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Beto, este foi meu primeiro trabalho c/ os Waimiri Atroari. Rosélis

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Subsistence hunting among the Waimiri Atroari Indians in central Amazonia, Brazil

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Abstract. Subsistence hunting among the Waimiri Atroari Indians in central Amazonia, Brazil, was studied from September 1993 to October 1994 to assess the current levels of resource exploitation. Hunting effort, harvesting yields and species composition of the hunt were recorded daily in five villages varying in number of people, location and age of the settlement. The Waimiri Atroari harvested a total of 3004 individuals of 41 species in one year. Lowland tapir (*Tapirus terrestris*), white-lipped peccary (*Tayassu pecari*), collared peccary (*T. tajacu*) and spider monkey (*Ateles paniscus*) represented 87% of the total yearly game weight. Sex ratios of spider monkeys killed were heavily biased towards females indicating a stronger hunting pressure on those individuals. Harvesting yields was proportional to hunting efforts indicating no evident game depletion in the study period. However, capture per unit of effort was significantly different among villages. Differences in total game mass harvested may be explained by local resource depletion associated with age and size of the settlement. However, this relationship is confounded by the capacity of some villages to exploit distant hunting sites. Data obtained in one village showed that harvest rates were higher in hunting sites located far from settlement indicating game depletion in hunting sites surrounding the village.

Key words: Amazonia, game depletion, subsistence hunting, Waimiri Atroari Indians

Introduction

Wildlife species are an important part of the diet of most people living in Amazonia's rain forest habitats but hunting may have a negative impact on wildlife populations (Peres 1990; Alvard 1994; Bodmer 1994; Alvard et al. 1997). Recent research suggests that many Amazonian people are becoming more sedentary (Milliken et al. 1992; Stearman and Redford 1995; Leeuwenberg 1997). Such sedentism and the availability of more efficient hunting weapons and transportation are likely to intensify hunting pressure and result in declining wildlife populations and hunting yields. Hunting pressure also varies depending on the species. Large mammals such as tapirs, peccaries and monkeys are among the most harvested followed by bird and reptile species (Vickers 1984, 1991; Redford and Robinson 1987; Alvard 1993).

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In general, hunting areas close to settlements are used more frequently for hunting than more distant areas and tend to have lower capture per unit of effort than remote hunting sites (Hames 1980; Alvard 1994; Fragoso 1998). Capture per unit of effort is usually higher in more remote and lightly hunted areas than in areas close to the settlements in Amazonia (Vickers 1980; Bodmer 1994; Alvard et al. 1997).

Hunters who live in permanent villages are expected to have lower yields per unit effort than those who relocate more frequently. Hames and Vickers (1982) and Alvard (1994) showed that hunting yields increased with distance from the settlement for the Yanomamo and Yek'wana Indians in Venezuela and for the Piro in Peru. Species composition of the catch can also change with distance from the village (Hames and Vickers 1982). Preferred species may become rare near settlements when compared to distant hunting sites. Most studies that investigated the effects of distance from the village on harvesting in Amazonia were done in areas where hunting trips are single day events and the Indians go hunting by foot (Vickers 1991; Alvard 1994; Alvard et al. 1997). Foot transportation limits the distances that hunters can travel round trip, restricting the access to larger areas that can work as source habitats for 'sink' areas near the villages.

Here we report on the patterns of catch per unit of effort in Waimiri Atroari villages varying in number of people, age of the settlement and different degrees of access to motorized transport and show that simple source and sink models may not work where mechanized transport is available and distance does not act as a strong barrier to access by hunters.

The Waimiri Atroari are Carib speakers and live in the Central Amazon region in Brazil with a population of 801 people. The Waimiri Atroari have undergone several changes in the last 30 years that have altered their traditional way of living. Highway BR 174, which joins the cities of Manaus and Boa Vista in the northern region of Brazil, was completed in 1974 and crosses the Waimiri Atroari Reserve. An assistance program agreement with the Waimiri Atroari was signed between the electric company (ELETRONORTE) and the National Indian Foundation (FUNAI) after the Reserve had part of its territory flooded by the Balbina Hydroelectric Dam in 1987. This support program will end in 2013. The program provides health assistance, education and technical support for agricultural production and environmental issues. Shotguns and motor boats were introduced to the area and are currently part of the everyday life of the Waimiri Atroari. The presence of FUNAI offices in each village, providing health care and technical support, creates incentives for the Indians to remain in the same area for long periods of time. Indians living along Highway BR 174 frequently use FUNAI trucks for hunting excursions to more distant sites. The impact of these changes on the traditional subsistence hunting is unknown.

The specific questions to be addressed by this study are: (a) What is the annual harvesting yield in five Waimiri Atroari villages? (b) Which species are more frequently hunted? (c) Does the game composition vary seasonally? (d) Are hunting

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Table 1. Data on location, settlement age, number of people and access to motorized transport of the villages involved in this study.

Village	Settlement age	Population	Location	Transportation to hunting sites
Mynawa	5	100	5 km from BR 174	Truck
Xeri	8	45	2 km from BR 174	Truck
Iawara	10	46	1 km from BR 174	Truck
Maikon	8	45	Upper Alalaú River	On foot
Maryda	2	20	Upper Alalaú River	On foot

yields proportional to hunting efforts in all villages? and (e) Do hunting yields change with distance from the settlement?

