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Indigenous collaborative research for wildlife management in Amazonia: The case of the Kaxinawá, Acre, Brazil

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ABSTRACT

Wildlife is a critical food resource throughout Amazonia. Consequently, adaptive management based on continued resource evaluation is essential to ensure long-term sustainable use of Amazonian wildlife. Since 1996, the Kaxinawá people of Western Amazonia have participated in a capacity-building program focused on natural resource management leading to the development of a territorial management plan that includes monitoring of wildlife use. In this study, we report the results of collaborative management-oriented research where hypotheses designed by the Kaxinawá about game availability within their territory were supported by the analysis of self-monitoring hunting data collected through a methodology designed in collaboration with conservation biologists. Results support Kaxinawá hypotheses that: (1) there is variation of game availability among villages in Kaxinawá territory; (2) preferred game species are more available to those villages closest to the isolated headwaters; and (3) previous land and wildlife use, present density of villages, and human population density are the main factors causing observed variations of game availability. The results of this study suggest the relevance and value of long-term participatory studies to complement short-terms academic studies of biodiversity and natural resource use and management.

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1. Introduction

“The native may be aware that he cannot depend on the hunting of certain species as the mainstay of his meat supply since he has available to him many of the data that serve as the scientist’s basis for reaching the same conclusion.”

K. M. Kensinger, *How real people ought to live*

A conservative estimate indicates that 2.2 million forest-dwellers consume game meat in Amazonia (Peres, 2000). Wildlife still represents the main protein source for many indigenous and rural populations (Peres and Zimmerman, 2001; Jerzolimski and Peres, 2003; Franzen, 2006). However, even small-scale subsistence hunting has the capacity to locally deplete wildlife if hunting is unsustainable (Redford, 1992; FitzGibbon et al., 1995; Peres, 2000, 2001). In a broader

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sense, unsustainable hunting is a serious socio-ecological problem since it reduces animal populations, in some cases leading to extirpations and extinctions, while at the same time diminishing the food availability and/or financial income of forest-dwellers (Bennett and Robinson, 2000; Bodmer and Lozano, 2001; Milner-Gulland and Bennett, 2003; Bennett, 2005). Consequently, hunting pressure influences the variation of wildlife populations in inhabited areas of Amazonia and may lead to subsequent changes in the socio-ecological systems of human populations that rely on game meat (Ross, 1978; Hames and Vickers, 1982; Peres, 2000; Jerzolimski and Peres, 2003). Communities hunting in large protected forests may benefit from a wildlife source–sink dynamic where the dispersal from source populations supplies hunting needs of human population at the sink area (Novaro et al., 2000), reducing the risk of socio-ecological impacts caused by game species depletion.

Amazonian hunters preferentially target large-bodied ungulates and primates, which are the most sensitive species to harvesting (Redford and Robinson, 1987; Bodmer et al., 1997; Peres, 2000) and play key roles in forest ecosystems (Wright et al., 2000; Stoner et al., 2007 and references therein). The diet breadth model predicts that in depleted sites a constant reduction in the availability of preferred species leads to the inclusion of other small bodied, non-preferred species in a hunter's prey assemblage, relaxing food taboos in traditional societies (Hames and Vickers, 1982; Kensing, 1995; Jerzolimski and Peres, 2003; Milner-Gulland and Bennett, 2003). The period of exploitation, human population density, purpose of harvest, and hunting technology influence historical, geographical, economical and social processes that shape hunting pressure and drive consequent wildlife depletion (Novaro et al., 2000; Peres, 2000; Robinson and Bennett, 2000; Bodmer and Lozano, 2001; Jerzolimski and Peres, 2003).

The concern for natural resource depletion by local people has led to greater local community participation in decision-making and management of natural resources (Redford and Stearman, 1993; Brown, 2003; Robinson, 2006). However, the effectiveness of this strategy relies on the community's appropriation of conservation goals through community collaboration, and integration of local and scientific knowledge during management design and execution (Brown, 2003; Noss et al., 2004; Lawrence et al., 2006). Under this strategy, wildlife monitoring programs should work with simple indicators that are easy for community members to analyze and interpret, as well as being compatible with more robust analyses made by scientists (Bodmer and Puertas, 2000; duToit et al., 2004; Moller et al., 2004; Stuart-Hill et al., 2005).

Since 1996, the Kaxinawá people of Western Amazonia have participated in a long-term capacity-building program to train indigenous agroforestry agents (IAA) on natural resource management. The program was developed by the NGO Comissão Pró-Índio do Acre (hereafter CPI-AC) following requests from indigenous leaders for help in natural resource management within their territory. In 2005, led by NGO-trained IAAs, the Kaxinawá people finalized a territorial management plan based on the discussion undertaken during the nine years of the capacity-building program. The creation and implementation of the plan are the subjects of upcoming collaborative publications (Gavazzi, 2008). Reflecting the promi-

nence of wildlife among natural resource management issues, the plan included the self-monitoring of wildlife use within Kaxinawá's territory. Presently, wildlife is hunted mostly for community subsistence, and its present use and conservation are important concerns to the Kaxinawá, being recurrent subjects discussed daily and in formal meetings.

In this study, we report the results of collaborative management-oriented research where the Kaxinawá participated in the research design of wildlife monitoring and developed hypotheses about game availability and hunting practices within their territory. The methodology was designed to identify and validate reliable, simple indicators (number of preferred species and mean body mass), to be used in future analyses within the indigenous villages, and by doing so improve the monitoring system's application and use.

We also describe wildlife hunting and game availability among villages within the Kaxinawá territory, and identify processes influencing this variation by addressing the hypotheses proposed by the Kaxinawá: (1) There is variation of game availability among villages; (2) Preferred game species are more available to those villages located in the headwaters; (3) Previous land and wildlife use, present density of villages, and human population density are the main factors causing observed variations of game availability. We focus part of our analysis on the comparison between our participatory findings and the results and conclusions from a conventional biodiversity assessment done 12 years earlier. We conclude by evaluating the effect of game availability on the socio-cultural hunting practices of the Kaxinawá.

