmeat consumption (Brashares et al. 2011), which is also more common in places close to game sources (Brashares et al. 2011, Foerster et al. 2012, Mgawe et al. 2012). Moreover, distance to urban center was more important than forest cover for explaining bushmeat consumption, the same pattern we found in Chapter 1 with a different data set. This can be related to people having less access to domestic meat from markets, which can be more important in determining consumption than game availability, since most bushmeat consumed was a gift instead of hunted.

We found, however, some evidence for the interaction between both environmental factors and monetary income. The evidence for - and the strength of - the interaction between monetary income and forest cover was weaker – and less drastic - for bushmeat consumption than for hunting. This is probably related to the minor importance of game availability to bushmeat consumption compared to hunting, as stated above. However, although not strong, we found evidence for the interaction between monetary income and distance to urban centers for bushmeat consumption, which was not found for hunting. A similar interaction was also observed by Brashares and colleagues (2011), who found that people from wealthier households consumed more bushmeat in settlements nearer urban areas with the opposite pattern in more isolated settlements. We observed a strong positive effect of monetary income on bushmeat consumption in areas close to urban centers, and a weaker negative effect of

this variable on consumption in remote areas. The observed interaction is consistent with our hypotheses and the results of Brashares and colleagues (2011) that bushmeat is an inferior good in remote areas, but a normal good in areas close to urban centers. This interaction can also explain previous findings in the literature (Apaza et al. 2002, Wilkie et al. 2005, Godoy et al. 2010). Both Apaza and colleagues (2002) and Godoy and colleagues (2010) found no association between income and bushmeat consumption, which can be due to the fact that they sampled households in villages that differed in the proximity to the market town.

Implications for conservation and rural livelihoods

Our study adds to the evidence that bushmeat hunting and consumption are associated with a complex set of different factors and involve interactions between economic variables and both cultural and environmental contexts. It can thus be difficult to find general patterns of bushmeat hunting and consumption with economic variables worldwide. Our results suggest that bushmeat can be a different type of good in economic terms in different environmental contexts - a normal good in altered areas close to urban centers but an inferior good in more remote and forested areas - and may be also in different cultural contexts.

As rural populations face changes in their economic conditions through integration of autarkic communities into markets, through government development projects and cash transfer programs, it becomes important to understand how these changes affect livelihood strategies, resource use and biodiversity conservation (Billé et al. 2012). As for game species, improvements in economic conditions might actually increase hunting and consumption in some scenarios (Damania et al. 2005). In that sense, our results suggest that win-win solutions for both poverty alleviation and

biodiversity conservation depend on the environmental contexts and that improving people's economic conditions and the availability of alternative sources of meat may help conservation in more remote and forested areas. However, in less forested areas close to urban centers, economic improvement should be accompanied by stricter forms of hunting control. Interestingly, for those that rely heavily on subsistence activities, the increase in income from cash-generating activities might alleviate hunting pressure in any context. Our results also suggest that strategies for poverty alleviation and biodiversity conservation should also take into account differences in cultural contexts. For communities where hunting is a culturally important activity and bushmeat is preferred, simply increasing monetary income or the availability of alternative sources of meat might not alleviate hunting pressure. In these cultural contexts, sustainable hunting may be feasible and more effective for game species conservation in more forested areas (Peres & Nascimento 2006), whereas hunting control and environmental education are extremely important in less forested areas.

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Table 1. Model selection results for hunting probability among 240 rural households in the study region. All candidate models are GLMM models with landscapes as a random factor. Only selected models with weight ΔAICc≤2 and the intercept-only model for reference are shown.

Model description	K	logLik	AICc	ΔAICc	ωi	Inc	Prop	Wea	For	Urb	Orig	Inc:For	Prop:Orig
Inc+Prop+For+Orig+Inc:For	7	-130.39	275.26	0.00	0.06	-0.40	0.39		0.30		1.23	-1.20	
Inc+Prop+Wea+For+Orig+Inc:For	8	-129.91	276.44	1.18	0.04	-0.08	0.38	-0.30	0.28		1.17	-1.34	
Inc+Prop+For+Urb+Orig+Inc:For	8	-130.25	277.13	1.86	0.03	-0.42	0.39		0.45	-0.17	1.20	-1.21	
Inc+Prop+For+Orig+Inc:For+Prop:Orig	8	-130.28	277.19	1.93	0.02	-0.39	0.48		0.30		1.24	-1.20	-0.14
Intercept-onlymodel	2	-148.26	300.58	25.31	0.00								

Inc: per capita monetary income; Prop: reliance on non-monetary income; Wea: per capita asset-wealth; For: forest cover; Urb: distance to urban center; Orig: origin; K: number of parameters; logLik: log-Likelihood of the model; AICc: AICc value; ΔAICc: difference in AICc value compared to the first-ranked model; ωi: Akaike weight; coefficients for each variable of the model.

Table 2. Model selection results for bushmeat consumption probability among 240 rural households in the study region. All candidate models are GLMM models with landscapes as a random factor. Only selected models with weight ΔAICc≤ 2 and the intercept-only model for reference are shown.

Modeldescription	K	logLik	AICc	ΔAICc	ωi	Inc	Prop	Wea	For	Urb	Orig	Inc:For	Inc:Urb
Prop+Orig	4	-144.04	296.24	0.00	0.03		0.26				0.64		
Prop+Urb+Orig	5	-143.06	296.38	0.13	0.03		0.24			0.34	0.72		
Urb+Orig	4	-144.31	296.80	0.56	0.03					0.38	0.77		
Prop+For+Orig	5	-143.34	296.94	0.70	0.02		0.24		0.29		0.69		
Inc+Prop+Orig	5	-143.45	297.15	0.91	0.02	0.19	0.29				0.71		
Inc+Prop+Urb+Orig+Inc:Urb	7	-141.36	297.20	0.96	0.02	0.23	0.25			0.34	0.80		-0.33
Orig	3	-145.58	297.27	1.03	0.02						0.70		
Prop+Wea+Orig	5	-143.53	297.32	1.08	0.02		0.28	0.17			0.73		
Inc+Prop+Urb+Orig	6	-142.49	297.35	1.10	0.02	0.18	0.26			0.35	0.78		
For+Orig	4	-144.62	297.41	1.17	0.02				0.33		0.75		
Prop+Wea+Urb+Orig	6	-142.57	297.50	1.26	0.02		0.25	0.16		0.35	0.81		
Inc+Prop+For+Orig+Inc:For	7	-141.52	297.53	1.28	0.02	0.26	0.26		0.27		0.76	-0.37	
Prop	3	-145.81	297.71	1.47	0.02		0.29						
Inc+Urb+Orig+Inc:Urb	6	-142.75	297.85	1.61	0.01	0.19				0.37	0.84		-0.34
Inc+Prop+For+Orig	6	-142.78	297.92	1.67	0.01	0.18	0.26		0.29		0.76		
Prop+Wea+For+Orig	6	-142.88	298.12	1.88	0.01		0.26	0.16	0.28		0.78		
Inc+Urb+Orig	5	-143.94	298.13	1.89	0.01	0.14				0.39	0.83		
Wea+Urb+Orig	5	-143.97	298.20	1.96	0.01			0.13		0.39	0.85		
Intercept-onlymodel	2	-147.8	299.6	3.31	0.00								

Inc: per capita monetary income; Prop: reliance on non-monetary income; Wea: per capita asset-wealth; For: forest cover; Urb: distance to urban center; Orig: origin; K: number of parameters; logLik: log-Likelihood of the model; AICc: AICc value; ΔAICc: difference in AICc value compared to the first-ranked model; ωi: Akaike weight; coefficients for each variable of the model.