Study area

The Waimiri Atroari Indigenous Reserve is located in the Brazilian states of Amazonas and Roraima (1°00′ N to 2°30′ S, 50°30′ to 61°30′ W) covering an area of 25,000 km^2. The five villages studied varied in number of people, site and age of the settlement (Table 1). Villages Mynawa, Xeri and Iawara are located along the Highway BR 174 and villages Maikon and Maryda are located on the banks of the Alalau River (Figure 1). The predominant vegetation type is *terra firme* (upland) forest although other types occur at a small scale (Milliken et al. 1992). The rainy season is from February to July and the dry season is from August to January. Each village has its own hunting areas that can be used by Indians of the other villages only with permission. Hunting excursions involving Indians of several villages occur when the whole tribe is together for some communal work (building a new hut, clearing plantation fields or rituals). Indians from Xeri, Mynawa and Iawara frequently use trucks to go hunting in areas far from their settlement and they have permanent hunting trails in these areas. Indians from Maikon and Maryda possess motor boats, but, generally hunt on foot.

Methods

This study was carried out in five Waimiri Atroari villages from September 1993 to October 1994. Data sheets were filled out each day after every hunting excursion in each village. A Waimiri Atroari Indian in each village was trained to fill out the sheets in the native language. They were chosen because they fluently speak and write their native language and Portuguese and teach both languages in their home villages. The data sheets contain information about departure and arrival time, number of Indians

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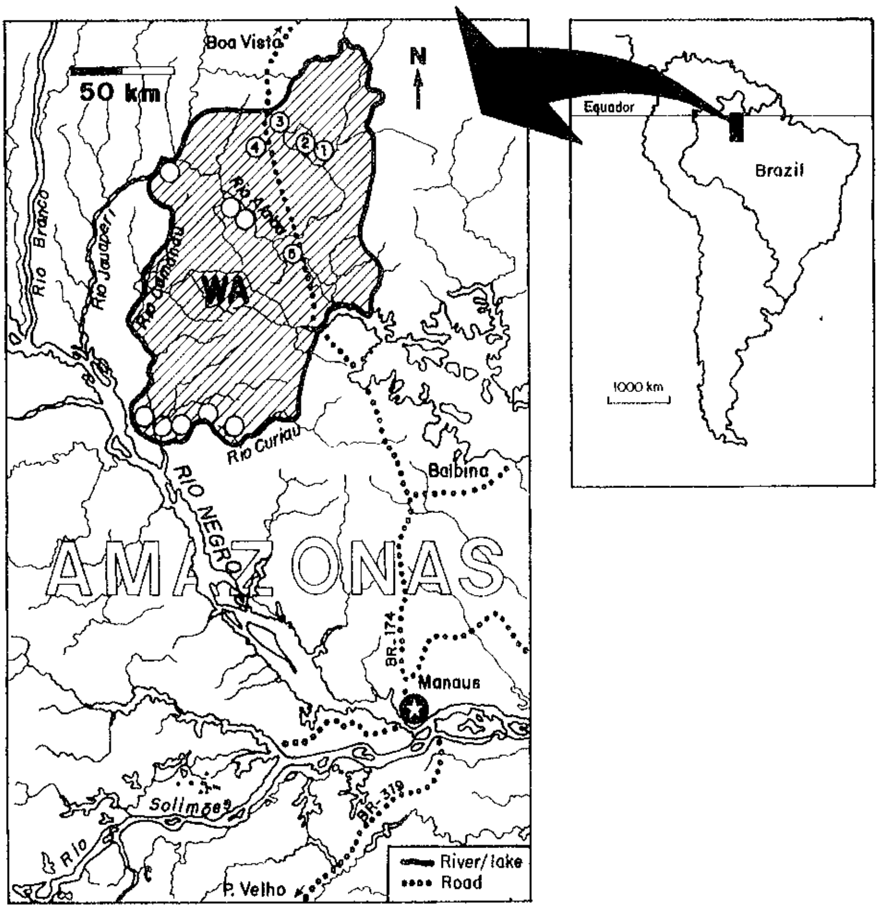

Figure 1. Map of the study area and distribution of the five villages used in this study in the Waimiri Atroari Reserve (WA). 1: Maikon, 2: Maryda, 3: Xeri, 4: Iawara and 5: Mynawa.

hunting, hunting site, sex of the animals hunted, size (qualitative: young or adult), reproductive state of the females (pregnant or not) and if they were lactating. Days with no hunting activities and fishing excursions were also noted. Fish harvesting was not included in this part of the study although fish is an important resource for Indians living by the rivers. Souza-Mazurek checked the accuracy of the information on the data sheets monthly through direct observation. Time spent hunting was defined as being the sum of hours from the time the hunters left the village until the time they came back. The Waimiri Atroari rarely hunt for more than one day. The hunting effort was calculated by multiplying the number of men hunting by the number of hours hunting. Incomplete data sheets were eliminated from the hunting effort analysis, but the number of animals hunted was included in the total number during the study period. Harvest of each species per consumer-year was calculated by the formula: HR = number of individuals killed/number of consumers × duration of the study

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(1 year) (Redford and Robinson 1987). Consumers were defined as all people living in the villages during the study period.