2. Methods

2.1. Study area

The Kaxinawá people live in indigenous lands in Brazilian and Peruvian Amazonia. In Brazil, the Kaxinawá people of Jordão live within three adjacent indigenous lands comprising a 1075 km² territory in the alluvial forests of the Tarauacá and Jordão river headwaters, located in the state of Acre, on the border with Peru. The Kaxinawá community of Rio Jordão earned legal title to 873 km² in 1991, Seringal Independência to 115 km² in 2000, and Baixo Rio Jordão to 87 km² in 2002. In 2005, there were 1720 Kaxinawá people living in 27 villages along the Jordão and Tarauacá rivers (Fig 1). Jordão City, which has the second lowest HDI (human development index) in Brazil (PNUD, 2003), is located at the confluence of the Tarauacá and Jordão rivers only 5.4 km from the entrance to the Kaxinawá territory. From Jordão City, the first village is accessible by foot path (4 h) or by motorized dugout canoe (2 h).

On the Brazilian side, the Kaxinawá territory is surrounded by other indigenous lands (including lands of uncontacted groups), and two extractive reserves (Fig. 1). On the Peruvian side, there is part of a territory for non-contacted indigenous groups, and overlapping timber and oil concessions (SICNA, 2005; Amazonwatch, 2007). Aside from the concessions, these territories represent a landscape mosaic of protected areas that is part of the Brazilian Western Amazon Ecological Corridor augmented in size by adjacent protected areas in Peru (Fig. 1).

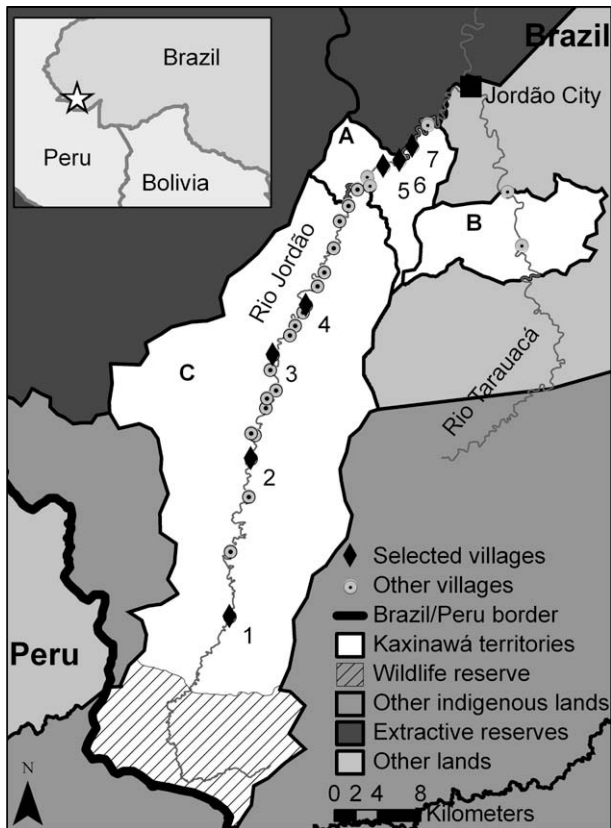


Fig. 1 – Map of the Kaxinawá indigenous territory and surrounding protected areas in Brazil and Peru. (A) Terra Indígena Kaxinawá do Baixo Rio Jordão, (B) Terra Indígena Kaxinawá do Seringal Independência, (C) Terra Indígena do Rio Jordão. Numbers indicate selected Kaxinawá villages: (1) Novo Segredo, (2) Belo Monte, (3) Bom Jesus, (4) Boa Vista, (5) Nova Empresa, (6) Nova Cachoeira, (7) Nova Extrema. Source: CPI-AC, SEMA/IMAC/ZEE-AC, Reserva Territorial Murunahua – Expediente AIDSESP.

In 1993, a biodiversity assessment was conducted in the Lower Jordão and Upper Tarauacá rivers region, more precisely at the Seringal Independência (Peres, 1993) before the *de facto* establishment of the Seringal Independência and Baixo Rio Jordão indigenous lands. The faunal abundance was evaluated through line-transect sample census walk accumulating 91.5 km in a one month long study, complemented by few interviews with local people (Peres, 1993). At this time, the sampled area was occupied and used by indigenous and non-indigenous people (Benavides et al., 1996). The biodiversity assessment indicated extreme depletion of faunal populations all over the Kaxinawá territory in Jordão region (Peres and Zimmerman, 2001) including the extinction of several sensitive species, allegedly caused by high hunting pressure by the Kaxinawá (Peres, 1993). Since then, the data, results and conclusions from this study directly supported various other scientific studies (e.g. Peres, 2000, 2001; Galetti, 2001; Peres and Zimmerman, 2001; Peres and Lake, 2003; Peres and Palacios, 2007), that were cited by other innumerable publications. To the original 1993 study's merit, the Kaxinawá independently recognized a decrease in game

availability in the lower Jordão river at this time (Benavides et al., 1996).

2.2. Data collection

Under the long-term capacity-building program started in 1996 the IAA seldom recorded communities' hunting practices in their working diaries. In 2005 the hunting self-monitoring system was improved using standardized indicators. IAAs were trained during five CPI-AC workshops in 2004–2006, and became responsible for recording hunts in each of 24 villages. Data sheets used to record hunting activities were developed by CPI-AC biologists and community members and later improved at subsequent meetings. Prey and hunting characteristics recorded were selected to meet the data needs of biologists and the indigenous communities. IAA in each village recorded hunting data through daily surveys of households. For every animal hunted, monitors recorded the date and purpose of the hunt, number of hunters, species, weight (measured using 20 or 50 kg scales), age class, sex, location of catch, and distance from the village (estimated in hours of walking based on Kaxinawá's extensive knowledge of their territory).

