HUNTING IMPACTS ASSOCIATED WITH BRAZIL NUT HARVESTING IN THE BOLIVIAN AMAZON

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ABSTRACT

We assessed the hunting practiced by workers on a 63,900 ha - Brazil nut gathering property on the Madre de Dios River, northern Bolivia (11º 54' 05" S; 67º 57' 31" W). During 45 days of the dry season, we monitored 18 nut storage depots ranging from the central depot (the "Barraca") to remote sites. We recorded species, weight, and hunting technique for all harvested mammals, birds and reptiles. Number of individuals and total biomass harvested per person and per day were estimated for different taxa and compared between depots near to and far from the central Barraca. The recorded harvest included 445 individual animals (total biomass 2,428 kg) belonging to 61 species. Of these, mammals contributed 26 species, 55.3% of individuals and 88.8% of biomass. Birds (29 species) contributed 40% of individuals and 6.7% of biomass, whereas reptiles (6 species) contributed 4.7% individuals and 4.5% of biomass. Per capita harvest rates for the14 most closely monitored depots were 0.072 animals/person/day (s.d.=0.036) and 0.367 kg/person/ day (s.d.=0.241). Harvest rates for primates were lesser near the Barraca than in more remote depots. Successful hunting trips averaged 6.98 hr (range 1-44) and yielded on average 1.53 animals per trip or 0.22 animals per hour. Comparisons with other studies suggest that some species are suffering from a high hunting pressure and that improved practices of forest management should be applied.

KEY WORDS: *Bertholletia*, Bolivia, Brazil nuts, conservation, forest management, hunting, wildlife harvest

RESUMEN

Evaluamos la cacería practicada por trabajadores de una propiedad castañera de 63.900 ha sobre el río Madre de Dios, en el norte de Bolivia (11º 54' 05" S; 67º 57' 31" W). Durante 45 días de la estación seca monitoreamos 18 centros de almacenamiento de castaña, incluyendo la Barraca principal y los centros alejados, registrando la especie, peso y técnica de captura de los mamíferos, aves y reptiles cazados. Estimamos el número de individuos y biomasa cosechada por persona y por día para los distintos taxa y lo comparamos entre sitios cercanos y alejados de la Barraca. La cosecha registrada incluyó 445 animales (biomasa estimada 2.428 kg) pertenecientes a 61 especies, en la cual los mamíferos contribuyeron con 26 especies, 55,3% de los individuos y 88,8% de la biomasa. Las aves (29 especies) contribuyeron con el 40,0% de los individuos y 6,7% de la biomasa, mientras que los reptiles (6 especies) representaron el 4,7% de los individuos y el 4,5% de la biomasa. La tasa de cosecha per capita para 14 centros con mayor esfuerzo de monitoreo tuvo una media de 0,072 animales/persona/día (s.d.=0,036) y 0,367 kg/persona/día (s.d.= 0.241). Las tasas de cosecha de primates en los centros próximos a la Barraca fueron menores que para los centros más alejados. Las salidas de caza exitosas duraron en promedio 6,98 hr (rango 1 - 44) y reportaron un promedio de 1,53 animales por jornada y 0,22 animales por hora. Comparaciones con otros estudios sugieren que algunas especies están sufriendo un fuerte impacto y que debería adoptarse nuevas prácticas de manejo de recursos forestales.

PALABRAS CLAVE: *Bertholletia*, Bolivia, cacería, castaña, conservación, cosecha vida silvestre, manejo forestal

RESUMO

Avaliámos a caça praticada pelos trabalhadores duma propiedade de castanha de 63,900 ha sobre o rio Madre de Dios ao norte da Bolivia (11˚54`05``S; 67˚57`31``W). Durante 45 dias da estação seca monitoramos 18 centros de depósito de castanha incluindo a barraca principal e os centros afastados, registrando a espécie, o peso e a técnica de captação dós mamíferos, aves e répteis caçados. Avaluamos o número de indivíduos e a biomassa colheitada por pessoa e por dia para os diferentes taxa e comparamos entre lugares próximos e afastados da barraca. A colheita registrada incluiu 445 animais (biomassa avaliada 2428 kg) que pertencen a 61 espécies. Os mamíferos contribuíram com 26 espécies, 55.3% dos individuos e 88.8% da biomassa. As aves (29 espécies) contribuíram com o 40.0% dos indivíduos e o 6.7% da biomassa, e os répteis (6 espécies) representaram o 4.7% dos indivíduos e o 4.5% da biomassa. A taxa de colheita per cápita para 14 centros com maior esforço de monitoreio teve uma média de 0.072 animais/pessoa/dia (d.s.=0.241). As taxas de colheita de primates nos centros próximos à barraca foram menores que para os centros mais afastados. As saidas de caça com bom êxito duraram uma média de 6.98 hr (intervalo 1-44) e tiveram uma média de 1.53 animais por jornada e 0.22 animais por hora. Comparações com outros estudos sugerem que algumas espécies sofrem actualmente um forte impacto e que são necessarias novas praticas de manejo dos recursos florestais.

