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Flood pulse dynamics affects exploitation of both aquatic and terrestrial prey by Amazonian floodplain settlements

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ABSTRACT

Rural populations in the tropics frequently rely on game vertebrates and fish to supply their daily protein requirements. However, few studies have quantified the environmental and socioeconomic drivers of hunting and fishing effort and the potential compensatory relationship between these extractive activities. Here, we assessed game and fish extraction by 222 semi-subsistence households from 28 villages along a major white-water tributary of Brazilian Amazonia. During the 44 months study, a total of 32,114 kg of game and 261,752 kg of fish were harvested, amounting to an average extraction rate of 30.5 ± 109.9 g person^{-1} day^{-1} and 1519.4 ± 1037.6 g person^{-1} day^{-1} for game and fish, respectively. While 97.93 ± 0.03% of all fishing trips resulted in fish catches, only 77.12 ± 27.02% of the hunting forays successfully obtained at least one forest vertebrate. The flood pulse had a strong effect on both fishing and hunting activities. However, the seasonally rising floodwaters had a negative effect on fish yield and catch per unit effort (CPUE), but had a positive effect on game yields. Game yield was also an important variable explaining fish yield, indicating a strong compensatory interaction between these two forms of protein acquisition. Our results highlight the importance of considering different modes of animal protein harvesting in conservation planning and management of both forest vertebrates and aquatic organisms.

1. Introduction

Terrestrial game vertebrates and fish are central to the nutritional livelihoods of a large number of rural people, particularly in remote tropical forest regions where access to farmed plant protein and livestock are limited (Fa et al., 2002; Siren and Machoa, 2008; Golden et al., 2011). The heavy reliance of rural semi-subsistence communities in the tropics on wild animal protein and fat makes the sustainability of fishing and hunting activities a cause of great concern for conservation, food security and social welfare agencies (Ceballos and Ehrlich, 2010; Brashares et al., 2014; Dirzo et al., 2014).

In Amazonia, the dietary importance of vertebrate populations to human populations is exacerbated by the poor protein content of food crops typically cultivated in this region (e.g. manioc and plantain; Vasey, 1979; Roosevelt, 1980), fueling the annual consumption of a minimum of 89.2 t of wild meat by local communities in Brazilian Amazonia alone (Peres, 2000). Despite recent efforts by governmental and non-governmental agencies to minimize impacts of human activities on natural areas (Nepstad et al., 2014; Tollefson, 2015), policies and management guidelines for wildlife extraction are still at their infancy in the Amazon and further studies are needed in order to design evidence-based conservation strategies. Moreover, the relentless human population growth and conversion or degradation of natural forest habitats currently seen in tropical forest regions (Davidson et al., 2012; Castello et al., 2013) are likely to compromise current levels of fish and game consumption, as well as the long-term persistence of overexploited vertebrate populations.

Lowland Amazonia is comprised of a vast mosaic of ecosystems spanning an area of 4.2 million km^2 (≤300 m asl) across nine countries. In addition to myriad minor habitat types, lowland Amazonia primarily consists of two broad forest types representing distinct floristic and faunal communities (e.g. Peres, 1997; Haugaasen and Peres, 2005a, 2005b, 2006; Bobrowiec et al., 2014): unflooded forests (hereafter, terra firme) above the maximum flood level of Amazonian rivers, and forests subject to seasonal flooding. Seasonally flooded forests along major rivers may experience an inundation period of up to six months each year, as river water level fluctuations may reach 15 m in amplitude (Goulding et al., 2003). This dramatic flood pulse clearly affects the distribution and seasonal dynamics of both terrestrial and aquatic organisms (Bodmer, 1990; Fernandes, 2006; Haugaasen and Peres, 2007; Beja et al., 2010).

Seasonal changes in landscape structure may provide challenges to local human populations in terms of access to different food resources.

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For example, the prolonged annual flood pulse results in the spatial dispersion of fish across vast floodplains that may extend tens of kilometers from the main river channel (Goulding et al., 2003).

Consequently, semi-subsistence Amazonians settled along major rivers must alter their foraging strategies in response to such climatic and hydrological events, or shift their exploitation activities to alternative targets. A decline in fish density, therefore, is expected to lead human foragers to focus on terrestrial game populations more intensively as fishing yields per unit of foraging effort decline substantially. This is consistent with a study in West Africa, where noticeable shifts in offtake and consumption from fish to bushmeat coincide with periodic shortages of marine and freshwater fish stocks (Brashares et al., 2004). However, this pattern of seasonal alternation between terrestrial and aquatic sources of animal protein is yet to be comprehensively assessed in a tropical forest setting. Several studies have described the patterns of fishing and hunting activities conducted by rural Amazonians (e.g. Nietschmann, 1972; Behrens, 1981; Kaplan and Kopischke, 1992; Endo et al., 2010), but do not consider the drivers of vertebrate prey consumption or the potential inter-relation between these two important subsistence activities. This is a crucial wildlife conservation and food security issue, because animal protein intake by local communities is inherently compensatory on a per capita basis across prey species within the same or different environments. In other words, eventual depletion of a given protein source is likely to lead human populations to rely on alternative sources of protein so that an emphasis on fishery exploitation in freshwater settings can alleviate local demand on equivalent protein offtake from terrestrial vertebrate populations hunted in forest environments and vice versa.