Data collected during this capacity-building process was screened for known data quality issues. This led to the exclusion of data from villages that only recorded harvest of large animals or had less than eight months of monitoring data available. As a result, seven villages were used in the remaining analyses (Fig. 1). The monitoring period used in the following analyses was 06/2005–05/2006 with all seven villages having 8–11 months of collected data, therefore comprising possible variation between seasons. Additionally, data on species presence/absence from other villages and previous years were used to complement information on rare or purportedly extinct species. Lastly, to identify factors related to potential differences in game availability among villages, 20 economical, historical, geographical, and ecological attributes that could influence hunting and game availability were assessed for each village in the Kaxinawá territory. These attributes were chosen based on a review of the academic literature on wildlife conservation and were assessed through data from semi-structured surveys developed by CPI-AC and reports from the local government indigenous agency and CPI-AC.

2.3. Kaxinawá hypotheses

The hypotheses of game availability variation and its causes were designed by the authors based on CPI-AC reports from the five workshops mentioned above, recorded interviews conducted by CPI-AC members with community members, and dialogue with Kaxinawá people during 2004–2006.

2.4. Game availability, its drivers and monitoring indicators

Two simple univariate indicators and five multivariate indicators were selected to analyze game availability variation among the seven villages based on standardization with previous studies of wildlife harvest (Moller et al., 2004; Noss

et al., 2005; Peres, 2000; Jerozolinski and Peres, 2003; Bodmer and Puertas, 2000) and Kaxinawá perception. Univariate indicators considered were (1) the number of preferred species and (2) the mean body mass of hunted animals. All multivariate indicators were in the form of village by species matrices that avoid information loss by the grouping of species data. These include (3) the median distance from the village that species were killed (4) the total biomass of animals hunted, (5) the number of animals hunted, (6) the catch-per-unit-of-effort using the number of animals hunted per hunter-day (hereafter abundance-CPUE), and (7) the catch-per-unit-of-effort using the biomass of harvested animals per hunter-day (hereafter biomass-CPUE).

2.5. Ordination with nonmetric multidimensional scaling

For each of our multivariate indicators, we used nonmetric multidimensional scaling (NMS) to reduce their dimensionality into fewer axes that represent the majority of the multidimensional variation present. Since these axes summarize the often subtle patterns present in a multidimensional dataset, axes may reflect underlying wildlife gradients that were not previously apparent. By having the choice of multiple indicators but no *a priori* reason to select one over another, we chose to use NMS on all multivariate indicators. This strategy allowed us to compare our results and check for the consistency of our detected wildlife gradients based on the use of alternate indicators.

We followed the steps and considerations outlined in McCune and Grace (2002) to perform our NMS analyses. For each multivariate indicator, we searched for the best one to four axes ordination results using Monte Carlo approaches with Sorensen's distance measure, and a conservative 0.00001 stability criterion (McCune and Grace, 2002). After NMS results were obtained for each multivariate indicator, simple correlation analyses were conducted to consider the consistency of ordination results across multivariate indicators. Following the previous step, we explored the correlation between detected wildlife gradients and individual species distributions to determine which species were being represented by the detected gradients. We then evaluated our univariate indicators by comparing them with the detected wildlife gradients. Lastly, we ran further correlation analyses to detect relationships between wildlife gradients and environmental and social factors that potentially drive them.

2.6. Consequences of game availability on traditional hunting practices

We compared the diversity of species hunted and detected wildlife gradients with the percentage of hunts when meat was shared, the number of hunters per hunt, the hunting of non-game species, and the area used by hunters to catch their prey. These variables are hunting-related socio-cultural traits that could be affected by game availability. The area used by Kaxinawá hunters to catch their prey (harvesting area) was calculated based on hunting and reserve zones indicated during the participatory mapping. We used the software Spring 4.3.2 (INPE, 2006) to calculate the harvest area.

3. Results

Hunters from the seven Kaxinawá villages caught 33 species during the duration of the study (Table 1). Additionally, one jaguar (*Panthera onca*) and two pumas (*Puma concolor*) were killed in self-defense. Five game species deemed locally extinct in 1993 (Peres, 1993) were hunted in 2005–2006. Of these, the white-lipped peccary (*Tayassu pecari*) was the most hunted species in lower river villages and the third most hunted in headwater villages during 2005. Additionally, the collared peccary (*Pecary tajacu*), the red brocket deer (*Mazama americana*), and the howler monkey (*Alouatta seniculus*), rare species in the area according to the previous study (Peres, 1993), are some of the most consumed species. The spectacled caiman (*Caiman crocodilus*) and the large tinamous (*Tinamous tao*), also rare species in the 1993 study, were hunted in several villages throughout the territory (Table 1, Peres, 1993). Three species considered extinct in 1993; the Brazilian tapir (*Tapirus terrestris*), the woolly monkey (*Lagothrix lagothrica*), and the razor-billed curassow (*Mitu tuberosa*) were hunted in only one or two villages located in the headwaters. Although not systematically collected, hunting records from previous years suggest that some sensitive species have been hunted throughout the Kaxinawá territory since 1999 or earlier. As an example, in 2002, tapir, peccaries, deer and spider monkeys were already hunted in headwaters and lower river villages. However, with the exception of peccaries, hunting of these sensitive species in lower villages is now a rare event.

3.1. Game availability variation

The NMS analyses were able to best summarize the multivariate indicators of biomass of hunted animals, number of animals hunted and biomass-CPUE into two axes ordination results (Fig. 2). These two axes are by definition independent and represent more than 90% of the variability present in the multivariate indicators listed above. The first axes of the NMS results were highly correlated with each other but not correlated with the second axes of any NMS results and vice-versa (Table 2). These results indicate that the two axes of these three NMS results reflect the same two distinct wildlife gradients and show the consistency of the multivariate indicators in detecting wildlife gradients among villages. Wildlife gradient 1 is represented by the first axis of the three NMS results while wildlife gradient 2 is represented by the second axes. On the other hand, the hunted animal median distance and the abundance-CPUE indicators were excluded from further analyses after they yielded no satisfactory ordination results. The poor ordination results from hunted animal median distance were likely a result from estimation error and low precision of data recorded primarily at hourly intervals.