PALAVRAS CHAVE: *Bertholletia*, Bolivia, caça, castanha, colheita da vida silvestre, conservação, manejo florestal

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The extraction of non-timber forest products such as "castaña" or Brazil nut (*Bertholletia excelsa*), rubber (*Hevea brasiliensis*) and palm heart (*Euterpe precatoria*) has a long tradition in the Departments of La Paz, Pando, and Beni, northern Bolivia. Bolivia became the world's largest Brazil nut exporter between 1989-1991, with exports totaling $15 million in 1990 (Beekma *et al*. 1996, López 1993). Brazil nut extraction occurs over 8,744 km^2 in Pando Department (PLUS 1996). The labor of extraction involves a large population of seasonal workers, about 10,000 families of "castañeros" coming from nearby cities and towns during the wet season "zafra" of Brazil nuts (December to March)(Beekma *et al.* 1996). "Castañeros" are paid by the nut volume (or "box") they harvest and are charged for the food and supplies delivered to the forest for their consumption. As in other tropical countries, these extractive activities have largely depended on bush meat to feed work crews. In Bolivia, the use of bush meat to support field workers is associated with timber extraction in Santa Cruz (Rumiz *et al*. 2001, Solar 1996) and other extractive activities elsewhere in the country (Ribera 1996).