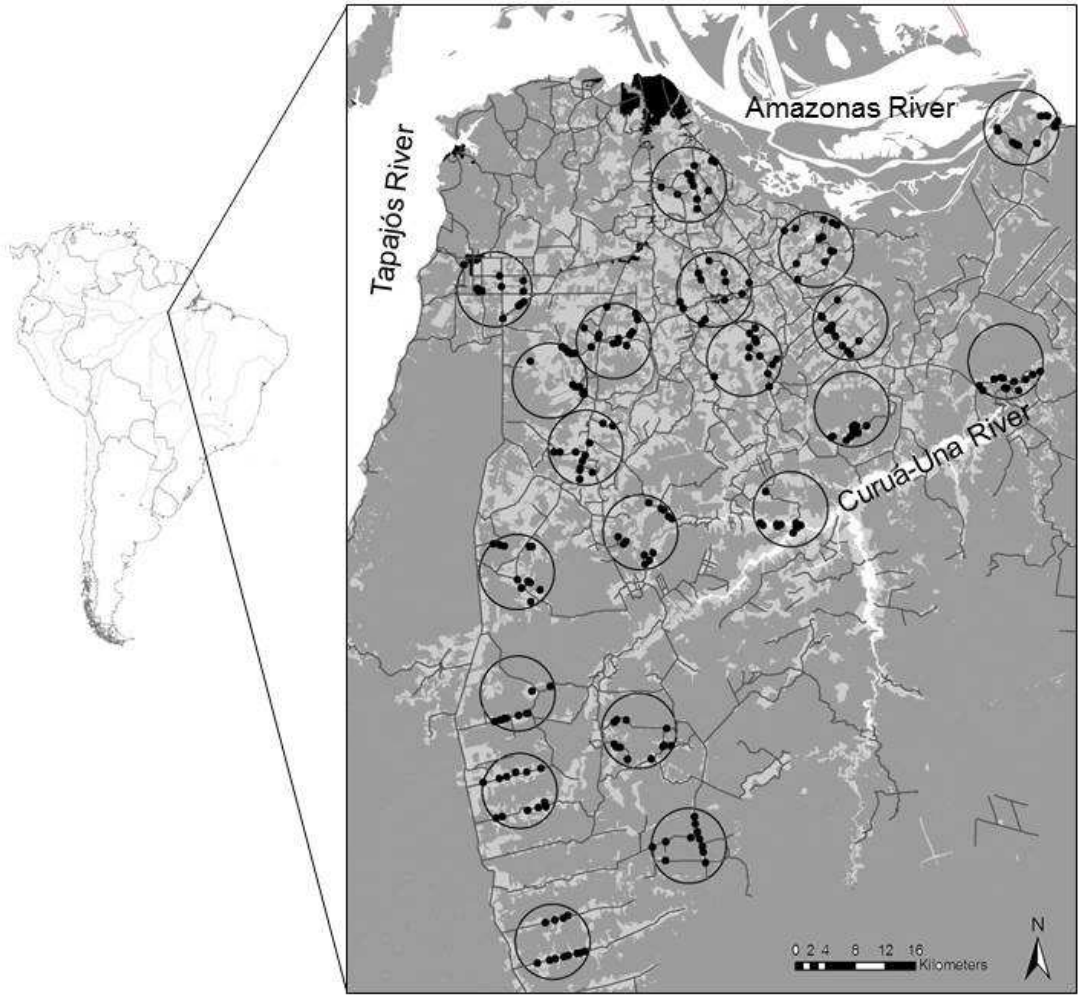

Figure 1. Land cover map of the study region. Location of the study region in South America and land-cover map of the study region, indicating the location of the 20 study landscapes (circumferences) and the 240 sampled households (black dots). Urban areas in dark grey, forests in grey, converted land in light grey, and water bodies in white.

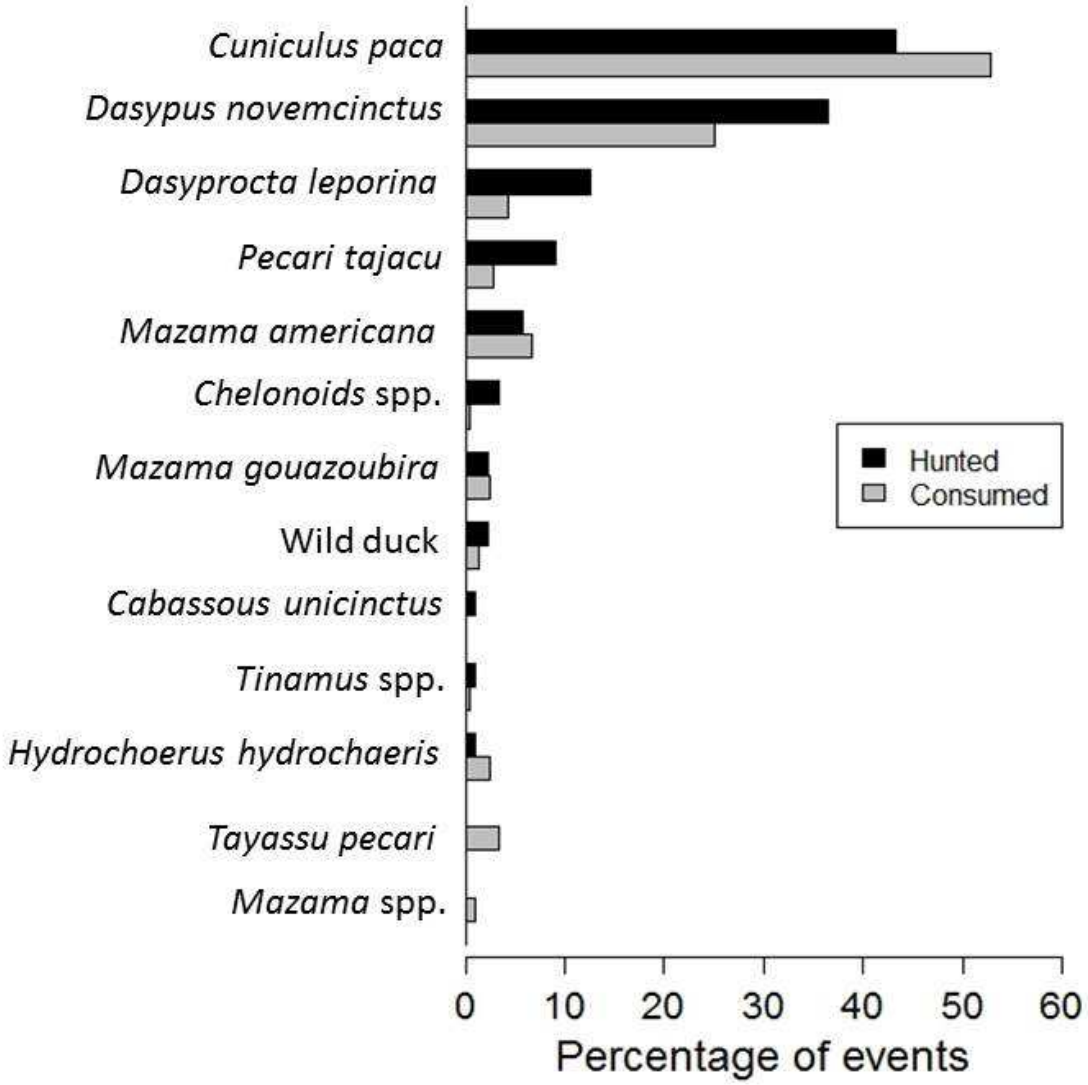

Figure 2. Species hunted and consumed in the study region. Percentage of hunting (n=88) and meal (n=208) events where the species was hunted or consumed. Totals sum to more than 100% because more than one species could have been hunted or consumed in the same event.

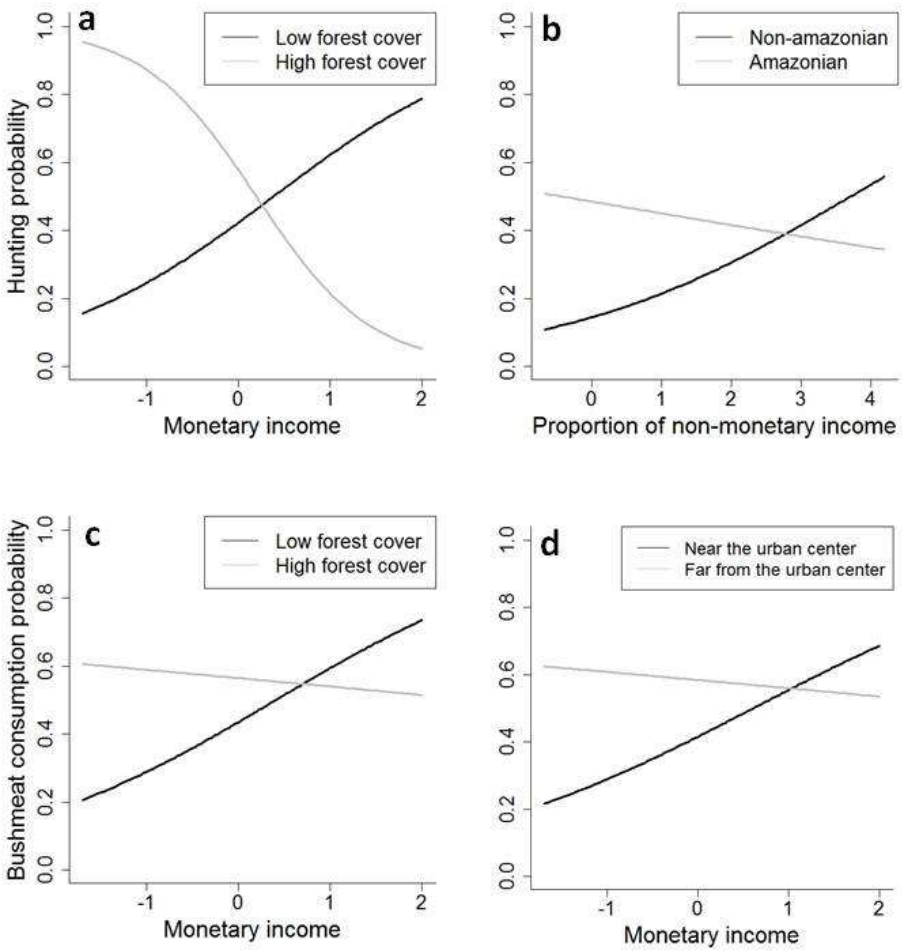

Figure 3. Relationship between economic factors and hunting or consumption in different environmental and cultural contexts. (a) Relationship between per capita monetary income and hunting probability in contexts of low and high forest cover as predicted by the first-ranked model in Table 1. (b) Relationship between the reliance on non-monetary income and hunting probability for households where the residents have an Amazonian and non-amazonian origin as predicted by the forth-ranked model in Table 1. (c) Relationship between per capita monetary income and bushmeat consumption probability in contexts of low and high forest cover as predicted by the 12th-ranked model, and (d) in contexts of proximity and remoteness from the urban center as predicted by the sixth-ranked model in Table 2. Data for model selection were standardized and so the values presented in the x-axis are standardized values.