Additional correlation analyses allowed us to determine that the wildlife gradient 1 is primarily driven by the variability of preferred species capture among villages. Using NMS axis 1 from the Number of Hunted Animals as an example, the number of hunted animals of all preferred large-bodied species excluding howler monkeys was correlated to wildlife gradient 1 (Table 1). On the other hand, none of the three secondary axes representing wildlife gradient 2 were correlated

Table 1 – Wildlife species hunted by 27 Kaxinawá's villages in 2005–2006 and surveyed by Peres (1993), ordered by presence on hunting records and Kaxinawá's preference

Common name	Scientific name	Preference ^c	Status in 1993 ^d	Axis 1 ^e	Axis 2 ^e	n ^f
Lowland tapir	<i>Tapirus terrestris</i>	1	†	0.82 ^a	0.26	5
Red brocket deer	<i>Mazama americana</i>	1	R	0.89 ^a	0.31	74
Collared peccary	<i>Pecari tajacu</i>	1	R	0.92 ^a	0.38	140
White-lipped peccary	<i>Tayassu pecari</i>	1	†	-0.81 ^a	0.27	111
Gray woolly monkey	<i>Lagothrix lagotricha cana</i>	1	†	0.82 ^a	0.26	4
Spider monkey	<i>Ateles paniscus chamek</i>	1	†	0.79 ^a	0.46	15
Red howler monkey	<i>Alouatta seniculus</i>	1	R	0.48	0.61	33
Brown capuchin	<i>Cebus apella</i>	1	U	0.70 ^b	0.31	20
Tortoise	<i>Geochelone denticulata</i>	1	U	0.85 ^a	-0.04	18
Spectacled caiman	<i>Caiman crocodilus</i>	1	R	0.83 ^a	0.41	7
Razor-billed curassow	<i>Crax mitu</i>	1	†	0.93 ^a	0.23	4
Agouti	<i>Dasyprocta fuliginosa</i>	2	U	-0.82 ^a	0.08	35
Paca	<i>Agouti paca</i>	2	C	0.28	-0.19	42
Nine-banded armadillo	<i>Dasybus novemcinctus</i>	2	U	-0.16	0.65	31
Coati	<i>Nasua nasua</i>	2	U	0.43	0.15	24
Grey squirrel	<i>Sciurus ignitus</i>	2	U	-0.43	0.32	61
Acouchi	<i>Myoprocta pratii</i>	2	C	-0.46	0.49	19
Pale-winged trumpeter	<i>Psophia leucoptera</i>	2	U	0.58	0.35	11
Spix's guan	<i>Penelope jacquacu</i>	2	U	0.48	0.47	20
Large tinamous	<i>Tinamus tao</i>	2	R	0.01	-0.06	1
Large tinamous	<i>Tinamus major</i>	2	R	-0.36	-0.48	17
Saki monkey	<i>Pithecia irrorata</i>	2	U	-0.39	0.47	9
Great long-nosed armadillo	<i>Dasybus kappleri</i>	2	U	-0.14	0.40	2
Seven-banded armadillo	<i>Dasybus septemcinctus</i>	2	-	-0.09	0.22	1
Small tinamous	<i>Crypturellus cinereus</i>	2	U	0.01	-0.06	1
Small tinamous	<i>Crypturellus soui</i>	2	U	-0.14	0.40	3
Squirrel monkey	<i>Saimiri boliviensis</i>	3	U	-0.14	0.40	4
Night monkey	<i>Aotus nigriceps</i>	3	C	-0.34	0.48	16
Toucan	Ramphastidae	3	-	-0.14	0.40	1
Macaw	<i>Ara</i> sp.	3	U	0.09	0.50	5
Variable chachalaca	<i>Ortalis motmot</i>	3	C	0.33	-0.09	1
White-face capuchin ^g	<i>Cebus albifrons</i>	3	U	-0.45	0.38	1
Pacarana	<i>Dinomys branickii</i>	4	U	0.17	-0.10	3
Common piping-guan ^h	<i>Aburria pipile</i>	2	†			0
Cabybara ^{g,h}	<i>Hydrochaeris hydrochaeris</i>	3	R			0
Red titi monkey ^h	<i>Callicebus cupreus</i>	3	C			0
Goeldi's marmoset ^h	<i>Callimico goeldii</i>	3	R			0
Parrot ^h	<i>Amazona</i> sp.	3	-			0
White-tipped dove ^h	<i>Leptotila verreauxi</i>	3	U			0
Harpy ^h	<i>Harpyia harpyja</i>	3	-			0
Forest falcon ^h	<i>Micrastur</i> sp.	3	-			0
Giant armadillo ^h	<i>Priodontes maximus</i>	4	R			0
Puma ^h	<i>Puma concolor</i>	4	R			0
Jaguar ^h	<i>Panthera onca</i>	4	R			0

a Significant correlation ($p < 0.05$).

b Marginally significant correlation ($p < 0.1$).

c Classification adapted from Peres (1993) and Cunha and Almeida (2002), where 1 – preferred large-bodied game species, 2 – non-preferred medium-bodied game species, 3 – non-preferred small bodied game species, and 4 – non-game species.

d Conservation abundance classification taken from Peres (1993), where † – extinct species, R – rare species, U – uncommon, and C – common species.

e Values of correlation between the number of animals hunted and values of NMS axis. Animals hunted in villages other than the seven selected villages have no correlation values.

f Total number of individuals hunted in the seven selected villages.

g Species related to strong taboos.

h Species hunted in other villages than the seven selected.

to the availability of any particular preferred or non-preferred species (Table 1). However, the percentage of animals hunted that were adults was significantly correlated to the second NMS axis of every multivariate variable (number of animals hunted: $r^2 = 0.95$, $p < 0.05$; biomass of animals hunted:

$r^2 = 0.90$, $p < 0.05$; biomass-CPUE: $r^2 = -0.90$, $p < 0.05$), and to the number of non-preferred species ($r^2 = 0.98$, $p < 0.01$). Given non-preferred species are small and typically hunted when adults, wildlife gradient 2 is likely associated to small non-preferred species.