In the Neotropics, hunting is often associated with a sub-

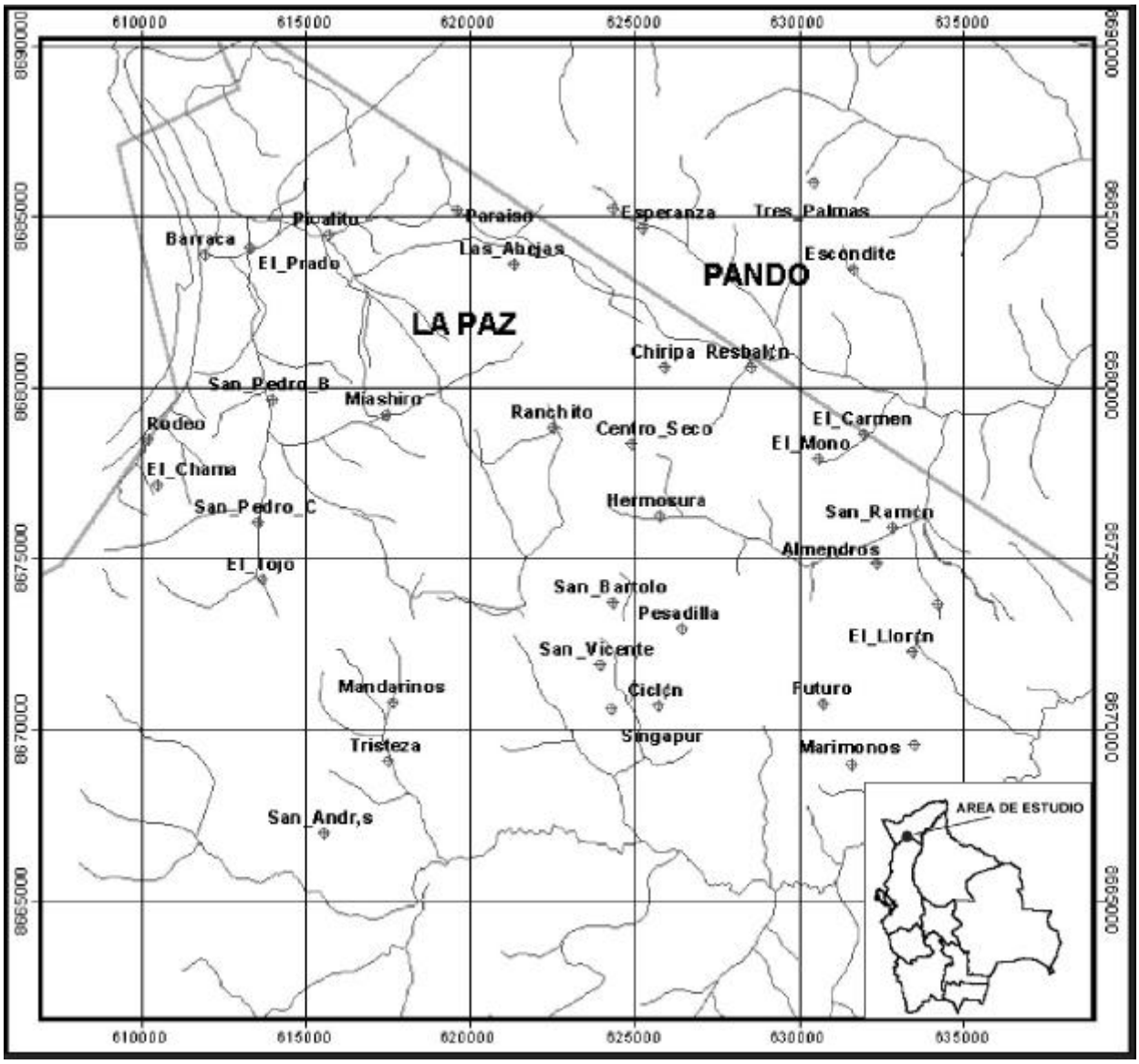

Figure 1. Map of the study area showing Brazil nut storage centers, streams, roads, and limits of the property.

stantial decline in wildlife populations, for example ungulates and primates (Bodmer *et al*. 1994, Bodmer *et al*. 1997*a*, Fragoso 1991, Peres 1990, 2000) and cracids (Begazo 1997, Cox 1992, Silva and Strahl 1991). The extinction or marked reduction in the abundance of large vertebrates may have manifold effects on forest dynamics because these species are often agents of herbivory, seed predation, seed dispersal, and predation on herbivores (Redford 1992, Terborgh 1992).

Responding to concerns about the loss of biodiversity in Bolivian forests, the BOLFOR project (USAID / Government of Bolivia) carried out monitoring studies whose goal was the sustainable use of forest resources. These included studies on the hunting associated with Brazil nut and palm heart extraction, in order to develop guidelines for reducing the negative effects these activities may have on wildlife. We report preliminary data on hunting recorded during 45 days of field work in different nut storage depots (the large, central "barraca" and smaller "payoles") on a Brazil nut property in the Amazon region of Bolivia. We describe patterns of wildlife harvesting during this period, and for certain game species, we analyze harvest rates in order to evaluate the potential sustainability of such wildlife harvest.

STUDY AREA

We carried out the study within a 63,940 ha property on the Río Madre de Dios (11º54'05''S; 67º57'31''W), covering

parts of Provincia Iturralde (Department of La Paz) and Provincia Madre de Dios (Department of Pando) in the north of Bolivia (Fig. 1). The site is quite isolated, reached from Riberalta only by light plane or by an 8-hr road trip followed by 30 hrs on the Río Madre de Dios. The climate is tropical wet; mean daily temperature varies between 25º and 27ºC except for occasional cold fronts coming from the south ("surazos"), while annual rainfall varies between 1800 and 2200 mm. The period June through August is considered the dry season (Beekma *et al.* 1996, Killeen *et al*.1993). Following Holdridge (1967), the life zone is tropical wet premontane forest, while Killeen *et al*. (1993) described the vegetation as Amazonian forest, with evergreen tree species spreading into three or more strata.

METHODS

Worker Movements and Population

The study took place during the dry season, the period of "jornaleo," in which longer term employees or seasonal workers remaining from the "zafra," are monthly employed to transport nuts stored at depots and to maintain roads and facilities. According to the administrator's report, seasonal activity at the property is divided into three periods which vary little between years. In 1997/98 the "zafra" lasted 132 days (November to March) and involved 682 people; the transitional period lasted 105 days (April-July) and involved 30 people, and the "jornaleo" lasted 105 days (July-October) and involved 172 people. During our 45-day study in this "jornaleo" season, the 172 workers and family members formed eleven groups and worked in and around 18 nut-storage depots. Depots were located along three main roads and trails converging into the main "Barraca" or port on the river (Fig. 1). Neighboring depots were 5 to 10 km apart from each other. Workers and families moved in groups between depots. The Barraca was constantly inhabited but there was high turnover.