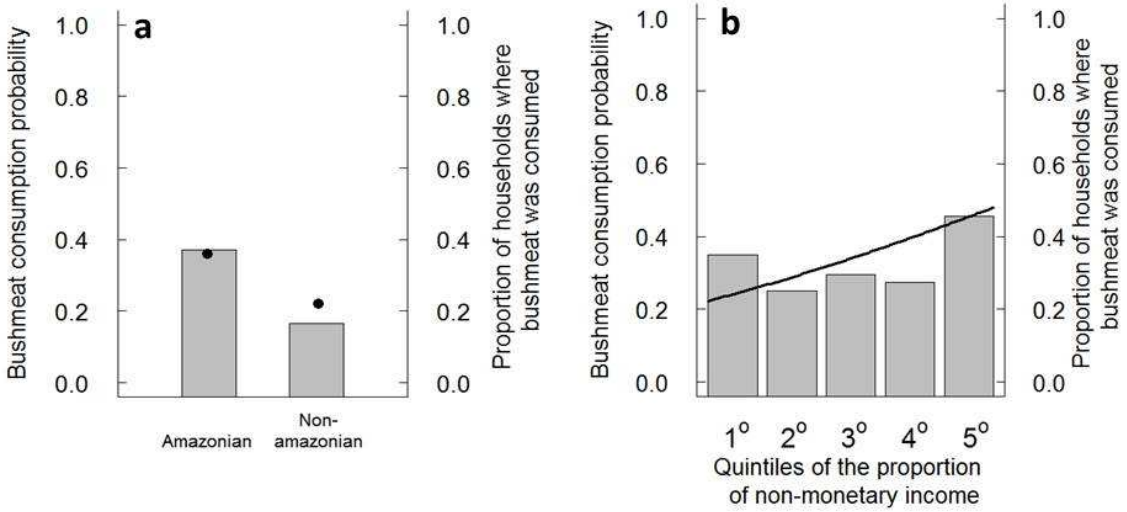

Figure 4. Relationship of origin and the reliance on non-monetary income with bushmeat consumption. (a) Bushmeat consumption probability in households where residents have different origins, as predicted by the simple selected model in Table 2 (dots). Bars represent the observed proportion of households where bushmeat was consumed in the last 15 days. (b) Bushmeat consumption probability as a function of the reliance on non-monetary income as predicted by the simple model selected in Table 2. Bars represent the observed proportion of households where bushmeat was consumed in the last 15 days for the quintiles of reliance on non-monetary income.

Capítulo 3

Using bushmeat and living close to forest: do they alter people's perception of utilitarian and intrinsic value of forests?

Abstract

Environmental values can partly determine people's willingness to engage in conservation initiatives. In tropical countries as Brazil, engaging rural people in conservation is vital, because most remaining forest is in private land, their persistence depending on landowners' attitudes and behavior. Although the majority of rural residents are unlikely to rely primarily on forest products, the provision of food, particularly bushmeat that is available all year round, can still be a valued resource influencing the perceived forest instrumental value. However, the availability and use of these resources likely decline with deforestation, which can also lead to decreased direct contact with forests, negatively affecting the perception of forest intrinsic value. By surveying perceptions of forest values among 363 rural residents from 20 landscapes varying in forest cover across a 1 million-ha region in eastern Amazonia, we tested two hypotheses: (1) lower bushmeat harvest and consumption, and deforestation by reducing the supply of this important resource, erode perceptions of forest instrumental value; (2) deforestation erodes perceptions of forest intrinsic value. As expected, bushmeat consumption (but not hunting or forest cover) was positively associated with a favorable perception of forest instrumental value, and deforestation was negatively associated

with a favorable perception of forest intrinsic value. Our findings highlight that bushmeat is indeed a valued forest resource that shapes the perception of forest utility among people living in altered as well as more forested landscapes. They also provide evidence for a dangerous reinforcing cycle: deforestation and the loss of contact and experience with forests erode perceptions of forest intrinsic value, which may in turn facilitate further deforestation. Engaging rural communities in forest conservation initiatives are probably more difficult but also more urgent in more altered landscapes, where the utilitarian value linked to forest products such as bushmeat could be the focus of such initiatives.

Keywords: ecosystem services, environmental values, forest products, forest resources, game species, habitat loss, human-modified landscapes, over-exploitation, tropical forest

Introduction

Individual values are deemed fundamental to understand people's attitudes and behavior (Rokeach 1973, Azjen 1991, Dietz et al. 2005). In particular, those referring to people's perceptions about the environment have been shown to predict pro-environmental attitudes and behaviors (Stern et al. 1995, Schultz & Zelezny 1999, Schultz 2001). This assumption has received growing attention in conservation, with the recognition that understanding how and why people value nature can be a useful tool for the management and conservation of natural environments. Understanding people's perceptions on environmental values is important to identify ways for minimizing conflicts between stakeholders, promote the social acceptability of management activities and actively engage people in conservation of natural environments by taking into consideration people's uses and preferences (Lockwood 1999, Mascia et al. 2003, Lockwood 2005, Seymour et al. 2010, Knight et al. 2011, Brown & Reed 2012, Paletto et al. 2013, Ives & Kendal 2014).

Although there are different theoretical frameworks in environmental psychology distinguishing the types of environmental values, they hold many aspects in common and suggest there are multiple ways by which people value the natural environment (Dietz et al. 2005, Ives & Kendal 2014). Among these, two main kinds of environmental values are often distinguished: instrumental (or utilitarian), which refers to the utility of resources and products from natural environments that can fulfill people's needs; and intrinsic, those related to people's moral and aesthetic feelings about nature regardless of its utility (Sagoff 1991, Bengston 1994, Vilkka 1997).

In the attempt to value the natural environment and the importance to conserve it, instrumental values are often linked to ecosystem services (i.e., the benefits derived

from the ecosystems - Millennium Ecosystem Assessment 2005). It is argued that their incorporation into environmental conservation strategies, particularly economic strategies, provide a more efficient way of engaging stakeholders in conservation (Justus et al. 2009). However, ecosystem services encompass a broader set of value categories rather than solely instrumental values (Reyers et al. 2012, Jax et al. 2013), as they include not only provisioning services (e.g. timber, food, fresh water supply) but also other types of services such as cultural services (Chan et al. 2012) and therefore nonmaterial benefits such as spiritual enrichment, reflection and aesthetic experiences (Millennium Ecosystem Assessment 2005). Cultural services are then more clearly linked to the intrinsic value people attribute to the natural environment and there is growing awareness that these values are also important to understand people's propensity for pro-environmental behavior (Chan et al. 2012, Jax et al. 2013).

From a utilitarian perspective, the provision of bushmeat is an important forest service to those inhabiting developing countries, providing both animal protein and cash income (Milner-Gulland et al. 2003, de Merode et al. 2004). We can therefore expect that a decrease in the level of bushmeat harvesting and consumption lead to less favorable perceptions about the instrumental value of forests. However, the importance of bushmeat as an ecosystem service to local inhabitants can be compromised by deforestation, since forest loss likely decreases the availability of game animals (Michalski & Peres 2007). Plausibly, deforestation could thus also affect people's perceptions of the instrumental value of forests, if hunters and consumers are sensitive to decreases in the population size of less resistant large-bodied game animals. Although there is a plethora of studies stating the importance of bushmeat for livelihoods in virtually all tropical forest regions (Milner-Gulland et al. 2003), the association between bushmeat harvesting and consumption and people's perceptions

about forest value has been poorly studied (but see Meijaard et al. 2013). While overhunting have been associated with local decline and extinction of numerous species (Milner-Gulland et al. 2003, Peres & Palacios 2007), when sustainable the use of this forest product can be an important factor shaping people valuation of forests and willingness to conserve them.

From a cultural or aesthetic perspective, deforestation may also affect people's perceptions of the intrinsic value of forests. The disconnection and loss of direct contact with nature has been shown to lead to less favorable perceptions about nature and biodiversity, reflecting in less favorable attitudes towards biodiversity conservation (Miller 2005, Zhang et al. 2014). This disconnection leading to less favorable perceptions has been shown to occur due to increasing urbanization (Turner et al. 2004, Miller 2005). However, to our knowledge there is no study that focused on the more subtle process of increasing deforestation, which may as well lead to the loss of contact with nature in rural landscapes, negatively influencing peoples' willingness to conserve forests.

In post-frontier regions in the tropics - areas were deforestation has been consolidated - it is unlikely that the majority of rural residents rely mostly on forest products for a living (Futemma & Brondízio 2003), but the provision of food, particularly bushmeat, which is available all year round, can still be an important service provided by forests (Chapter 1 and 2). In these regions, the availability and the use of bushmeat are likely to negatively correlate with deforestation rates (Michalski & Peres 2007, Foerster et al. 2012, Chapter 1). As these regions are highly heterogeneous, encompassing a spatial gradient in forest cover as deforestation progresses (Fearnside 2005), they are well-suited to investigate the association of both deforestation and bushmeat harvest and consumption with people's perceptions about forest values.

We conducted interviews with 363 rural residents living in 20 landscapes varying in forest cover across a ~1 million ha recent post-frontier region in the eastern Brazilian Amazon to investigate the association between people's perceptions of the instrumental and intrinsic values of forests and deforestation and bushmeat harvest and consumption. We hypothesize that lower bushmeat harvest and consumption, as well as deforestation by reducing bushmeat supply, erode people's perceptions of forest utility (instrumental value). Deforestation should also be associated with less favorable perceptions of forest intrinsic value because it reduces people's direct contact with forests.

Methods

Study region

We conducted this study in a post-frontier region in eastern Brazilian Amazon, south of the city of Santarém, in Pará state, a region that has been an agricultural frontier where deforestation has been consolidated. Santarém region has been inhabited since pre-Colombian times but the city itself was founded in 1661. Since then, it has received different migratory influxes associated with various economic cycles (e.g., sugar cane, cocoa, rubber, timber) (D'Antona et al. 2006), which transformed the municipality into the main commercial center of the Lower Amazon (Futemma & Brondízio 2003). Important migratory fluxes started around 1958, with road construction and government-led colonization and land reform initiatives that promoted the influx of low income immigrants from the arid northeastern Brazil, and from the southern part of the country (Castro et al. 2004, Nepstad et al. 2006), but a previous wave of migration from

northeastern Brazil had arrived around 1877, to work in the forests, tapping rubber (Fonseca 1996). Agriculture mechanization began at the end of the 1990s, with a new migratory wave of farmers from south and Midwest Brazil (Nepstad et al. 2006). The study region is therefore home to both recent and long-term in-migrants from various regions of Brazil.