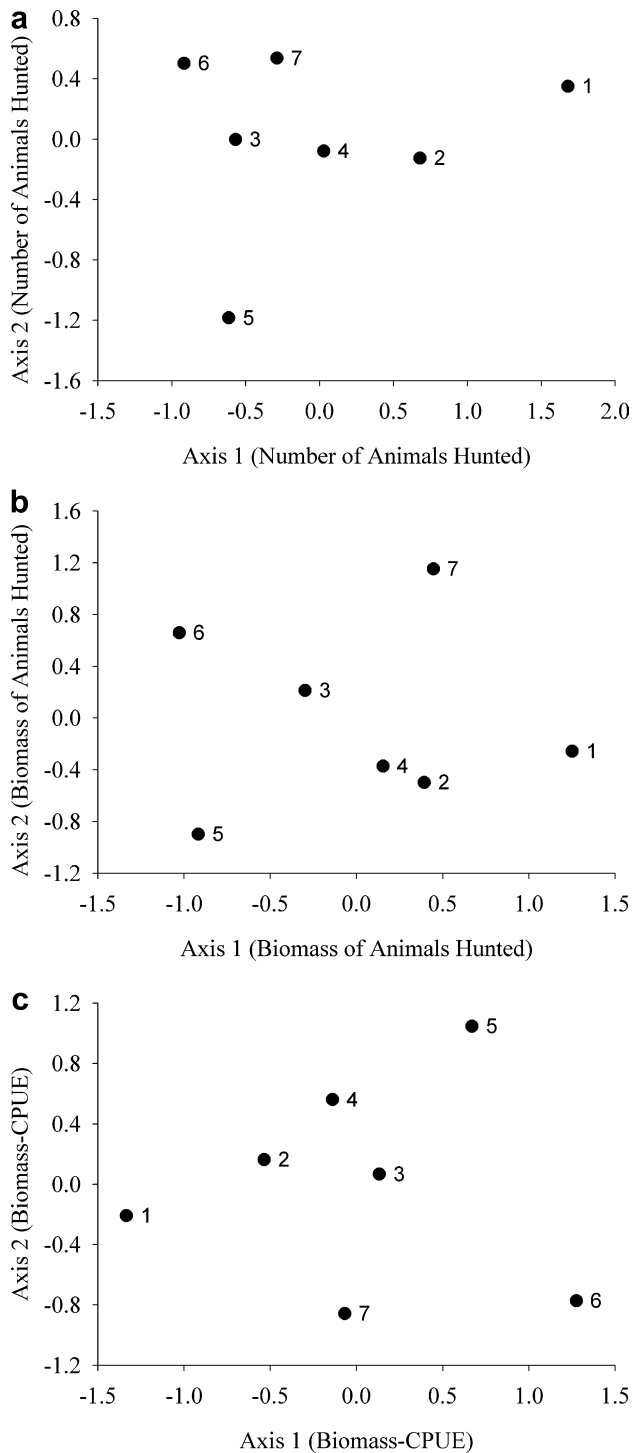


Fig. 2 – NMS ordination analysis results for game availability variation among villages within Kaxinawá territory based on multivariate indicators. (a) Number of animals hunted; (b) Biomass of animals hunted; and (c) Biomass-CPUE. Numbers indicate Kaxinawá villages (see Fig. 1 caption).

Because the wildlife capture data used in the study is a result of hunter capture choice, it is important to note the likely fundamental differences in the two wildlife gradients detected in the multivariate analysis. Due to Kaxinawá’s game preferences, when a hunter finds a preferred species, hunters

will always try to catch the prey. Because of this, we assume that monitoring data that show differences in the capture among villages likely reflect underlying differences of distribution of these species. On the other hand, capture data for non-preferred species is not as clear a representation of their actual distribution within Kaxinawá territory, since the capture of small bodied non-preferred species is not only related to differences in species distribution between villages but most importantly a decision to consider the capture of non-preferred species given limited alternatives to fulfill dietary needs.

All axes 1 of the NMS results representing wildlife gradient 1 were significantly correlated to village distance from the headwater, and to village settlement age, the number of rubber trails, and the density of villages (Table 3). However, village distance from the headwater was significantly and negatively correlated to village settlement age ($r^2 = -0.93$, $p < 0.01$) and the number of rubber trails ($r^2 = -0.68$, $p < 0.05$), and significantly and positively correlated to the density of villages ($r^2 = 0.90$, $p < 0.01$) and human population density ($r^2 = 0.79$, $p < 0.01$). As a group of related variables, these variables seem to represent the regional occupation process of the last 25 years. On the other hand, human population density, the number of cattle in a village, and the percentage of hunts using dogs were significantly correlated to some of the axes 2 of the NMS results representing wildlife gradient 2 (Table 3). Although these correlations may suggest potential relationships between these social–environmental variables and capture choice related to non-preferred species, these were correlations that were not observed consistently across the second axes of the NMS results and therefore preclude general conclusions. Additionally, due to the large number of tested correlations and the fact that none of these correlations showed highly significant values, it seems probable that they are statistical artifacts from multiple correlation tests.

3.2. Univariate indicators

The univariate indicator number of preferred species was significantly correlated to all axes 1 of the NMS results representing wildlife gradient 1, while species mean body mass was significantly correlated to axis 1 of two NMS results. This relation between simple univariate indicators and detected wildlife gradients is further supported by the strong correlations between the univariate indicators and environmental factors which were also correlated to the axis 1 of the NMS results (Table 2). As expected, wildlife gradient 2 which likely represents non-preferred species capture was not correlated to any univariate indicator. In effect, these results show that both simple univariate indicators selected by the Kaxinawá are good representations of important wildlife variability among villages in their territory.