Here we examine natural resource use by human populations in the lowland Amazon by providing a large-scale assessment of patterns of fish and game harvest activities in the Juruá river basin, Brazil. Specifically, we investigate the environmental and settlement trait covariates that may affect such activities, and the potential inter-relation between fishing and hunting activities in this region. Finally, we discuss the implications of these findings for the long-term sustainability of wildlife resource extraction in a pan-Amazonian context.

2. Material and methods

2.1. Study area

The study was conducted along a ~400-km section of the middle third of the Juruá River, in the western Brazilian Amazon (Fig. 1). This area includes two major sustainable-use protected areas: the federally managed 253,227 ha Médio Juruá Extractive Reserve, and the state managed 632,949 ha Uacarí Sustainable Development Reserve. These reserves combined are home to ~4000 semi-subsistence people who exploit natural resources, including fish and other aquatic prey (e.g. freshwater turtles), forest game vertebrates and non-timber forest products. A large proportion of their carbohydrate staple diet is based on manioc, which is cultivated by virtually every resident family (Newton et al., 2011). Additionally, the area encompasses the urban center of Carauari. This town is located 60 km from the border of the Uacarí Sustainable Development Reserve, and is inhabited by ~19,700 people (IBGE, 2011). Our study area encompassed a fluvial distance from Carauari of 392 km, thereby setting a strong human population density gradient.

The region has a wet tropical climate (mean temperature ≈ 27.1 °C) and a well-defined rainfall regime, with the rainiest period from December to May. Mean annual rainfall is 3679 mm (2008–2010; Bauana Field Station; S 5°26′19″, W 67°17′12″). Terra firme and seasonally flooded várzea forest are the two main forest types in the region, with terra firme forest comprising 76%, várzea forest 22%, and open wetlands <1% of the total study area. Várzea forest is a type of floodplain forest that occurs along white-water rivers of Andean or pre-Andean origin, and are exceptionally productive due to the annual deposition of nutrient-rich sediments brought by the floodwaters (Junk, 1984). Várzea forests in the study region are subjected to a maximum annual flood pulse of around 12 m in amplitude (Fig. S1), although the inundation period varies with topography. Mean monthly values of river discharge range from 135 to 1407 m^3/s (1973–2010; Porto do Gavião; Petrobrás S.A.) and January–May is the period with highest water discharge.

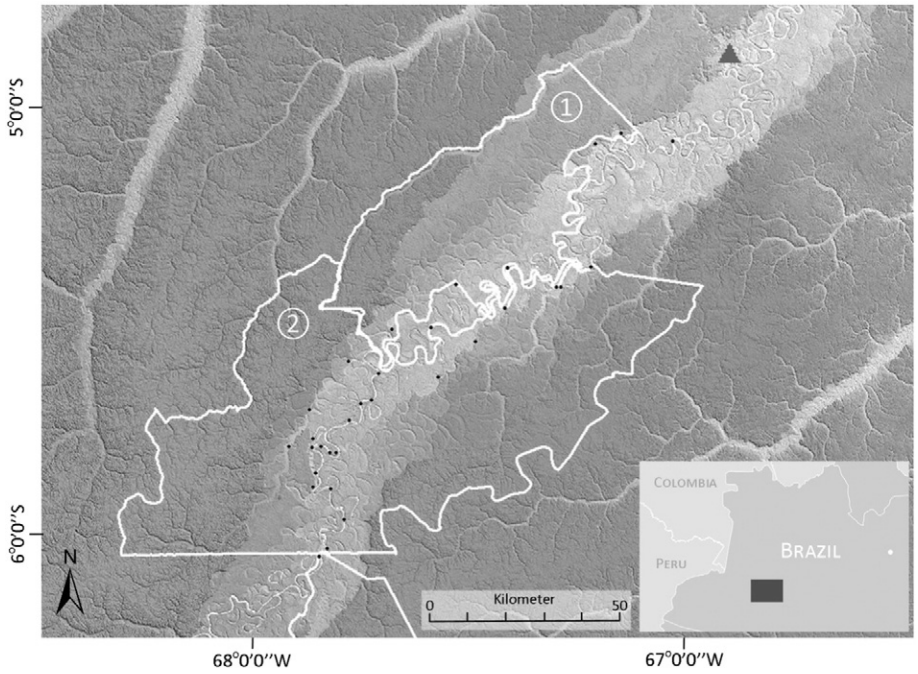

Fig. 1. Map of the study area showing the two contiguous forest reserves, (1) Médio-Juruá Extractive Reserve, (2) Uacarí Sustainable Development Reserve, all surveyed villages (black dots), and the urban center of the municipal county of Carauari (solid triangle). Várzea and terra firme forests are shown by light and dark grey areas, respectively.