Wildlife Harvest Monitoring

For 45 days (13 July to 28 August, 1998), we collected qualitative and quantitative data on the hunting practiced at 18 depots. We stayed from one to three days at each depot and made return visits in order to record hunting first-hand and to conduct interviews about prey taken while we were at other sites. During each visit we identified, measured and weighed each prey item actually observed and accompanied hunters on their trips whenever possible. Prey reported by hunters for days in-between our visits were confirmed later by examining skulls, hairs, skins, feathers, and carapaces. If no animal remains were available, we double-checked reports with other persons at the depot. Mammal identifications followed Emmons and Feer (1990) and Anderson (1997). Bird identifications were based on Hilty and Brown (1986), Narosky and Yzurieta (1987), Ridgely and Tudor (1994), and the list of Bolivian birds compiled by the organization Armonía (1995).

We estimated mean mass for each prey species from the weights of harvested animals (about 16% of all harvested individuals) using spring scales. Individuals that could not be weighed were assigned an estimated weight based on the interview with the hunter. Assigned masses always fell within ranges reported in the literature. We estimated harvested biomass by multiplying the number of individuals hunted by mean mass for each species.

Estimating Monitoring Effort and Harvest Rates

The worker population at each depot and the length of its monitoring period varied as shipping and maintenance tasks were completed and people moved to other depots. Monitoring effort was expressed as "person days", the number of workers (and family) present at the depot times the number of days of monitoring (direct or indirect, through interviews)(Table 1). The central depot (Barraca) was monitored throughout the 45 days; 13 other depots were monitored from 16 to around 30 days each, covering all or the most part of the depot's period of activity. Four depots (Escondido, Ranchito, San Pedro B and San Ramón) were monitored for 8 days or less due to logistic limitations. In six depots where the number of people changed during the monitoring period, sampling effort was calculated for each sub-period and these weighed values were then summed. Although spread over 45 days, our total monitoring effort (6035 person days) represented an effective sample of 35 days for the known worker plus family population of 172 people.

We calculated the mean consumer population per depot by dividing the sampling effort (in person days) by the number of monitored days at that depot. *Per capita* rates of harvested individuals (number of animals/person/day) and biomass (kg/person/day) were estimated for each depot by dividing number of prey and biomass brought to the depot by its corresponding sampling effort. We also estimated harvest rates for selected taxa exhibiting different degrees of vulnerability to hunting pressure, such as primates, cracids, parrots and rodents (Begazo 1997, Bodmer *et al*.1997*b*; Cox and Cox 1992, Franco and Santamarina 1997), in order to compare these rates with distance from the Barraca. For this comparison, we assigned each harvested animal to the depot nearest the killing site, even if it had been harvested and consumed by people on a hunting trip from the Barraca. The fourteen best-monitored depots were divided into two groups according to their distance to the central depot, Barraca.

We used simple regression analyses to obtain values for the coefficient of determination R^2, between harvest rates and numbers of people per depot. Mann-Whitney U test was used to compare harvest rates between depots far and near the Barraca, and Spearman's rank correlation to look for association between different variables. To estimate the harvesting area size and to give an idea of hunting pressure we calculated the area of a polygon that enclosed all the depots on a map with a 1 km^2 grid.

Table 1. Number of prey and biomass harvested at 18 storage depots of a Brazil nut collecting property in northern Bolivia.