Similarities in species composition of hunts among villages were summarized by Multi-Dimensional Scaling (MDS) (Belbin 1992). Ordinations were based on proportion of the total body mass of individuals of the 16 most-hunted species. MDS is a conceptually simple method of obtaining ordination in a reduced number of dimensions. MDS was chosen because it is generally more robust to non linear effects and can often summarize more information in fewer axes than other indirect ordination techniques (Minchin 1987). Bray-Curtis index was used for calculation of the dissimilarities among villages. Ordination was done in two dimensions. The effects of villages and periods (hunting data from each 2 months) on the two axes of species composition were tested by Analysis of Variance.

We used Contingency Table analysis to test the independence of number of individuals of the five most-hunted mammal species and seasons in all villages.

Species were identified by reference to field guides. Data on mammal and bird weights were taken from the literature and were based on the average adult weight (Peres 1990; Arita et al. 1990; Emmons and Feer 1990; Sick 1984). Reptile weights were taken from animals brought back to the villages by the hunters. We excluded the weight of individuals that were not identified at the species level. The weight of one manatee was not included because the Waimiri Atroari ate very little of its meat (Souza-Mazurek, personal observation). Felids and otters are also hunted by the Waimiri Atroari but not eaten. Wild cats represent a direct threat to the Indians and otters because they compete with the Indians for fish. The electric eel was included in this study because it was consumed frequently by the Indians and is collected during hunts and not during fishing trips.

Results

The Waimiri Atroari Indians from five villages consumed 3004 individuals of at least 41 species between September 1993 and October 1994 (Table 2). Mammals were the most-hunted group comprising 49% of the total number of individuals, followed by reptiles (27%) and birds (21%). Nine species of mammals (n = 1390), four species of reptiles (n = 781) and four species of birds (n = 457) represented 87% of the total game consumed.

Mammals represented 91% of the total weight of the 16 species most consumed in the villages. Among mammals, tapir (*Tapirus terrestris*) represented 46%, collared peccary (*Tayassu tajacu*) 20%, white-lipped peccary (*Tayassu pecari*) 13%, and the spider monkey (*Ateles paniscus*) 8% of the total weight. Small rodents (*Agouti paca*, *Dasypus* sp. and *Dasyprocta agouti*) together represented 2% of the total weight.

The spider monkey was the most commonly hunted mammal, followed by the collared peccary, white-lipped peccary and tapir. After mammals, reptiles were the

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Table 2. Number (N) and harvest weights of game animals in five Waimiri Atroari villages in one year.

Scientific name	Common name	Waimiri Atroari name	N	Individual weight (kg)	Total weight (kg)
Edentata					
Tamandua tetradactyla	Collared anteater	Wariri	2	5	10
Myrmecophaga tridactyla	Giant anteater	Saryma	3	30	90
Priodontes maximus	Giant Armadillo	Akenyhehe	6	30	180
Dasypus kappleri	Armadillo	Kabaha	44	10	440
Dasypus sp.	Nine banded Armadillo ?	Kapaxi	8	1.5	12
Primates					
Ateles paniscus	Spider monkey	Kwata	421	8.1	3410.1
Alouatta seniculus	Howler monkey	Arawyta	99	6.18	611.8
Cebus apella	Capuchin monkey	Meky	51	2.9	147
Chiropotes satanus	Brown bearded saki	Kixi'y	3	3	9
Rodentia					
Agouti paca	Paca	Waryna	66	9	594
Dasyprocta agouchi	Agouchi	Akiri	54	4.5	243
Myoprocta acouchi	Red acouchy	Axiwi	33	1.2	39.6
Artiodactyla					
Tayassu tajacu	Collared peccary	Pakia	358	23.2	8305.6
T. pecary	White lipped peccary	Petxi	166	32.5	5395
Mazama americana	Red brocket deer	Syweri	18	26.1	469.8
M. gouazoubira	Gray brocket deer	Kaiaky	10	17.5	175
Perissodactyla					
Tapirus terrestris	Lowland tapir	Mepiri	131	148.9	19505.9
Carnivora					
*Eira barbara**	Tayra	Wiria	1		
Felis sp.*	?		3		
Cracidae					
Crax alector	Black Curassow	Wuky	168	3.4	571.2
Penelope sp.	Guan	Mare'e	77	0.85	65.45
Pipile pipile	Blue-throated guan	Kiwi'e	7		
Mitu tomentosa	Crestless curassow	Awyty	7	3.5	24.5
Psophiidae					
Psophia crepitans	Trumpeter	Ikemi	162	1.5	243
Psittacidae					
Ara ararauna	Blue and yellow macaw	Marabia	50	1.5	75
Ara chloroptera	Scarlet macaw	Byryiyhy	19	1.5	28.5
Amazona sp.	Parrot	Kyrywaky	1	?	
Ramphastidae					
Ramphastus tucanus	Red billed toucan	Txamyky, Kiamyky	24	0.5	12
R. vitelinus	Channel billed toucan	Kyry	1	0.5	0.5
Pteroglossus sp.*	Toucanet	Irida	1	?	

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Table 2. Continued.