The study region from where we drew our sample was approximately 1 million ha, bordered by the rivers Amazon, Tapajós and Curuá-Una, and with more than half of the area covered by primary or secondary forest, with larger tracks of continuous primary forest mostly further from urban centers (Fig. 1). The area encompasses the rural and peri-urban areas of the municipalities of Santarém, Belterra and Mojuí dos Campos, with a total population of 310,898 inhabitants, of which approximately 85,000 live in rural settings (IBGE 2010).

Sampling design

The sampling design was hierarchical, first selecting large areas (landscapes) within the study region that captured the variability in forest, and then selecting households within each landscape to interview household heads. In total, we sampled 20 7,850 ha landscapes (each a 5-km radius circumferences), distributed across a gradient of current forest cover (from 33 to 93%) (Fig. 1). The 20 sampled landscapes encompassed 70 communities of different sizes, varying from 10 to 400 households.

Within each of the 20 landscapes, we randomly selected 12 households. After mapping roads, rivers and households within each landscape in the field and with the help of GOOGLE EARTH images, we used ArcGis 9.3 to establish a set of points every 10 m in each stretch of roads and rivers that had at least one household. A stretch was

defined as the section between two vertices and, from them we randomly drew 12 points per landscape at least 400 m apart from each other (the maximum possible distance in all landscapes). Selected households were those nearest to these 12 points. When a certain household was nearest to more than one of these points, the second point was excluded and another one was randomly drawn. When a certain point was at equal distance to more than one household, we randomly selected one of these households. We skipped individual households if the household heads declined to take part in the study (n = 3), or if after three visits no resident was encountered (n = 4).

In total we selected 240 households, and interviewed both household heads (man and woman). When one of the household heads was absent, we revisited the household in one more occasion and conducted the interview with only one of the heads if the other was again absent. In 77 of the 240 households, we could not interview both household heads (in 29 we could not interview the woman and in 48 the man). In total, we interviewed 363 residents, 190 women and 173 men.

Perceptions of forest value and its determinants

We used an interview-based survey (structured questionnaire) with household heads, applied by PCT and a team of three trained assistants, who conducted the interviews between July and December 2013. Using the interview-based survey, we quantified: (i) people's perceptions of forest value using a Likert-type scale; (ii) independent variables, i.e. household bushmeat harvest and consumption and (iii) other control variables. Before data gathering the survey was pre-tested in the field for comprehensiveness and repetition.

Perceptions of forest value

We aimed at investigating two types of environmental values: instrumental and intrinsic (Bengston 1994). We equate instrumental values with the utility of nature in the sense that it serves a purpose, satisfies a preference, or meets a need, whereas intrinsic value is the inherent worth of something as an end in itself rather than the benefits one can receive from it, including aesthetic and moral components (Sagoff 1991). In this study, we focused on the aesthetic component of intrinsic values, because moral components are identifiable only in the context of action (Sagoff 1991).

For each of the two types of values, we constructed a Likert-type scale (hereafter Likert scale) composed of six statements (items) through which we evaluated the respondent's perception of the instrumental and intrinsic values of forest (Supporting Information 1). A statement is defined as a single sentence that expresses a point of view, a belief, a preference, a judgment, an emotional feeling or a position for or against something (Oppenheim 1992). Because an appropriate constructed scale should have an equal proportion of positive (favorable) and negative (unfavorable) statements (Oppenheim 1992), for each scale three statements were positive and three negative. The response to each statement was in a Likert-type response format, i.e. "strongly agree", "agree", "neutral/or could not answer", "disagree", and "strongly disagree". To each answer, we assigned points from 1 to 5: 5 representing the extreme of favorable perceptions towards forests, 3 assigned to "neutral/or could not answer" (undecided position), and 1 representing the extreme of unfavorable perceptions towards forests (Likert 1932). For each respondent and each type of value (instrumental or intrinsic), the Likert scale was then the sum of the points attributed to the responses to all the six

statements, therefore ranging from 6 to 30, with higher scores reflecting a more favorable perception of forest values.

Forest cover and bushmeat harvest and consumption

Forest cover was initially measured as the amount of forest cover (in km^2) at five different spatial scales around each household location of residence: 1-km radius buffer (3.1 km^2), 2-km (12.6 km^2), 3-km (28.3 km^2), 4-km (50.2 km^2) and 5-km (78.5 km^2). For each spatial scale, forest cover was quantified considering either: only non-degraded primary forest, total primary forest (degraded and non-degraded), or total forest (total primary plus secondary forest older than 10 years). The measure of forest cover that best explained the variation in the Likert scale for each type of forest value was then selected in a model selection approach, using Akaike's Information Criterion modified for small samples (AICc) (Supporting Information 2). Primary forest at 5-km radius buffer was selected for the instrumental value, and primary forest at 1-km radius buffer for the intrinsic value.

Bushmeat harvest was measured as the total hunting offtake (total kilograms of animals killed) in the household in the previous 30 days, while bushmeat consumption was total kilograms of bushmeat consumed in the household over the previous 15 days. There was no correlation between bushmeat harvest and any measure of forest cover (Person correlation coefficient varying from 0.01 to 0.12), nor between bushmeat consumption and any measure of forest cover (Person correlation coefficients varying from 0.06 to 0.1).

Gender, origin and forest dependence

To control for confounding factors that could also explain perceptions of forest values, three additional variables were considered: gender, whether the respondent was born in the community of residence or not (origin), and an estimate of household-level forest dependency, all of which had been associated with perceptions of the value of protected areas and conservation attitudes (Xu et al. 2006, Kijazi & Kant 2010, Sohdi et al. 2010, Tomicevic et al. 2010, Meijaard et al. 2013). Forest dependency was included to account for all other forest products that people could extract from forests besides bushmeat, and we estimated it following Coomes and colleagues (2004) as the proportion of the total household income in the last 30 days originating from the extraction of forest products.

A similar number of interviewed men and women were born in the community of residence (34 and 38 respectively). Mean values of bushmeat harvest, bushmeat consumption and forest dependency did not differ between genders and origins ($p \geq 0.4$), but mean values of forest cover (in each of the two scales) were lower for respondents born in the community of residence ($p < 0.01$). Forest dependency was only slightly correlated to bushmeat harvest ($r = 0.33$, $p < 0.01$) and it was not correlated with the other determinants ($r \leq 0.11$, $p \geq 0.05$).

Data analysis

Scale evaluation

We evaluated our Likert scales in terms of their unidimensionality and internal consistency (reliability). Unidimensionality indicates weather the scale encompasses only one concept or construct (Oppenheim 1992). Internal consistency is a measure of

item-total correlations and thus reliability of the scale, therefore describing the extent to which all items in a test measure the same concept or construct (Dunlap et al. 2000, Tavakol & Dennik 2011). To evaluate the unidimensionality of each of the two Likert scales (one for each value type), we conducted a principal component analysis (PCA). To test the internal consistency and thus reliability of each scale, we adopted the Cronbach's α (Cortina 1993, Carifio & Perla 2007). All these exploratory analyses were implemented in R 3.0.3 (R Core Team 2014), using the psych package (Revelle 2014).

From the PCAs, we found that in both cases the first component was more important in explaining the variation in the dataset (Table 1), whereas the eigenvalue of the second component was only slightly higher than 1, therefore unimportant from a variance perspective (Tabachnick & Fidell 2001). As expected when creating a proper scale (Fig. 2), the items were correlated and the Cronbach's α revealed an acceptable degree of fit among the 6-items of each scale ($\alpha = 0.64$ for the instrumental value of forests and $\alpha = 0.58$ for the intrinsic value of forests). Although the unidimensionality of the scales improved when one item from the instrumental value scale and two items from the intrinsic value scale were excluded, the Cronbach's α values did not change for the scales with fewer items (Supporting Information 3). We then decided to analyze the data for the 6-items scales, since a higher number of items increases the linearity of the scale (Carifio & Perla 2007) and because the number of dimensions are often sample specific and, for this reason, some researchers see unidimensionality as a rather unrealistic goal (Dunlap et al. 2000).

Determinants of the perceptions of forest values

We investigate the relationship between forest perceptions and its determinants (forest cover, bushmeat harvest and bushmeat consumption), controlling for gender, origin and

forest dependency using a model selection approach. We used generalized linear mixed-effects models (GLMM) to account for the hierarchical nature of the sampling design, with landscapes as random factors. We modeled the dependent variables as variables with normal distribution and used linear function (link identity), because Likert scales, created by summing up the values of several items, are not considered ordinal scales but rather produce interval data (Carifio & Perla 2007).

All fixed factors, besides gender and origin (which were categorical), were then standardized so that each had a mean of zero and a standard deviation of one, a procedure adopted that helps to improve convergence of the fitting algorithm (Zuur et al. 2009). We compared a set of candidate models for each type of value: an intercept-only model for reference (with no fixed factors), six simple models with each of the six independent variables on their own as fixed factors, and models with all possible combinations among the six independent variables as fixed factors, without accounting for interactions between them. Alternative models in each set were compared using the difference in their AICc values in relation to the first-ranked model (ΔAICc) (Burnham & Anderson 2002), adopting a value of $\Delta\text{AICc} \leq 2$ to indicate equally plausible models. All analyses were implemented in R 3.0.3 (R Core Team 2014) using the lme4 package (Bates et al. 2011).