Name of Depot	No. Prey Individuals Harvested	Biomass Harvested (kg)	Monitoring Effort (Person Days)	Monitoring Period (Days)	Mean No. Persons/ Depot	No. of Hunters/ Depot	Mean No. Prey/ Day/Depot	Mean kg Biomass/ Day/Depot	Mean No. Prey/Person/ Day	Mean kg Biomass/ Person/Day
Barraca*	117	543.70	1550	45	34.4	25	2.60	12.08	0.075	0.351
Chama*	32	264.45	381	43	8.9	7	0.74	6.15	0.084	0.694
Rodeo*	3	17.34	725	35	20.7	3	0.09	0.50	0.004	0.024
San Pedro C*	7	34.68	308	22	14.0	2	0.32	1.58	0.023	0.113
San Pedro B*	4	23.38	24	6	4.0	3	0.67	3.90	0.167	0.974
Tres Crucero*	18	57.48	288	16	18.0	7	1.13	3.59	0.063	0.200
Escondido	10	23.90	72	4	18.0	5	2.50	5.98	0.139	0.332
Hermosura	21	111.08	380	20	19.0	4	1.05	5.55	0.055	0.292
El Lloron	42	134.24	448	32	14.0	8	1.31	4.20	0.094	0.300
Mandarino	22	98.63	300	24	12.5	6	0.92	4.11	0.073	0.329
Pesadilla	26	101.79	352	20	17.6	7	1.30	5.09	0.074	0.289
Ranchito	5	5.60	6	2	3.0	2	2.50	2.80	0.833	0.933
Resfalón	31	169.91	306	17	18.0	8	1.82	9.99	0.101	0.555
San Vicente	3	12.22	54	27	2.0	1	0.11	0.45	0.056	0.226
San Ramón	20	132.29	56	8	7.0	4	2.50	16.54	0.357	2.362
Singapur	8	30.07	120	30	4.0	2	0.27	1.00	0.067	0.251
El Triunfo	46	481.61	525	35	15.0	9	1.31	13.76	0.088	0.917

*Depots near the Barraca

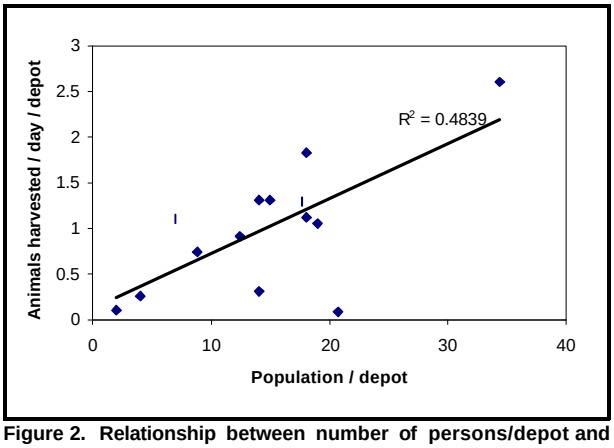

Figure 2. Relationship between number of persons/depot and number of animals harvested daily at each of 14 depots of a Brazil nut collecting property in northern Bolivia.

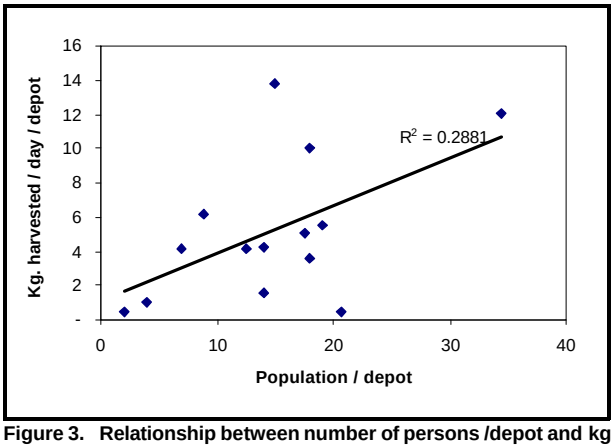

Figure 3. Relationship between number of persons /depot and kg of biomass harvested daily at each of 14 depots of a Brazil nut collecting property in northern Bolivia.

RESULTS

Wildlife Harvested

We recorded a total of 445 hunted animals of 61 species. Of these, 55.3% were mammals (26 spp), 40.0% birds (29 spp) and 4.7% reptiles (6 spp) (Appendix A). Fifty-two species were harvested for food while a few individuals (5 mammals, 2 birds and 2 reptiles) were hunted for other reasons. Two snakes (*Boa constrictor* and *Lachesis muta)* were killed for their skins, two birds (both *Trogon melanurus)* for fishing bait, and several unidentified wild cats (ocelot, margay?) were shot (and killed) as target practice. We recorded a few young monkeys and parrots being kept as pets, but did not include them in our analyses.