Scientific name	Common name	Waimiri Atroari name	N	Individual weight (kg)	Total weight (kg)
Tinamidae					
Tinamus sp.	Tinamou	Iamy	11	1	11
Accupritidae					
*Harpia harpyja**	Harpy eagle	Kwany	1		
? *	Hawk		4		
Anatidae					
Cairina moscata	Muscovy duck	Paty	3	3	9
Testudinata					
Geochelone denticulata	Yellow-footed tortoise	Waiamy	450	4	1800
G. carbonaria	Red-footed tortoise	Waiamytxa	148	4	592
Rhinoclemys punctularia	Guiana wood turtle	Arykaka	23	0.7	16.1
Platemys platycephala	Grooved sideneck turtle	Masyry	6	0.6	3.6
Phrynops sp.	?	Sypa'a	10		
Crocodilidae					
Caiman crocodilus	Spectacled caiman	Iake tamixa	183	2	366
Paleosuchus trigonatus	Schneider's smooth-fronted caiman	Iake tapyryma	19	3	57
Electrophoridae					
*Electrophorus electricus***	Electric eel	Pareki	149		
Total			3004		43235.6

* Not eaten.
** Not available.

second most consumed taxonomic group and the yellow footed tortoise (*Geochelone denticulata*) was the most frequent item of all groups. Two large birds, black curassow (*Crax alector*) and gray-winged trumpeter (*Psophia crepitans*) were also often consumed by the Waimiri Atroari Indians.

It was possible to compare the extraction levels per species of the Waimiri Atroari with other indigenous groups using the number of individuals per consumer-year with data from Redford and Robinson (1987). Hunting rates of tapir, spider monkey and collared peccary were much higher among the Waimiri Atroari than the average of other groups (Table 3). On the other hand, they relied much less on rodents such as paca, agouti and acouchy. Capuchin monkeys (*Cebus apella*) were also captured at much lower rates by the Waimiri Atroari than by other Indians.

Sex ratios of the most commonly hunted species were equal or slightly skewed towards male except for spider monkey and white-lipped peccary (Table 4). Female spider monkeys represented 80% of the catch for this species. On the other hand, males of howler monkeys, capuchin monkeys, agoutis and red footed tortoise were

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Table 3. Comparison of harvest rates of most commonly taken prey species between the Waimiri Atroari and other indigenous groups (number of animals taken per consumer-year).

Scientific name	Average*	Waimiri Atroari
Mammals		
Tamandua tetradactyla	0.183	0.008
Dasypus sp.		0.2
Ateles paniscus	0.49**	1.7
Alouatta seniculus	0.505**	0.39
Cebus apella	2.51	0.204
Agouti paca	0.892	0.264
Dasyprocta and *Myoprocta*	0.639	0.348
Tayassu tajacu	0.652	1.432
T. pecary	0.923	0.664
Mazama sp.	0.175	0.112
Tapirus terrestris	0.049	0.52
Birds		
Crax alector	0.506	0.67
Penelope sp.	0.895	0.308
Pipile pipile	0.654***	0.028
Psophia crepitans	0.459**	0.648
Ara sp.	0.094	0.276
Amazona sp.	0.149	0.004
Ramphastus sp.	0.869	0.1
Reptiles		
G. denticulata		1.8
G. carbonaria		0.59
Rhinoclemys punctularia		0.092
Caiman crocodilus		0.7
Paleosuchus trigonatus		0.076
Fish		
Electrophorus electricus		0.596

* From Redford and Robinson (1987).
** Genus only.
*** Includes colonist groups.

harvested more than expected considering the data on natural sex ratio available for these species (Table 4).

Species composition of the hunts varied with season ($X^2_{4,0.001} = 85$). Spider monkey, howler monkey and tapir were more abundant in the catch in the wet season than in the dry season. White-lipped peccary was slightly more abundant in the dry season and collared peccary was hunted evenly throughout the study period (Figure 2).

The particularly high number of spider monkeys harvested during the wet season may be related to the seasonal activity patterns of this species, but also to the Waimiri Atroari hunting behavior. Roosmalen (1985) showed that spider monkeys are particularly active during the wet season when abundance of fruit resources is high and are probably easier to find during this period. In addition, the Waimiri Atroari avoid

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Table 4. Comparison of sex ratio for Waimiri Atroari kills and censused population from literature.

Species	Sex ratio of kills (*n*)	Sex ratio censused*	Source
Ateles paniscus	23:100 (411)	34:100	Van Roosmalen (1980) Symington (1988) cited in Alvard (1995)
Alouatta seniculus	200:100 (84)	58:100 (34) 85:100 (178)	Queiroz (1995) Rudran (1979)
Cebus apela	325:100 (51)	101:100	Izawa (1980); and Janson (1984), cited in Robinson and Janson (1987)
Tayassu tajacu	122:100 (353)	120:100	Alvard (1993)
Tayassu pecari	69:100 (166)		**
Tapirus terrestris	97:100 (128)		**
Dasyprocta agouti	141:100 (53)		**
Agouti paca	276:100 (64)		**
Crax alector	137:100 (100)		**
Psophia crepitans	96:100 (161)		**
Penelope sp.	123:100 (76)		**
Geochelone denticulata	117:100 (448)	153:100 (38)	Moskovits (1998)
G. carbonaria	234:100 (147)	120:100 (174)	Moskovits (1998)

* Sex ratios represented as number of males per 100 females.
n = number of individuals used to calculate sex ratios.
** Not available.

killing spider monkey in the dry season because they are lean during that period (Indians personal communication), what could have influenced its low numbers in the dry season.

In the case of howler monkeys, they are frequently seen in the *Igapós* (flooded forests) during the wet season in the study area. They often stay close to the river edges and can be easily seen and killed from the boats (authors personal observations). Waimiri Atroari Indians organized hunting trips to the *Igapós* specifically targeting howler monkeys during the wet season. *Terra firme* forest contains more game species targeted by the Waimiri Atroari than do flooded forests, making hunting less directed towards a particular species in this habitat. The directed search for howler monkeys in the *Igapós* may have influenced the seasonal pattern encountered for this species in this study.