Results

Among interviewees, 52% were women and 48% were men, and 20% were born in the community of residence. The perceptions of both forest values were more often favorable (i.e. high values on the Likert scale), indicating that most people see forests as

important (instrumental value - range 7 to 30, mean = 24.3, SD = 4.5; intrinsic value – range 10 to 30, mean = 22.7, SD = 4.7). Perceptions of forest values were more favorable among men, particularly for the intrinsic value of forests (Fig. 3).

Forest cover varied widely across the 240 households both in the smaller and larger spatial scales (1-km radius buffer - 0 to 2.78 km^2, mean = 0.73, SD = 0.73; 5-km radius buffer - 2.3 to 73.3 km^2, mean = 31.4, SD = 21.1). Bushmeat harvested within the last 30 days varied from 0 to 120 kg (mean = 4, SD = 13.6), with 26% respondents declaring harvest in their household. Bushmeat consumption within the last 15 days varied from 0 to 17 (mean= 0.9, SD = 2.1), with 33% of respondents declaring bushmeat consumption in their households. Forest dependency (the proportion of the total household income in the last 30 days originating from the extraction of forest products) varied from 0 to 99% of total income (mean = 6, SD = 13), with 61% of respondents declaring some extraction of forest products in their households.

Determinants of the perceptions of forest values

As expected, the instrumental value of forests was positively associated with bushmeat consumption, but only when controlling for both origin and gender (as the third-ranked selected model included gender, origin and bushmeat consumption, Table 2). On the other hand, neither bushmeat harvest nor forest cover were associated with perceptions of the instrumental value of forests (i.e. they were not included in the selected models). The instrumental value of forests was strongly associated with origin and gender, but gender was more important when controlling for origin. The model including origin and gender was the first-ranked among the three selected models, followed by the model including only origin, and all models that performed better than the reference model included the variable origin and/or gender (Table 2). Being born in

the community and being a male were positively associated with more favorable perceptions of the instrumental value of forests. The results of the model selection procedure did not change by altering the scale (i.e. 1, 2, 3, 4 or 5-km radius buffer) and the type of forest (i.e. non-degraded primary, total primary or total forest) considered when quantifying forest cover.

In turn, the intrinsic value of forests was strongly and positively associated with forest cover, as expected, when controlling for gender or gender and origin (both selected models included forest cover, Table 3). Neither bushmeat harvest nor bushmeat consumption were associated with perceptions of the intrinsic value of forests (i.e. they were not included in the selected models). Gender was also strongly associated with the intrinsic value of forests. As for the instrumental value, being a male was positively associated with more favorable perceptions of the intrinsic value of forests. Gender was included with forest cover in both selected models, and gender and/or forest cover were included in all 40 models that performed better (ΔAICc > 2) than the reference model (Table 3). Origin was only important if controlling for both forest cover and gender (second-ranked selected model), but its effect was not clear (i.e. the standard deviation of the coefficient included zero; Table 3). As for the instrumental value, the results of model selection did not change by altering the type of forest considered when quantifying forest cover. However, increasing the spatial scale for quantifying forest cover decreased the importance of forest cover relative to gender.

Discussion

We began this article by hypothesizing that lower bushmeat harvest and consumption, as well as higher deforestation by reducing the supply of this important resource, would erode people's perceptions of forest utility. Our results provide evidence that reduced bushmeat consumption is indeed associated with less favorable perceptions of the instrumental values of forests, whereas bushmeat harvest and forest cover did not significantly influence the perception of forest utility. However, the importance of bushmeat consumption was apparent only when controlling for both origin and gender; residents born in the community and men have a more favorable perception of the instrumental values of forests. We also hypothesized that deforestation should be associated with less favorable perceptions of the intrinsic value of forests, because deforestation should reduce people direct contact with forests. Our findings indicate that indeed living in less forested areas is associated with less favorable perceptions of the intrinsic value of forests, with gender again being an important determinant. In the following paragraphs, we discuss the three main findings of this study, namely the association between perceptions of forest instrumental value with bushmeat consumption, the association between perceptions of forest intrinsic value and forest cover, and the importance of gender and origin for perceptions of both instrumental and intrinsic value of forests. We end up by discussing the implications of these findings to conservation initiatives.

Bushmeat consumption seems more important in shaping people's perceptions of forest instrumental value than either bushmeat harvest or the amount of forest cover in the landscape. To our knowledge there is no previous study that investigated the association between bushmeat harvest and consumption at the household scale with

perceptions of forest value. Nevertheless, the occurrence of hunting at the village scale (i.e., whether or not hunting was a predominant activity in a village) has been found to be positively associated with perceived economic values of forests in Borneo (Meijaard et al. 2013). Likewise, the provision of wild animals for food increased the value attributed to forests by farmers living nearby forest reserves in Ghana given its importance for immediate subsistence and livelihoods (Ramcilovic-Suominen et al. 2013). These two studies, however, do not distinguish between bushmeat harvest and consumption. These two activities are not necessarily correlated because trading and sharing often provide important means of acquiring bushmeat (de Merode, et al.2004), making bushmeat consumption typically more widespread than hunting (Chapter 1). In our study, we show that bushmeat is indeed a valued resource, even for consumers that did not hunt frequently, and that consumption is a better predictor of perceptions of utilitarian forest value than hunting.

In contrast to our initial hypothesis, forest cover was not associated with the perceptions of forest instrumental value. The negative effects of deforestation on the abundance and persistence of preferred game species is widely accepted (Michalski & Peres 2007), and thus the availability and rates of harvest and consumption of these preferred species should decline with deforestation. However, studies on hunting effects on wildlife have shown that as preferred, large-bodied species are overexploited, hunters start targeting non-preferred, smaller species (Jerozolimski & Peres 2003). Indeed, in our sample bushmeat harvest and consumption was not correlated to forest cover. Thus deforestation may change which species are harvested but not the rates of bushmeat consumption. Rather bushmeat consumption in more deforested landscapes are probably sustained by species with high reproductive rates that persist in highly altered areas (e.g. paca and armadillos -Redford & Robinson 1987, Parry et al. 2009) or

by long-distance hunting to adjacent more forested landscapes (Chapter 1). The lack of association between forest cover and forest utilitarian value may thus result from the independence between forest cover and bushmeat consumption, when considering a quantitative measure of consumption.

For perceptions of forest intrinsic value, however, forest cover is an important determinant, as we hypothesized, regardless of bushmeat consumption or harvest, with people living in more forested areas reporting more favorable perceptions. We did not directly test whether those living in areas with more forest remnants had in fact more direct contact with the forest, for instance by frequently walking along forest trails or simply contemplating any forest element from outside the forest patch (a tree or animal). It is noteworthy, however, that the estimate of forest cover that best explained variations in the perception of the intrinsic value of forests was at the smallest spatial scale (i.e. within 1 km from the household). This indicates that the proximity to forest is relevant in this case. Indeed the loss of experience with natural environments, a consequence of urbanization, has been argued to be the main driver of people no longer valuing nature (Miller 2005). The gap between humans and nature cause mainly by urbanization has also been linked to the erosion of the intrinsic value attributed to nature by children (Zhang et al. 2014). However, to our knowledge, this study is the first to show that this erosion of the perception of the intrinsic value of nature can also occur in rural landscapes by a much subtler process when compared to urbanization, i.e. the decrease in forest cover in people's living surroundings.

Our findings also highlight that individual characteristics - origin and gender – are more important determinants of people's perception of forest utilitarian value than bushmeat consumption, and gender is as important as forest cover for perception of

forest intrinsic value. Origin, as an indicative of long residence in the community, may be linked to knowledge about the forest, as the acquisition of traditional ecological knowledge is linked to how long people lived in an area (Necheim et al. 2006). Thus people born in the locality of residence should display greater awareness of forest utility. More years of residence in the village has been linked to perceptions of higher economic importance of forests (Meijaard et al. 2013), although the reasons for this finding have not been discussed. The association between men and more favorable perceptions of forest utilitarian value has already been reported elsewhere for people leaving near protected areas or forests (Brown & Reed 2000, Paletto et al. 2013) as well as for the general public in developed countries (Tarrant & Cordell 2002). One study also reported the same relationship for forest intrinsic value (Paletto et al. 2013). They suggest that the more favorable perceptions of all forest values by men is due to the fact that men visit forests more frequently than women and spend more time engaged in traditional activities such as extraction of forest resources for food and fuel. Therefore they have more knowledge of the environment and stronger connection with the forest. Forest-related activities in our study region are also usually performed by men, which could explain why men reported more favorable perceptions of both forest utility and its intrinsic value.

Implications for conservation

By exploring the factors affecting the diversity of values people may attribute to forests, we show that most rural residents in a vast and heterogeneous post-frontier region in the Amazon had favorable perceptions of the intrinsic and utilitarian values of forests. Because pro-environmental behaviors and attitudes are linked to perceptions of environmental values (Stern et al. 1995, Schultz & Zelezny 1999, Schultz 2001), our results suggest there are opportunities for conserving the forest in private lands in

altered, human-modified Amazonian regions through initiatives involving rural communities. Despite the methodological challenges for measuring cultural ecosystem services (Plieninger et al. 2013), our findings add to the growing literature suggesting that cultural and aesthetic benefits provided by ecosystems, which are shaped by intimate human–nature interactions (Bhagwat 2009, Plieninger et al. 2013, Brancalion et al. 2014), are perceived as equally valuable as the provision of resources. Knowing why and how people value forests is strategic to conceive initiatives that can be accepted and hence fomented by local people, increasing the chance of success of such efforts.

Nevertheless, by comparing the perception of forest values across different landscape contexts, our study highlights the possibility of a dangerous reinforcing cycle: deforestation and the subsequent loss of direct contact with forests erode perceptions of forest intrinsic value, which may in turn facilitate further deforestation. Thus engaging people in forest conservation initiatives are probably more difficult but also more urgent in more altered landscapes. The utilitarian value linked to forest resources such as bushmeat, the consumption of which seems to be independent of forest cover, may then be the focus for engaging rural communities in forest conservation initiatives in more altered landscapes.