Total harvested biomass was estimated at 2,427.88 kg (without fish), comprising 88.8% mammals, 6.7% birds, and 4.5% reptiles. The harvest included seven orders of mammals, of which primates were the most species-rich group. Rodents were the most abundant (43.5%) in terms of individ uals harvested, followed by primates (25.2%) and ungulates (19.9%). *Agouti paca* was the most hunted species (71 individuals), followed by *Cebus apella* (25), *Pecari tajacu* (23), and *Dasyprocta variegata* (18) (Appendix A). In terms of biomass, ungulates were the most important taxa with 53.2% of all mammalian biomass, followed by rodents (22.4%), primates (8.0%), and carnivores (7.0%). *Tayassu pecari* was the species contributing most of the mammalian biomass (32.9%), followed by *A. paca* (19%), *M. guazoupira* (8.8%), and *P. tajacu* (8.1%).

Workers hunted 29 bird species belonging to 12 families,

Table 2. Total harvest and harvest rates (ind/day) for selected game taxa at the 14 best-monitored Brazil nut depots.

Name of	No. of Captured Individuals				Per Capita Capture Rate (n/person/day)			
Depot	Primates	Rodents	Cracids	Psittacids	Primates	Rodents	Cracids	Psittacids
Barraca*	4	26	8	2	0.0026	0.0168	0.0052	0.0013
Chama*	0	7	2	1	0	0.0184	0.0052	0.0026
Rodeo*	0	3	0	0	0	0.0041	0	0
El Prado*	0	8	0	2	0	0.0571	0	0.0143
San Pedro C*	0	4	0	0	0	0.0130	0	0
Tres Crucero*	1	1	2	0	0.0035	0.0035	0.0069	0
Hermosura	12	3	0	2	0.0316	0.0079	0	0.0053
El Lloron	3	4	4	3	0.0067	0.0089	0.0089	0.0067
Mandarino	9	6	6	1	0.0300	0.0200	0.0200	0.0033
Pesadilla	4	7	4	4	0.0114	0.0199	0.0114	0.0114
Resfalón	9	8	8	15	0.0294	0.0261	0.0261	0.0490
San Vicente	0	1	1	0	0	0.0185	0.0185	0
Singapur	1	2	1	1	0.0083	0.0167	0.0083	0.0083
El Triunfo	4	4	12	3	0.0076	0.0076	0.0229	0.0057
TOTAL	47	84	48	34	0.1311	0.2385	0.1335	0.1079
MEAN	3.3571	6.0000	3.4286	2.4286	0.0094	0.0170	0.0095	0.0077

*Depots near the Barraca

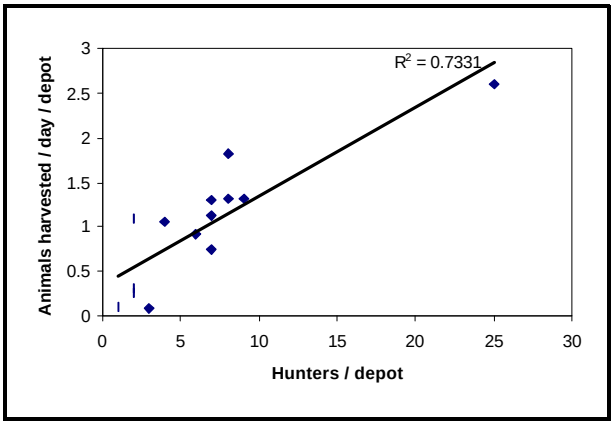

Figure 4. Relationship between number of hunters and number of animals harvested daily at each of the 14 depots of a Brazil nut collecting property in northern Bolivia.

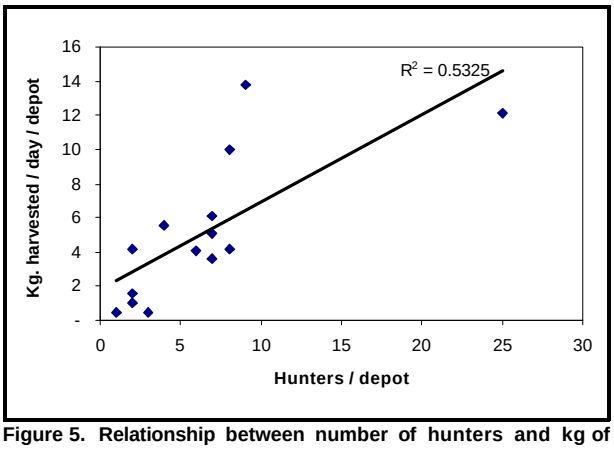

Figure 5. Relationship between number of hunters and kg of biomass harvested daily at each of 14 depots of a Brazil nut collecting property in northern Bolivia.