3.3. Consequences of game availability on traditional hunting practices

The Kaxinawá hunters of Jordão reported four types of one-day hunts; waiting for prey by a fruit tree or a salt lick, opportunistic hunting in their gardens or during trips, walking using dogs, and walking while looking for prey. Hunters from

Table 2 – Correlations among simple and multivariate indicators for game availability in Kaxinawá territory

Variable	Axis 1			Axis 2			Univariate indicators	
	Number of animals hunted	Biomass of animals hunted	Capture per unit of effort (biomass)	Number of animals hunted	Biomass of animals hunted	Capture per unit of effort (biomass)	Mean body mass	Number of preferred species
Axis 1	0.89 ^a	–0.96 ^a						
Biomass of animals hunted								
Capture per unit of effort (biomass)	–0.94 ^a							
Axis 2	0.19	0.41	–0.2					
Number of animals hunted				0.80 ^a				
Biomass of animals hunted	–0.33	0.01	0.24	–0.92 ^a	–0.90 ^a			
Capture per unit of effort (biomass)	0.01	–0.2	–0.03					
Univariate indicators								
Mean body mass	0.68 ^b	0.51	–0.67 ^b	–0.01	–0.44	0.23		
Number of preferred species	0.96 ^a	0.95 ^a	–0.99 ^a	0.16	–0.27	0.04	0.64	
Number of non-preferred species	–0.53	–0.24	0.49	0.64	0.84 ^a	–0.69 ^b	0.72 ^b	–0.51

^a Significant correlation ($p < 0.05$).

^b Marginally significant correlation ($p < 0.1$).

the seven villages most commonly hunt by walking while looking for prey, varying from 87% to 93% of hunts. These hunts occur along defined hunting tracks using shotguns. One-day hunts walking on hunting tracks are reported as the traditional practice among the Kaxinawá, since they seldom use bows and arrows in Jordão (Aquino and Iglesias, 2002; Kensinger, 1995). For hunts in gardens or with dogs, hunters use alternative weapons such as machetes and smoke. Only three hunts were reported to be longer than one-day; in such cases hunters used campsites. Ninety percent of animals were hunted in a total harvest area of 892 km², which represents 83% of the total territory. The three villages in the headwaters hunt in an area of 308 km², while the other 24 villages hunt in an area of 583 km². Median distances for hunters to find prey were approximately two to three hours' walk from the village center, although some animals were caught as far as six hours from villages. These median distances showed minimal non-significant variation among villages.

The wildlife meat was shared among households for an average of 64% of successful hunts (minimum of 45%, maximum of 75%). The average number of hunters in a hunt varied between 1.6 and 3.4. Nevertheless, there was no significant correlation between the univariate indicators of game availability or the detected wildlife gradients and the percentage of hunts with meat shared between households, or the number of hunters per hunt.

The giant armadillo (*Priodontes maximus*), traditionally considered a non-game species, was hunted four times at a lower river non-selected village. The pacarana (*Dynomis branikii*), another non-game species, was more often hunted in lower villages than in headwater villages. The capybara (*Hydrochaeris hydrochaeris*) remains a very rare species in Jordão since 1993, but was hunted three times in two lower river non-selected villages, despite being an object of severe taboo. The white-face capuchin (*Cebus albifrons*) and the goeldi's marmoset (*Callimico goeldii*), only eaten during times of food scarcity, were hunted in lower river villages.

4. Discussion

The Kaxinawá's current harvest of several game species deemed extinct in 1993 (Peres, 1993) has two feasible explanations: game population recovery, or inadequate sampling effort of the 1993 study in terms of geographical representation and sampling intensity. Considering the first explanation, the results suggest the existence of a source area able to repopulate game populations close to Kaxinawá villages, as happens in other Neotropical subsistence communities (Novaro et al., 2000). Nevertheless, considering the possibility that the second explanation is correct, our results indicate the relevance and value of long-term participatory studies to complement short-term academic studies of biodiversity and natural resource use and management.

4.1. Processes creating game availability variation

The hunting pattern and variability of game animals caught among villages indicate that the headwater region is better preserved than the lower river region. The gradient of wildlife

Table 3 – Factors correlated to game availability gradient in Kaxinawá territory

Variable ^c	Number of animals hunted		Capture per unit of effort (kg)		Biomass of animals hunted	
	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
Village distance from headwaters (km ²)	–0.88 ^a		0.84 ^a		–0.72 ^b	
Density of villages	–0.92 ^a		0.82 ^a		–0.72 ^b	
Settlement age (years)	0.79 ^a		–0.80 ^a			
Number of rubber trails	0.85 ^a					
Number of cattle in village		–0.78 ^a				
Human population density (no./km ²)						0.82 ^a
Hunts using dogs (%)						–0.76 ^a

a Significant correlation ($p < 0.05$).
b Marginally significant correlation ($p < 0.1$).
c A list of all socio-economic factors used in the analysis is available in the online [supporting materials](#).

availability decreasing from the preserved headwater to the lower river region closer to Jordão City correlates with settlement age, density of villages and number of rubber trails. These factors together are likely associated with the occupational process that has occurred over the past 25 years in the Jordão region. Until the early 1980's the Kaxinawá people were integrated into the rubber-tapping economic system, inhabiting settlements of a few households in the center of the headwaters forest, where the rubber tree (*Hevea brasiliensis*) was abundant. Although Kaxinawá men were involved on rubber-tapping activities they were able maintained subsistence activities such as swidden agriculture, fishing and hunting. At that time, they were market-linked to company stores ("barracão") by the debt peonage credit system ("aviamento"). In contrast, the lower river region economy (dominated by non-indigenous people) was more linked to the Jordão market, and therefore dominated by hunting and cattle ranching (Benavides et al., 1996). Consequently, hunting pressure was historically much lower in the headwaters compared to the lower river region. The indigenous and non-indigenous rubber-tapper socio-economy changed during the region's rubber cycle crash in the 1990s. Simultaneously, the political negotiation for indigenous recognition in the Acre state by the national government was under development: retired rubber-tappers were receiving pensions, professors and health agents were receiving salaries, and the Rio Jordão Indigenous Land was titled. This economic shift was accompanied by a migration within Kaxinawá lands: people left settlements in the center of the forest to settle villages alongside the rivers, concentrated closer to the small city of Jordão. The Jordão City market substituted rubber company stores in supplying community needs. This economic shift allowed subsistence hunting to return to its fundamental role as protein source for Kaxinawá people (Aquino, 1977; Benavides et al., 1996). In addition to wildlife use by local people engaged in the rubber economy, the wildlife of the Jordão region, mainly in the lower river region, was constantly harvested from the 1930s through the 1980s (although under varying intensity) for pelt and hide commercialization by Brazilian and Peruvian professional hunters. This activity focused on large animals such as ungulates, felids, otters, capybara and caimans (Nissly, 1966; ONERN, 1980; Almeida, 1996; Benavides et al., 1996; Almeida et al., 2002). The headwater region was better preserved due to the presence of isolated indigenous people and difficult ac-