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Table 1. Results for the principal component analysis of the two Likert scales for the perception of the instrumental and intrinsic values of forest with six items each.

	Factor	Eigenvalue	Proportion explained	Cumulative proportion
Instrumental value	1	2.25	0.37	0.37
	2	1.12	0.19	0.56
	3	0.82	0.14	0.70
	4	0.71	0.12	0.82
	5	0.63	0.11	0.92
	6	0.47	0.08	1.00
Intrinsic value	1	1.97	0.33	0.33
	2	1.24	0.21	0.53
	3	0.87	0.14	0.68
	4	0.75	0.12	0.80
	5	0.65	0.11	0.91
	6	0.53	0.09	1.00

Table 2. Model selection results for the determinants of the perception of the instrumental value of forests among 363 rural residents in the study region. All candidate models are GLMM models with landscapes as a random factor. Only candidate models with weight ⩾ 0.02 are shown.

Model description	K	logLik	AICc	ΔAICc	ωi	Origin	Gender	Bushmeat Consumption	Forest Cover	Bushmeat Harvest	Forest Dependency
Origin+gender	**5**	**-1058.0**	**2126.2**	**0.0**	**0.18**	**1.26 (0.59)**	**0.79 (0.47)**	-	-	-	-
Origin	**4**	**-1059.6**	**2127.3**	**1.1**	**0.10**	**1.26 (0.59)**	-	-	-	-	-
Origin+gender+consumption	**6**	**-1058.0**	**2128.2**	**2.0**	**0.07**	**1.25 (0.59)**	**0.80 (0.47)**	**0.25 (0.23)**	-	-	-
Origin+gender+forest cover	6	-1058.1	2128.4	2.2	0.06	1.09 (0.62)	0.81 (0.47)	-	-0.22 (0.25)	-	-
Origin+gender+harvest	6	-1058.2	2128.7	2.5	0.05	1.26 (0.59)	0.19 (0.23)	-	-	0.80 (0.47)	-
Origin+gender+forest dependency	6	-1058.5	2129.2	3.0	0.04	1.25 (0.59)	0.79 (0.47)	-	-	-	0.09 (0.23)
Origin+consumption	5	-1059.6	2129.3	3.1	0.04	1.24 (0.59)	-	0.25 (0.24)	-	-	-
Gender	4	-1060.7	2129.5	3.3	0.03		0.79 (0.47)	-	-	-	-
Origin+forest cover	5	-1059.7	2129.6	3.4	0.03	1.10 (0.62)	-	-	-0.21 (0.25)	-	-
Origin+harvest	5	-1059.8	2129.8	3.6	0.03	1.26 (0.59)	-	-	-	0.18(0.24)	-
Origin+gender+consumption+forest cover	7	-1057.9	2130.1	3.9	0.02	1.05 (0.62)	0.82 (0.47)	0.28 (0.24)	-0.25 (0.25)	-	-
Origin+forest dependency	5	-1060.0	2130.3	4.1	0.02	1.25 (0.59)	-	-	-	-	0.09 (0.24)
Gender+forest cover	5	-1060.1	2130.4	4.2	0.02	-	0.81 (0.47)	-	-0.35 (0.24)	-	-
Reference	3	-1062.2	2130.5	4.3	0.02	-	-	-	-	-	-
Origin+gender+forestcover+harvest	7	-1058.2	2130.7	4.5	0.02	1.07 (0.62)	0.82 (0.47)	-	-0.25 (0.25)	0.22 (0.24)	-
Origin+gender+consumption+harvest	7	-1058.3	2130.8	4.6	0.02	1.25 (0.59)	0.80 (0.47)	0.23 (0.24)	-	0.16 (0.24)	-

Selected models (ΔAICc<2) in bold; K: number of parameters; logLik: log-Likelihood of the model; AICc: AICc value; ΔAICc: difference in AICc value compared to the first-ranked model; ωi: Akaike weight; coefficients for each variable of the model.

Table 3. Model selection results for the determinants of the perception of the intrinsic value of forests among 363 rural residents in the study region. All candidate models are GLMM models with landscapes as a random factor. Only candidate models with weight ⩾ 0.02 are shown.

Model description	K	logLik	AICc	ΔAICc	ωi	Forest Cover	Gender	Origin	Bushmeat Harvest	Bushmeat Consumption	Forest Dependency
Forest cover+gender	**5**	**-1044.1**	**2098.4**	**0.0**	**0.29**	**0.72 (0.35)**	**3.35 (0.45)**	-	-	-	-
Forest cover+gender+origin	**6**	**-1043.4**	**2099.1**	**0.7**	**0.21**	**0.76 (0.27)**	**3.35 (0.45)**	**0.47 (0.59)**	-	-	-
Forest cover+gender+harvest	6	-1044.6	2101.5	3.1	0.06	0.72 (0.27)	3.36 (0.45)	-	0.08 (0.23)	-	-
Forest cover+gender+consumption	6	-1044.6	2101.5	3.1	0.06	0.73 (0.27)	3.35 (0.45)	-	-	-0.06 (0.23)	-
Forest cover+gender+forest dependency	6	-1044.7	2101.6	3.2	0.06	0.72 (0.27)	3.35 (0.45)	-	-	-	0.04 (0.23)
Forest cover+gender+origin+harvest	7	-1043.9	2102.1	3.7	0.04	0.76 (0.27)	3.36 (0.45)	0.47 (0.59)	0.08 (0.23)	-	-
Forest cover+gender+origin+ consumption	7	-1043.9	2102.2	3.7	0.04	0.76 (0.27)	3.35 (0.45)	0.48 (0.59)	-	-0.06(0.23)	-
Forest cover+gender+origin+forest dependency	7	-1044.0	2102.2	3.8	0.04	0.76 (0.27)	3.35 (0.45)	0.46 (0.59)	-	-	0.03 (0.23)
Gender	4	-1047.2	2102.5	4.1	0.04	-	3.41 (0.45)	-	-	-	-
Gender+origin	5	-1046.7	2103.5	5.1	0.02	-	3.42 (0.45)	0.27 (0.60)	-	-	-

Selected models (ΔAICc<2) in bold; K: number of parameters; logLik: log-Likelihood of the model; AICc: AICc value; ΔAICc: difference in AICc value compared to the first-ranked model; ωi: Akaike weight; coefficients for each variable of the model.

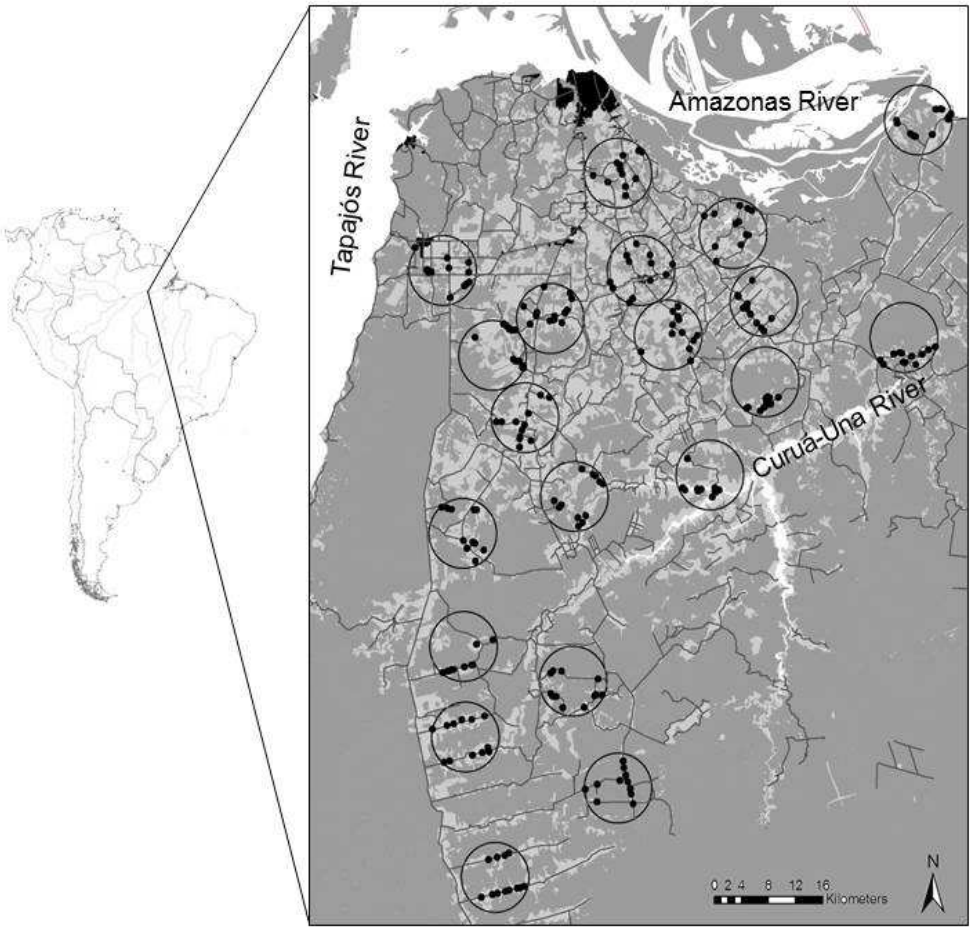

Figure 1. Land cover map of the study region. Location of the study region in South America and land-cover map of the study region, indicating the location of the 20 study landscapes (circumferences) and the 240 sampled households (black dots). Urban areas in dark grey, forests in grey, converted land in light grey, and water bodies in white.