The amount of game was positively correlated to hunting effort (Figure 3), but the analysis of covariance (ANCOVA $F_{1,47} = 3.09$, $P = 0.025$) indicated differences among villages. The Tukey test could not detect the differences but the least square difference (LSD) test (Wilkinson 1990) indicated that the villages Maikon and Mynawa tend to have a lower capture per unit of effort than the villages Xeri, Maryda and Iawara. However, none of the relations indicate a decline in slope in capture with increase in hunting effort.

Multi-Dimensional Scale analysis (MDS) (Belbin 1992) was used to create the axes that best describe the variation in hunted items among the five villages in the

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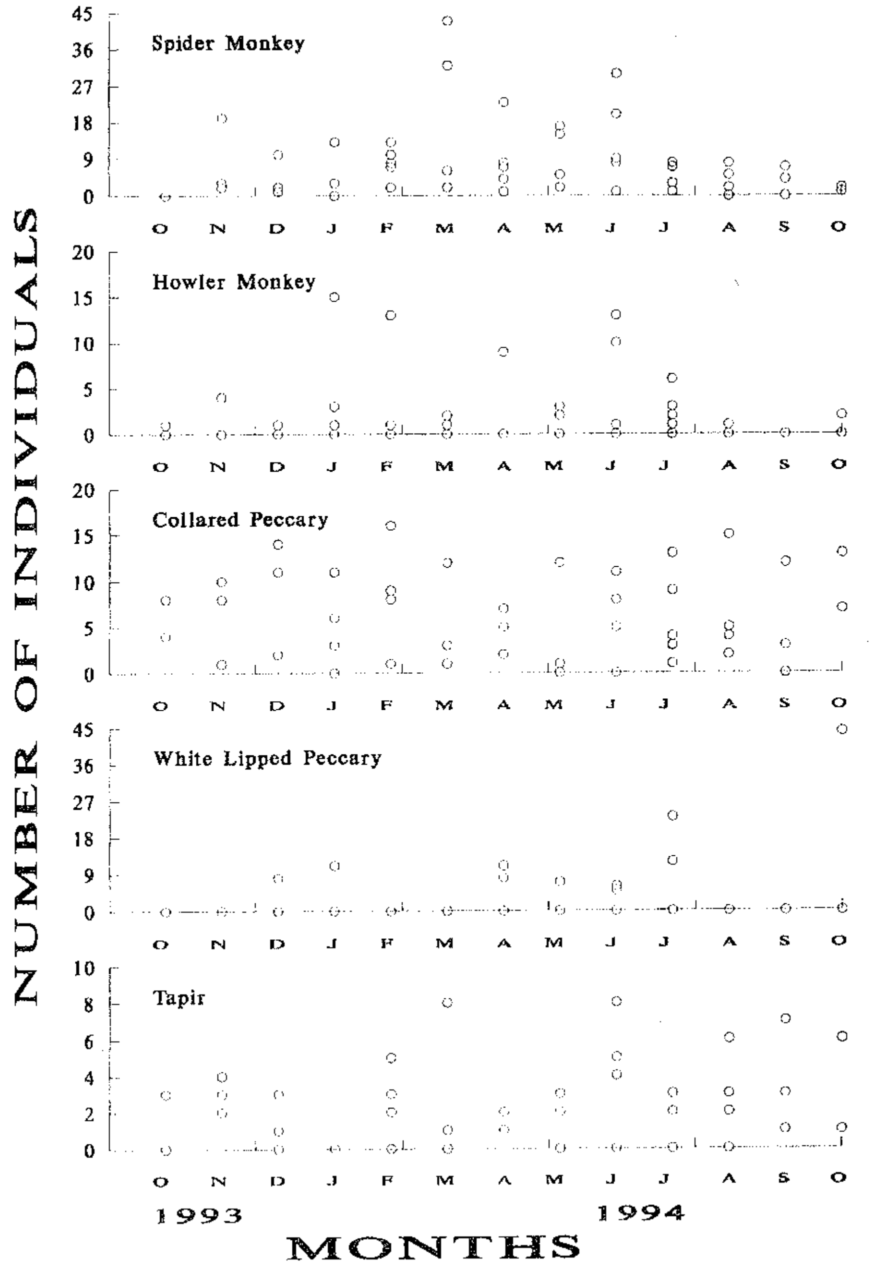

Figure 2. Number of individuals of the main game species hunted along the year in each village during the study period.

six periods of the year. Ordination of villages based on the body mass of the 16 most-hunted species did not separate well villages of different ages. This ordination explained 84% of the variance in the association matrix ($r^2 = 0.84$) but there was