cess. Illegal commercial hunting close to urban centers, and therefore far away from river headwaters, continued during the 1990s in the entire upper Juruá valley that is drained by the Purus and Juruá rivers (Nissly, 1966; Martins, 1992; Fuccio, 2003). Therefore, commercial hunting and not Kaxinawá hunting practices, as argued by Peres (1993), would have had a larger influence on the extinction of several non-game species reported in 1993, such as felids and otters (*Lutra longicaulis* and *Pteronura brasiliensis*).

The *de facto* titling of Rio Jordão Indigenous Land, in the late 1980s; of the lower rivers Indigenous Lands of Seringal Independência, in the middle 1990s; and Baixo Jordão, in early 2000, obligated non-indigenous people to move out (Iglesias, personal communication), reducing cattle, hunts using trained dogs, and overall hunting pressure (Benavides et al., 1996). Consequently, despite continued but less frequent forays of non-indigenous hunters, changes in management actions and land title regulation allowed for the recovery of wildlife populations within the majority of Kaxinawá's territory.

4.2. Socio-cultural consequences of game availability depletion

As in other Amazonian communities hunting for subsistence (Hames and Vickers, 1982; Bodmer, 1995; Peres, 2000; Jerozolimski and Peres, 2003), larger-bodied preferred species availability determined the harvest pattern in Kaxinawá territory. Although the two wildlife gradients detected by multivariate analyses indicate no direct relation between the distribution of preferred and non-preferred species, the number of small species hunted also seems related to the distance from the headwaters. Fig. 3 shows that the exclusion of the anomalous Nova Empresa village results in a very strong correlation between the two variables. The Nova Empresa is Kaxinawá village that is best-linked to the Jordão city market. Nova Empresa dwellers commonly own second homes in the nearby city where they sell manioc flour and sugar cane honey ("melaço") and purchase city food supplies. The example of Nova Empresa shows that the meat provided by large species hunted is not necessarily substituted by those from small species. Other types of food, including non-protein staples found in the Jordão market and small domestic animals, may become important in villages where preferred game availability is lowered.

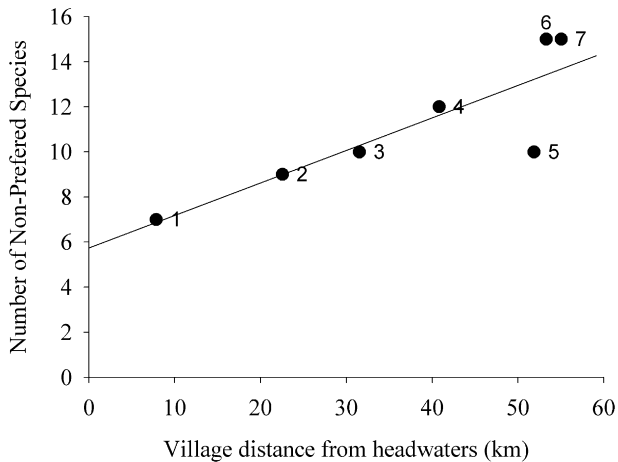


Fig. 3 – Correlation between the number of small species hunted and the distance from the headwaters. Excluding the Nova Empresa village, the correlation becomes extremely strong and significant. Numbers indicate Kaxinawá villages (see Fig. 1 caption).

Despite the potentially complex relationship between preferred species consumption and their substitutes, results from this study show villages in the lower river expanded their diet breadth by adding non-preferred smaller-bodied species and relaxed food taboos by hunting non-traditional game species. These cultural shifts are probably linked to a reduction in the availability of preferred game species caused by population depletion close to those villages. Socio-ecological behaviors similar to these were found in studies considering the diet breadth model as the main reason for the evolution in resource utilization (Hames and Vickers, 1982; Winterhalder and Smith, 2000). The optimal foraging theory predicts that hunters hunt to achieve the maximum profit by considering their energy balance. Since hunters in lower villages kill less-preferred large-bodied species they would maximize their hunting balance by killing larger animals. This maximization is represented by the positive correlation of the percentage of adult animals hunted with the number of non-preferred species hunted, confirming that smaller-bodied species hunted in lower villages are adult individuals. Also, hunting with dogs, correlated to the hunting of medium-bodied species such as pacas, agoutis and armadillos, is more often practiced in lower river villages.

Other social hunting-related characteristics, however, do not seem to be affected by game depletion, since the variation in hunters per hunt and in the percentage of hunts whose prey were shared by communities were not correlated to game availability variation. These social traits are addressed by Kensinger (1983) as two of the most important hunting-related characteristics of Kaxinawá society, where hunting is the principal male activity and meat sharing plays a regulating role in social relationships (Aquino and Cataiano, 2002). Since Kaxinawá villages in Jordão are concentrated in areas of lower game availability, game availability seems to no longer be playing the determinant role in settlement dislocation as was traditionally the case (Kensinger, 1995), but other factors, including the economic dependency on the Jordão city

market, may be influencing the spatial distribution of villages within the Kaxinawá territory.