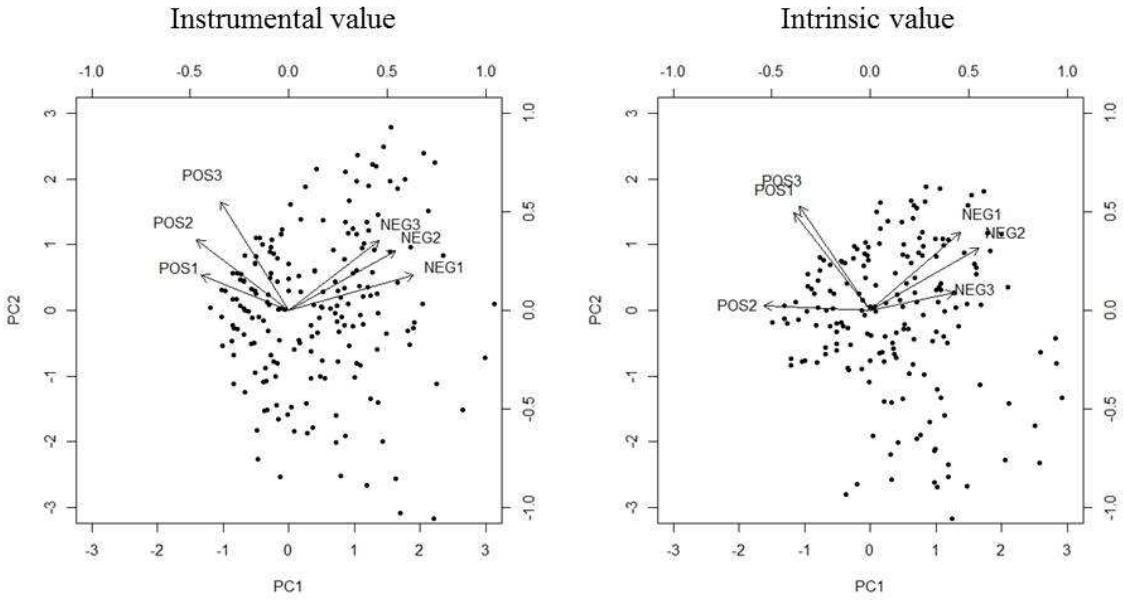

Figure 2. PCA biplots showing the variation in the values of the Likert scales for the perception of instrumental and intrinsic values of forests among 363 rural residents in the study region. Residents are shown as dots and the six items (three positive – POS and three negative – NEG) as vectors.

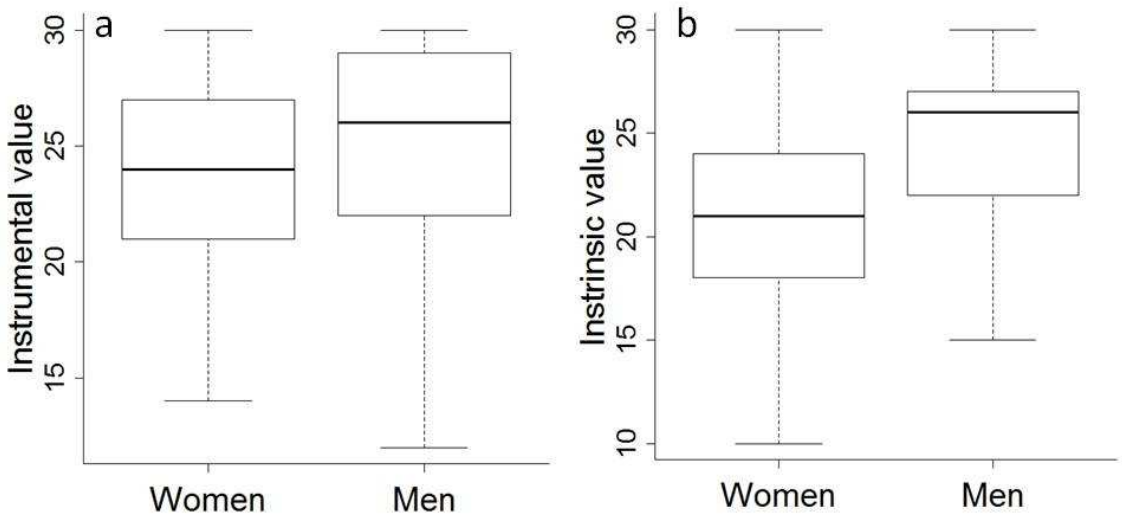

Figure 3. Variation in the perception of forest values between men and women among residents in the study region. Perceptions of (a) the instrumental and (b) the intrinsic value of forest showing Likert scale values. Boxplot showing the data median (horizontal line), 1st quartile (lower whisker), 2nd quartile (lower box), 3rd quartile (upper box) and 4th quartile (upper whisker).

Supporting Information 1

Positive and negative statements regarding the instrumental and the intrinsic values of forests in the order they were presented to the respondents.

Statements	Value	Type
1. Se a mata da região diminuísse, as pessoas teriam menos opções de ganhar dinheiro.	Instrumental	Positive
2. Gostaria que meus filhos e netos vivessem em um lugar com mata perto.	Intrinsic	Positive
3. Seria bom se tivesse menos mata na região porque a região seria mais rica.	Instrumental	Negative
4. Tenho medo que os bichos da mata cheguem perto da minha casa.	Intrinsic	Negative
5. As matas são importantes porque fornecem vários alimentos e outros produtos que a gente usa.	Instrumental	Positive
6. Manter mata na propriedade é bom pra roça.	Instrumental	Positive
7. Prefiro morar em lugar sem mata, porque os animais podem estragar a roça e provocar acidentes.	Instrumental	Negative
8. Gosto de caminhar no meio da mata.	Intrinsic	Positive
9. Seria bom derrubar mais mata, porque teria mais lugar para plantar.	Instrumental	Negative
10. Gostaria que continuasse a ter mata em pé porque gosto dos bichos que ela abriga.	Intrinsic	Positive
11. Tenho receio de entrar na mata.	Intrinsic	Negative
12. Prefiro que em volta da minha casa tenha bastante área limpa, sem mata.	Intrinsic	Negative

Supporting Information 2

We selected the measure of forest cover that best explained the variation in the Likert scale for each type of forest value in a model selection using Akaike's Information Criterion modified for small samples (AICc). For each dependent variable (Likert scale of instrumental and intrinsic value of forests), we compared a candidate set of simple models each containing a different measure of forest cover, and selected the measure contained in the first-ranked model (Table S1). To account for the hierarchical nature of the sampling design, we used generalized linear mixed-effects models (GLMM). We modeled the dependent variables as a variable with normal distribution and used a linear function (link identity), since Likert scale, which should be constructed summing the values of several items, are not considered ordinal scales, but rather produce interval data (Carifio & Perla 2007). We modeled the different measures of forest cover as fixed factors, and landscapes as a random factor. Fixed factors were standardized so that each had a mean of zero and a standard deviation of one, a procedure adopted to help improving convergence of the fitting algorithm (Zuur et al. 2009). Primary forest at 5-km radius buffer was selected for the perception of the instrumental value of forests, and primary forest at 1-km radius buffer for the perception of the intrinsic value of forests.

Table S1. Model selection results for choosing the best measures of forest cover for the perception of instrumental and intrinsic value of forests among 363 rural residents in the study region. All candidate models are GLMM models with landscapes as a random factor.

	Model	logLik	AICc	wAICc
Instrumental value	Non-degraded primary forest at 5-km	-1061.7	2131.6	0.088
	Degraded and non-degraded primary forest at 5-km	-1061.7	2131.6	0.087
	All forest types at 5-km	-1061.8	2131.7	0.084
	Non-degraded primary forest at 4-km	-1061.9	2131.8	0.078
	Degraded and non-degraded primary forest at 4-km	-1061.9	2131.8	0.078
	Degraded and non-degraded primary forest at 3-km	-1062.0	2132.0	0.071
	Non-degraded primary forest at 3-km	-1062.0	2132.0	0.070
	Non-degraded primary forest at 2-km	-1062.0	2132.1	0.069
	All forest types at 4-km	-1062.0	2132.1	0.068
	Degraded and non-degraded primary forest at 2-km	-1062.0	2132.1	0.068
	All forest types at 3-km	-1062.2	2132.5	0.056
	Degraded and non-degraded primary forest at 1-km	-1062.3	2132.8	0.048
	Non-degraded primary forest at 1-km	-1062.3	2132.8	0.048
	All forest types at 2-km	-1062.4	2132.9	0.045
	All forest types at 1-km	-1062.5	2133.1	0.042
Intrinsic value	Non-degraded primary forest at 1-km	-1070.0	2148.2	0.242
	All forest types at 1-km	-1070.1	2148.4	0.224
	Degraded and non-degraded primary forest at 1-km	-1070.6	2149.3	0.143
	All forest types at 2-km	-1071.2	2150.6	0.075
	All forest types at 3-km	-1071.9	2151.9	0.038
	All forest types at 4-km	-1072.0	2152.1	0.035
	Degraded and non-degraded primary forest at 2-km	-1072.0	2152.2	0.033
	All forest types at 5-km	-1072.1	2152.3	0.031
	Non-degraded primary forest at 2-km	-1072.2	2152.5	0.029
	Non-degraded primary forest at 4-km	-1072.3	2152.7	0.026
	Degraded and non-degraded primary forest at 4-km	-1072.3	2152.7	0.026
	Non-degraded primary forest at 5-km	-1072.3	2152.7	0.025
	Degraded and non-degraded primary forest at 5-km	-1072.3	2152.7	0.025
	Non-degraded primary forest at 3-km	-1072.3	2152.8	0.025
	Degraded and non-degraded primary forest at 3-km	-1072.4	2152.9	0.023

Supporting Information 3

Table S2. Results for the principal component analysis of the two Likert scales for the perception of the instrumental value (with five items) and intrinsic value (with four items).