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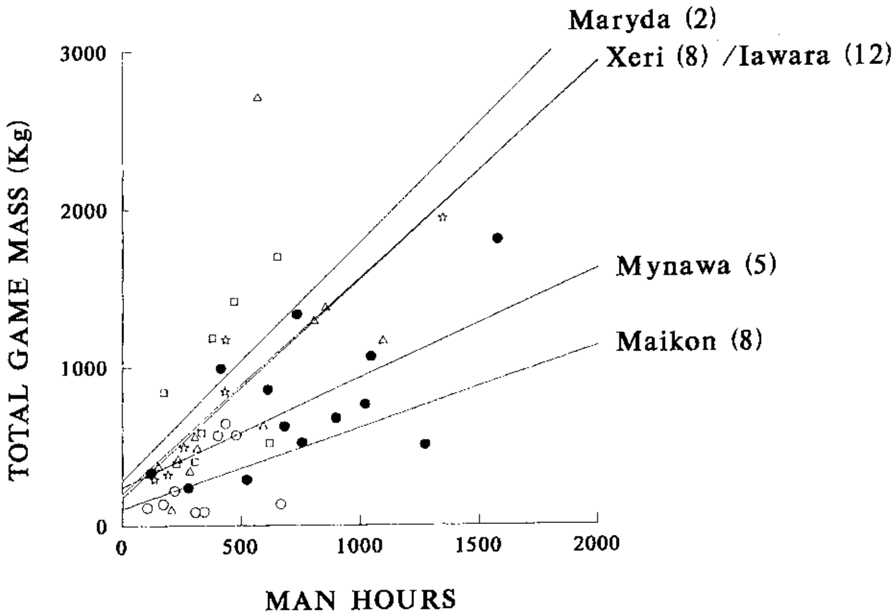

Figure 3. Total game mass harvested per month as a function of monthly hunting efforts in each village. ( ) Settlement age. Mynawa = solid circles, Xeri = triangles, Iawara = star, Maikon = open circles and Maryda = open squares.

a high residual variation (stress = 0.32) indicating only weak relations among the 16 most-hunted species. Analysis of variance indicated that the variation was not related to villages ($F_{0.05,1,15} = 0.78$, $P = 0.55$) or periods ($F_{0.05,1,15} = 0.66$, $P = 0.65$). MDS graphs in two dimensions also showed weak aggregation for villages (Figure 4A) and periods of the year (Figure 4B), so general conclusions can probably be applied for the five villages for all months of the year.

Indians living close to the highway often use trucks to reach hunting areas far from the villages (>25 km) The biomass of animals killed per unit of effort was much higher in the distant hunting sites, possibly indicating over-hunting in areas close to the settlement, for Mynawa village (Figure 5). Capture per unit of effort of tapir, spider monkey and collared peccary was also higher in more distant sites for this village (Figure 6). Data were not available for the other villages.

Discussion

The Waimiri Atroari Indians from five villages extracted nearly 44,000 kg of animal biomass in one year. Most of this biomass was represented by large mammals such as tapir, collared and white-lipped peccary, with small mammals representing only a small percentage of the total harvest. Harvesting of paca, agouti and acouchy per consumer-year was much lower than for tapirs, both peccaries and spider

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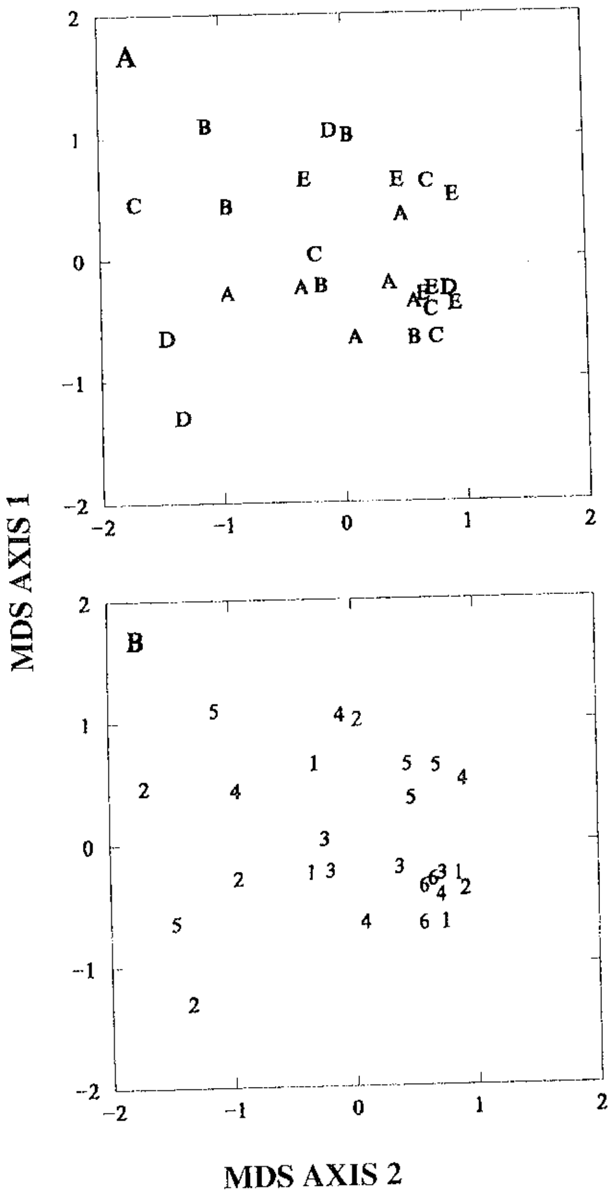

Figure 4. Ordination axes based on species composition for villages (A) and periods (B) of the year. A = Mynawa, B = Xeri, C = Iawara, D = Maikon, D = Maryda. 1 = No/Dc; 2 = Jan/Feb; 3 = Mar/Apr, 4 = May/Jun; 5 = Jul/Aug and 6 = Sep/Oct.

monkeys (Table 3) in spite of their high densities in the wild (Robinson and Redford 1986), indicating that the Waimiri Atroari are selecting larger animals. These findings differ from Redford and Robinson (1987) but agree with other studies (Vickers 1991; Alvard et al. 1997).