4.3. The landscape overview: the wildlife source–sink system

It appears that the occupational process over the last 25 years created a source–sink system where the mosaic of protected areas adjacent to the Kaxinawá territory headwaters functions as the source of species intensively hunted in sink areas surrounding Kaxinawá villages and the nearby Jordão City. The same headwaters region was also indicated as a source of wildlife to the highly exploited sink areas of the Alto Juruá extractive reserve, west of the Rio Jordão Indigenous Land (Ramos, 2005). Therefore, wildlife populations of overexploited sensitive species likely recovered in the sink area by dispersing from the headwater source following the reduction in hunting pressure associated with indigenous land titling, and are currently hunted by the Kaxinawá in virtually all their villages. Other examples of source–sink dynamics where overhunted species remain present in sink areas for several years were suggested to take place in the Neotropics (Naranjo and Bodmer, 2007), and particularly in Amazonia (Novaro et al., 2000; Peres, 2001; Ohl-Schacherer et al., 2007).

Moreover, as occurs in Kaxinawá villages along the Jordão river, the extraction of sensitive species has an increasing impact on local wildlife abundance as the distance increases from the source area due to the diminishing ability for sink areas to benefit from distant source areas (Novaro et al., 2000). Conversely, the overharvest in the headwaters region can potentially block the source–sink flow, hindering wildlife population recovery in the remaining of the Kaxinawá territory. Therefore, threats to the pristine status of the headwaters source areas can affect the current Kaxinawá game use pattern over their entire territory, particularly in the Lower Jordão region where game populations are already depleted. Regarding this scenario, the increase in illegal logging activities since 2003 in the Peruvian region bordering the non-contacted people's territory “Reserva Territorial Murunahua” (Castillo, 2002; Aquino and Iglesias, 2006; FUNAI, 2007a) threatens part of the source area necessary to support Kaxinawá wildlife consumption. When logging practices are poorly planned, wildlife populations are reduced by overhunting and habitat modification (Johns, 1997; Fimbel et al., 2001). Another consequence of illegal logging in this region is the displacement of non-contacted people from Peru into indigenous titled territory in Brazil, enhancing human density and conflict between different indigenous people (Castillo, 2002; FUNAI, 2007b). Other possible threats to Kaxinawá wildlife use are the oil exploitation activities planned by the Perupetro oil company in oil concessions overlapping the “Reserva Territorial Murunahua” (Amazonwatch, 2007; SICNA, 2005), since these activities may also alter natural resource use by indigenous people (Lu, 1999).

4.4. Indigenous collaborative research on game availability and management decision-making

The hypotheses designed using the Kaxinawá's perceptions were confirmed by the self-monitoring data analysis.

Headwater villages have more available game than lower river villages. The main process creating this gradient is the historical occupation related to previous land and wildlife use and current village distribution. Although the indigenous indicator for game availability (median distance to game capture) did not detect variation, other indicators showed that the occupational process affected principally the preferred large game species. Therefore, the occupational process affecting wildlife and the source–sink system concepts were already known and have guided Kaxinawá communities in their wildlife management actions (Benavides et al., 1996). Concerning this knowledge, the Kaxinawá territory management plan organized in 2005 established wildlife reserves in the lower river region beside the one previously created in the headwaters, established rules warning hunters not to hunt newborns or pregnant females, and only use dogs to hunt in gardens or when hunting smaller-bodied animals (ASKARJ et al. unpublished data).

Since simple univariate indicators (number of preferred species and mean body mass) were strongly correlated to wildlife gradients detected by more robust multivariate analyses, the easy comprehension and applicability of the former make them appropriate for participatory analyses. Similar to other community-based conservation programs, participatory analyses must empower Kaxinawá communities, increasing their participation and responsibility for wildlife management decision-making (Stuart-Hill et al., 2005; Brown, 2003), while giving them proper feedback at a lower cost than academic oriented research (Sheid, 2001; Moller et al., 2004; Danielsen et al., 2005; Noss et al., 2005). Currently, the CPI-AC capacity-building program adopt these recently developed univariate indicators to be used by the IAA, yet under the supervision of CPI-AC staff, to analyze hunting data and then present to their communities. Refinements of the Kaxinawá monitoring system will be adopted by other indigenous groups in the CPI-AC capacity-building program that are already setting their management plans, self-monitoring their wildlife use, and discussing wildlife management. Since the hunting self-monitoring program is to continue and widespread, both the IAA and CPI-AC staff expect results of monitoring would help communities make natural resources management decisions in the near future.

It is likely that the both game population recovery and differences in sampling effort between this and the previous 1993 study explain game availability differences between 1993 and 2005 (Peres, 1993). Wildlife populations were likely lower in 1993 at the lower Kaxinawá territory due to the historical commercial hunting by non-indigenous people and indigenous subsistence hunting. However, the focus of the 1993 study precisely on this contested area of the Kaxinawá territory resulted in an overly pessimistic evaluation of wildlife resources in the territory. This combination of factors led to the conclusion that in 1993 several species were extirpated or severely impacted by indigenous people's hunting. Consequently, in 2005 after the titling of the indigenous territory that reduced hunting pressure in the lower Kaxinawá territory and a larger sampling effort in terms of duration, manpower and geographical extent of monitoring made possible by the collaborative research approach a significant increase of game availability was observed. In fact, the collaborative

research approach was able to detect a gradient of wildlife availability that supports the idea of recovery in a source–sink system, as well as identify some socio-cultural consequences of game depletion for the Kaxinawá people of Jordão. However, further studies need to be conducted on the Kaxinawá diet to evaluate the influence of larger species availability on the consumption of smaller species and other food sources. The present study demonstrates how potential biases in collaborative research are outweighed by its advantages in providing ecological knowledge needed for sound management, and validates the strategy of increasing local communities' involvement on natural resource conservation research.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at [doi:10.1016/j.biocon.2008.08.008](https://doi.org/10.1016/j.biocon.2008.08.008).

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