	Factor	Eigenvalue	Proportion explained	Cumulative proportion
Instrumental value	1	2.14	0.43	0.43
	2	0.93	0.19	0.61
	3	0.79	0.16	0.77
	4	0.68	0.14	0.91
	5	0.47	0.09	1.00
Intrinsic value	1	1.80	0.45	0.45
	2	0.86	0.21	0.66
	3	0.81	0.2	0.87
	4	0.53	0.13	1.00

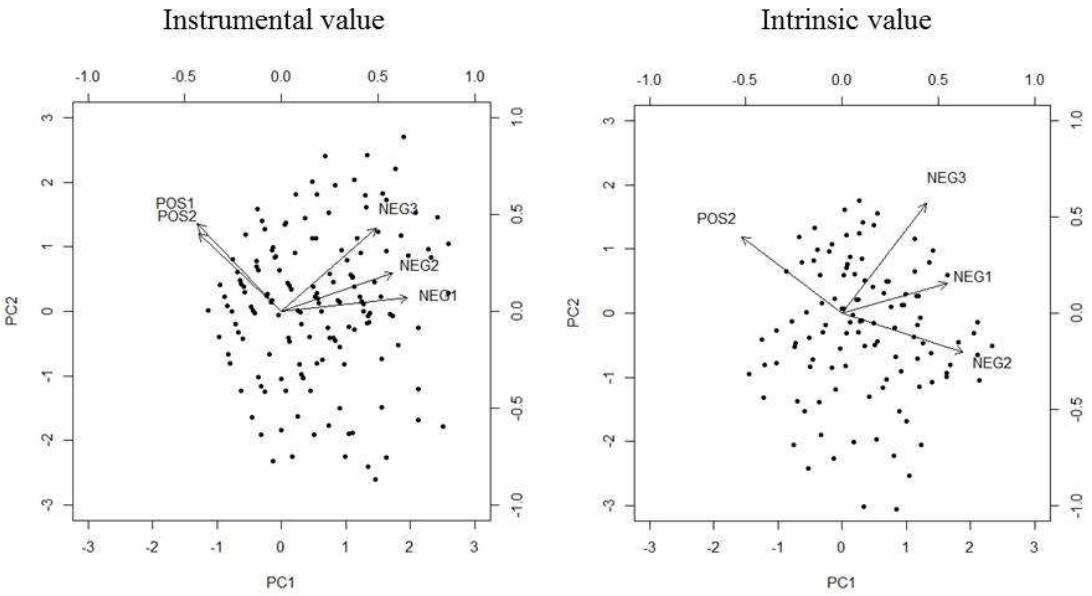

Figure S1. PCA biplots showing the variation in the values of the Likert scales for the perception of instrumental value (with five items) and intrinsic value (with four items) of forests among 363 rural residents in the study region. Residents as dots and the items (positive – POS and negative – NEG) as vectors.

Considerações finais

Esta tese contribui para preencher a lacuna de conhecimento sobre os determinantes da caça e consumo de carne silvestre, trazendo evidências de que fatores ambientais, culturais e econômicos, em conjunto, são necessários para entender os padrões de variação nessas atividades em regiões heterogenias, como as de fronteira agrícola recentemente consolidada. Traz evidências também de que o consumo de carne silvestre é um serviço importante provido pela floresta aos moradores da zona rural, em especial, mas não apenas, àqueles que vivem em áreas mais remotas e florestadas, e está positivamente relacionado à percepção das pessoas em relação ao valor da floresta.

No primeiro capítulo, os resultados indicam que fatores ambientais em maior escala são determinantes importantes da caça. Porém, menos importantes para determinar o consumo, que parece ser mais frequente que a caça, indicando a importância do compartilhamento e/ou comércio na obtenção de carne silvestre. O consumo de carne silvestre foi um pouco mais frequente em áreas remotas e mais florestadas. A caça, por sua vez, foi bem mais frequente em áreas florestadas, mas também em áreas mais próximas a centros urbanos, quando controlada a variação na cobertura florestal. Caçadores próximos a centros urbanos podem estar se beneficiando da extensa malha viária, característica de regiões de fronteira consolidada, para se deslocar e caçar em áreas mais afastadas, onde o retorno da caça é provavelmente maior (Fa et al. 2009, Brashares et al. 2011, Foerster et al. 2012), possivelmente contribuindo para diminuir a população de animais caçados em áreas mais remotas. Assim, os resultados sugerem que é improvável que a pressão de caça, mesmo em áreas mais

remotas, diminua com a migração para áreas urbanas (Parry et al. 2010, Wilkie et al. 2011), processo que vem se acentuando na Amazônia.

O segundo capítulo - primeiro estudo a avaliar diversos tipos de fatores em conjunto - traz evidências de que a caça depende não só do contexto ambiental, mas também do cultural, e ambos definem os efeitos de fatores econômicos. Para o consumo de carne silvestre, fatores econômicos e culturais parecem mais importantes que os fatores ambientais e podem sozinhos explicar a variação no uso deste recurso. Ainda assim é possível que o efeito dos fatores econômicos dependa do contexto ambiental também para o consumo de carne silvestre. De maneira geral, a caça e o consumo de carne silvestre aumentaram com a renda monetária em áreas próximas a centros urbanos e/ou menos florestadas, mas diminuíram com a renda monetária em áreas remotas e/ou florestadas. Assim, os resultados indicam que a carne silvestre é considerada um tipo de bem diferente a depender do contexto geográfico e ecológico, sendo um bem normal (ou seja, cuja demanda aumenta com o aumento do poder aquisitivo do consumidor) em áreas rurais alteradas próximas a centros urbanos e um bem inferior (ou seja, cuja demanda diminui com o aumento do poder aquisitivo do consumidor) em áreas remotas e florestadas. Além disso, os resultados ressaltam a enorme importância de dois fatores raramente considerados em estudos anteriores – a dependência de atividades de subsistência e a origem dos moradores. A caça e o consumo de carne silvestre foram mais frequentes nas famílias de origem na região Amazônica e entre os que dependem mais de atividades de subsistência para seu sustento.

Assim, estratégias que visem aumentar a renda dos habitantes da zona rural podem ter um efeito não desejado na fauna dos animais mais comumente caçados – aves e mamíferos de maior porte. Muitas vezes essas estratégias são fundamentais para

reduzir a pobreza em regiões rurais, mas também têm sido sugeridas como forma de diminuir a pressão de caça em áreas rurais na África (Milner-Gulland et al. 2003) e, de uma forma geral, o risco de extinção de espécies (McPherson & Nieswiadomy 2005). Os resultados deste trabalho sugerem que o sucesso de intervenções econômicas que visem tanto à redução da pobreza quanto à conservação da biodiversidade depende do contexto ecológico e geográfico. O aumento da renda pode ser muito importante em áreas mais florestadas e remotas, diminuindo a pressão de caça. Porém, em áreas mais desmatadas e próximas a centros urbanos esse efeito pode ser contrário e, portanto, devem vir acompanhados de maior controle da caça, em especial daquela voltada para o comércio. Interessantemente, nas comunidades mais dependentes de atividades de subsistência, aumentar a renda monetária pode diminuir a atividade de caça em qualquer contexto ambiental. Por fim, os resultados sugerem que é provável que a caça exercida por moradores originários da Amazônia se mantenha mesmo com o aumento de renda ou de fontes alternativas de proteína. Para esses moradores, embora a caça possa ser sustentável em áreas mais florestadas, controle da caça e educação ambiental são necessários em áreas mais desmatadas.

Os resultados do terceiro capítulo desta tese indicam que a quantidade de carne silvestre consumida influencia positivamente a percepção do valor utilitário da floresta. Já a percepção do valor intrínseco da floresta está relacionada à quantidade de florestas remanescentes no entorno imediato da residência dos moradores, sugerindo que o contato com a floresta é importante nesse caso (Miller 2005, Zhang et al. 2014). Apesar disso, há evidências de que fatores individuais são mais importantes que o consumo de carne silvestre para a percepção do valor utilitário da floresta e tão importantes quando a cobertura florestal no entorno para a percepção de seu valor intrínseco. Homens tendem a valorizar mais a floresta sob ambos os aspectos, enquanto moradores que nasceram na

comunidade onde vivem tendem a valorizar mais a floresta por seu valor utilitário. De fato, homens têm maior contato com a mata, são eles que no geral desenvolvem as atividades de extração de produtos florestais, em especial a caça e, assim como moradores que nasceram na comunidade, tem maior conhecimento sobre os seus recursos (Brown & Reed 2000, Necheim et al. 2006, Paletto et al. 2013).

Estes resultados sugerem que, para além de estratégias que visem o bem-estar humano via incentivos econômicos, há ampla oportunidade para iniciativas que considerem outros aspectos do bem-estar associados aos serviços providos pela floresta - sejam eles recursos como a carne de caça ou benefícios culturais e estéticos - uma vez que em geral a percepção do valor das florestas foi bastante favorável. O estudo também indica que um processo mais sutil que a urbanização – a perda de habitat em áreas rurais – também pode levar a erosão do valor intrínseco da natureza. Nesse sentido, aponta para a urgência em se implantar iniciativas de conservação que incluam as pessoas e seus valores nas áreas mais alteradas, uma vez que é provável que haja um perigoso ciclo de desvalorização da floresta, em que o desmatamento leva a diminuição da percepção do valor das florestas, que, por sua vez, pode agravar o desmatamento. Nessas áreas, o valor utilitário atribuído às florestas pela provisão de carne silvestre pode ser importante, já que essa valorização não parece depender da cobertura florestal.

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