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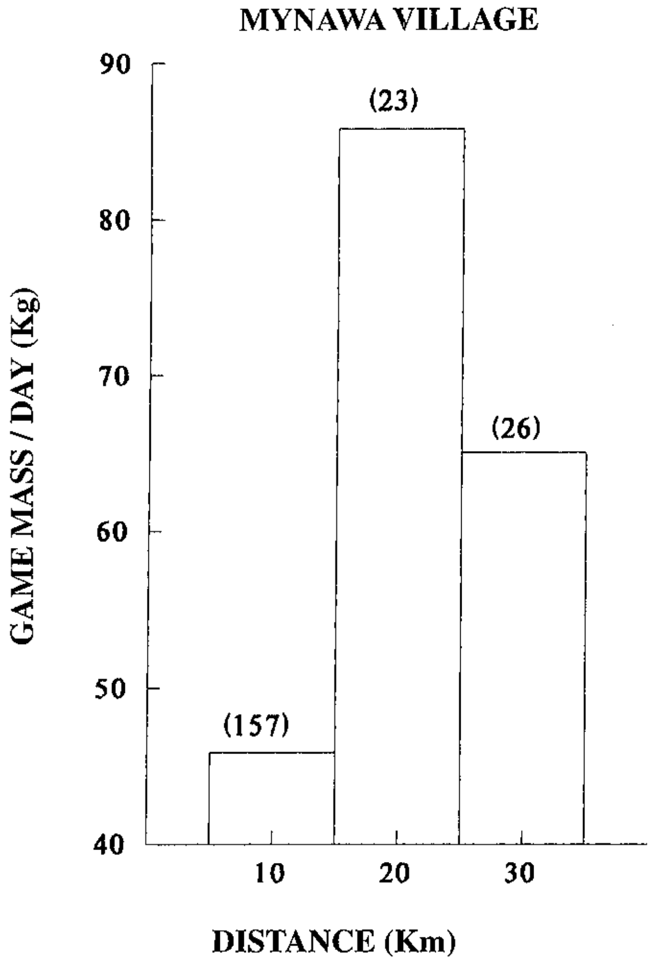

Figure 5. Total game mass (kg) per hunting day at hunting sites located at three different distances from Mynawa village.

Two species of primates represented 37% of the mammal species and spider monkey was the species most often hunted by the Waimiri-Atroari ($n = 421$). Its harvesting per consumer year was at least four times higher than for other Indians (Table 3). Most spider monkeys killed were females, while the sex ratios of most other species hunted were slightly skewed towards male. Although female-biased sex ratios (1:3 among juveniles) have been reported for this species in the wild (Symington 1987, see references in Alvard 1995) the Waimiri Atroari prefer to kill female spider monkeys because their bodies have more fat than males and are considered more 'tasty' than males (Indians, personal communication). Females can be easily identified from the ground due to their conspicuous red genitalia (authors personal observations). In this case, hunting affects a segment of the population that most influences the demography

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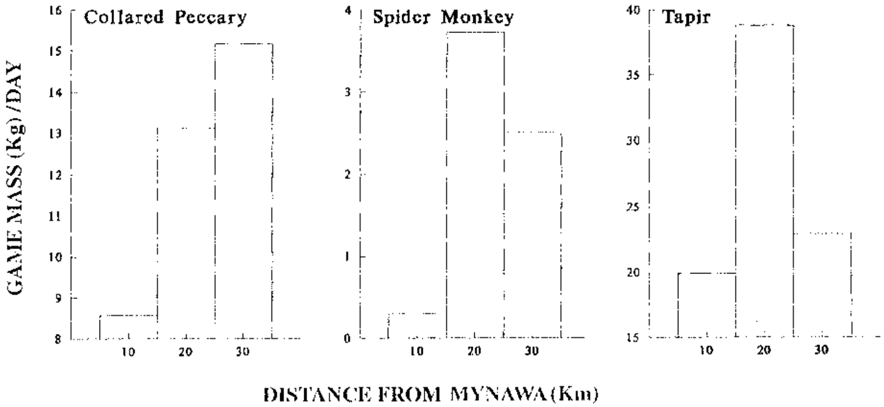

Figure 6. Game mass (in kg) of tapir, spider monkey and collared peccary per hunting day in three sites located at 3 different distances from Mynawa village. Number of hunting days at 10 km = 157, 20 km = 23, 30 km = 26.

of the species. Because the reproductive rate of the spider monkey is low (1 offspring every 3 years: Milton 1981) and hunting is concentrated on adult females, including pregnant ones, this selective hunting can reduce even more the replacement rate of the population. The spider monkey is one of the first species to disappear or became rare in areas of intensive hunting (Peres 1990; Bodmer 1994a).

After mammals, reptiles were the second most important group for the Waimiri-Atroari in number and weight. This differs from other indigenous groups in the Amazon region who consume more birds than reptiles (Vickers 1984; Redford and Robinson 1987). Townsend (1996) found the same trend among the Sirionо in Bolivia, although 57% of the reptile catch was the freshwater turtle *Podocnemis unifilis*, while the yellow-footed tortoise *Geochelone denticulata* was the most frequently collected item of all species in this study. Although the Waimiri Atroari do not hunt specifically for tortoises as happens among the Kaapor (Balée 1985), they are always collected when the Indians hunt for other items. Therefore, hunting for prey such as tapir and peccary which occur in low densities, indirectly affects the tortoise population, because it increases the area of tortoise collection. The body weight of *Geochelone denticulata* rarely reached more than 4 kg (personal observation), indicating that large individuals may be becoming rare in the area.

The Waimiri Atroari used 14 species of birds as food but they hunt more intensively large birds such as curassows and trumpeters. Harvest per consumer-year for these species was similar to other indigenous groups (Redford and Robinson 1987). Curassows and trumpeters are also the main bird species consumed by the Siona-Secoya (Vickers 1976), the Waorani (Yost and Kelley 1983) and the Bari Indians in Colombia (Beckerman 1980).

The high harvest rates of large mammals among the Waimiri Atroari during this study differ from other Amazonian groups. High harvest rates of large species have

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been associated with the use of shotguns (Yost and Kelley 1983) and dogs for hunting. The Waimiri Atroari use shotguns frequently (although there are only two to four shotguns available per village), but they also hunt with bow and arrow and normally take both when hunting. Tapir, monkey and peccary are frequently killed with both weapons (Souza-Mazurek, personal observation). The Waimiri Atroari also used dogs regularly when hunting during the study period. The presence of peccaries in the harvest was frequently associated with the use of dogs (Souza-Mazurek, personal observation) and probably influenced the high capture rates of this species.

Another possible explanation for the high harvest is that the Waimiri Atroari have access to trucks and can exploit distant sites that are under low hunting pressure and the density of large species is probably high in those areas (Hames and Vickers 1982; Bodmer 1994).

Analysis of capture per unit of effort as a function of age of the settlement and distance from the village

The amount of game harvested by the Waimiri Atroari was proportional to hunting effort in all villages. A positive linear relationship between the number of hours hunting and the amount of game obtained indicates that game is still available in the area. However, the villages of Maikon (8 years old) and Mynawa (5 years old) had lower CPUE than the other villages. The villages Maikon and Xeri have the same number of people and same age of settlement and were expected to have similar CPUE, but Xeri had a much higher CPUE than Maikon. This difference may be due to the fact that Indians from Xeri frequently use trucks to go hunting in more distant hunting sites that are under low hunting pressure and probably have more game. Hunters from Iawara, a 12-year-old village, also use trucks to go hunting and the CPUE for Iawara is as high as Xeri. Hames and Vickers (1982) and Alvard (1994) showed that distant hunting sites produce higher hunting yields than areas near villages due to depletion near the settlements. This trend is likely to be more evident for villages established in the same site for a long period of time.

Indians from Maikon, on the other hand, go hunting on foot and the low CPUE found in this village probably reflects an over-exploitation of game in nearby areas. The area where Maikon is located is not particularly poor in animals because the CPUE in Maryda, established in the same region only 2 years ago, is much higher than in Maikon.

Mynawa was the second village with a low CPUE. It is the largest village with 100 people, twice the number found in the other villages. It is possible that they are already having problems with game depletion in spite of having transportation to hunt in more distant areas. CPUE of collared peccary, spider monkey and tapir is higher in more distant hunting sites for this village, indicating game depletion in the nearby areas. The fact that this village is in the process of division may also support this hypothesis.

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This study shows that, in general, the Waimiri-Atroari are not lacking food due to over-exploitation of resources as suggested for other tribes in the Amazon region (Hames 1980; Alvard et al. 1997). They can still concentrate their hunting efforts on the 'noble' but most susceptible species such as tapir and spider monkey. However, these species are already becoming rare in areas close to settlements, and transportation is only a short-term solution. Also, Mynawa and Maikon seem to be suffering localized effects of game depletion. It is likely that the high CPUE found in Maryda will diminish with time due to intensive use of hunting areas close to the village. As an alternative to using only remote areas for preferred species they could consider a system of rotation of hunting sites to allow keep large game to survive in areas close to their villages. Simple source and sink models, to be used in subsistence hunting studies as proposed by Novaro et al. (1997) may not work in areas where Indians have modern transportation and can go far ('source' areas) and consequently have larger hunting areas than if they were hunting on foot. Indians hunting on foot can walk a maximum distance of 10 km from the settlement (Vickers 1984; Alvard 1997) generating an associated hunting area of 314 km^2. Waimiri Atroari Indians using trucks can have a hunting area of approximately 1000 km^2, considering a 314 km^2 area around the settlement plus a 600 km^2 rectangular area along the highway axis (60 km $\times$ 10 km). If all villages have the same potential to exploit the same size area, (as villages living along the rivers do because they have motorboats), their catchment area would occupy half the size of the Waimiri Atroari Reserve and 'source' areas, as proposed by the model, would not exist, considering the spatial distribution of the villages inside the Reserve. More complex models that include highly mobile hunters should be developed because the use of modern technology is becoming more common among indigenous peoples. The number of villages is also changing. Five new settlements were formed since this study was done, and we expect that the type of hunting impact we identified in this study will spread over even larger areas of the Reserve.

Long-term studies are being carried out to detect changes in composition and quantity of the species hunted and in the size of the catchment area over time. Data collected in one year are not sufficient to give a reliable interpretation of the sustainability of hunted species (Vickers 1991). In addition, the Waimiri Atroari population is growing by 7% per year indicating the need for much more food resources in the near future.

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