of which the tinamous (Tinamidae) contributed 6 species (Appendix A). Guans and curassows (Cracidae) were the most abundant birds in the harvest (30.9% of all individuals), followed by Psittacidae (24.2%) and Tinamidae (18.5%). The guan *Penelope jacquacu* was the most harvested bird (51 individuals), followed by the parrot *Amazona farinosa* (22), *Tinamus guttatus* (15) and *Ara macao* (11). The three bird families contributing most of the individuals were also the most important by biomass. Of a total of 162.97 kg, Cracidae made up 45.9%, Psittacidae 23.9% and Tinamidae 18.7%.

Among reptiles, the river turtle *Podocnemis unifilis* contributed 9 of 22 individuals, while the land tortoise *Chelonoidis denticulata* and the cayman *Caiman crocodilus* each contributed four. In terms of biomass, *C. crocodilus* was the most important with 55.1%, followed by *P. unifilis* (24.7%) and *C. denticulata* (19.2%) (Appendix A).

People also consumed fish obtained from the Madre de Dios River and smaller streams. Most commonly harvested species were *Pimelodus* sp, *Hydrolicus scomberoides*, *Geophagus* sp, *Prochilodus* sp and *Hoplias malabaricus*, belonging to the fish families Pimelodidae, Characidae, Cichlidae, Prochilodontidae and Erithrynidae, respectively. Generally, fish were small, contributed only 40.39 kg (1.6%) to the total harvested biomass, and were not used further in analyses.

Wildlife Harvested by Depot and *Per Capita*

Wildlife harvested at each of the 18 depots, and recorded

Table 3. Hunting pressure index (hpi = no. ind./km^2) for mammals and birds estimated during a 35-day sampling period and extrapolated to 342 days of yearly activity and fluctuating worker population at the property.

Species Harvested	No. Individuals Harvested in Sample	hpi (n/km^2) in Sample	No. Individuals Extrapolated 1 yr	hpi (n/km^2) Extrapolated 1 yr
Dasypus kappleri	8	0.017	147.80	0.32
Saguinus fuscicollis	7	0.015	129.30	0.28
Callicebus moloch	8	0.017	147.80	0.32
Saimiri sciurus	4	0.009	73.90	0.16
Cebus apella	25	0.054	461.80	0.99
Cebus albifrons	4	0.009	73.90	0.16
Alouatta seniculus	13	0.028	240.10	0.51
Ateles paniscus	1	0.002	18.50	0.04
Nasua nasua	9	0.019	166.20	0.36
Potos flavus	2	0.004	36.90	0.08
Tapirus terrestris	1	0.002	18.50	0.04
Tayassu pecari	23	0.049	424.80	0.91
Pecari tajacu	9	0.019	166.20	0.36
Mazama americana	3	0.006	55.40	0.12
Mazama guazoupira	14	0.030	258.60	0.55
Sciurus spadiceus	16	0.034	295.50	0.63
Sciurus ignitus?	2	0.004	36.90	0.08
Agouti paca	71	0.152	1,311.40	2.81
Dasyprocta variegata	18	0.039	332.50	0.71
Tinamus tao	2	0.004	36.94	0.08
Tinamus major	6	0.013	110.82	0.24
Tinamus guttatus	15	0.032	277.05	0.59
Crypturellus cinereus	7	0.015	129.29	0.28
Crypturellus soui	2	0.004	36.94	0.08
Ortalis motmot	1	0.002	18.47	0.04
Penelope jacquacu	51	0.109	941.97	2.02
Mitu tuberosa	3	0.006	55.41	0.12
Odontophorus guyanensis	2	0.004	36.94	0.08
Psophia leucoptera	8	0.017	147.76	0.32
Zenaida auriculata	5	0.011	92.35	0.20
Ara macao	11	0.024	203.17	0.44
Ara chloropthera	3	0.006	55.41	0.12
Amazona ochrocephala	5	0.011	92.35	0.20
Amazona farinosa	22	0.047	406.34	0.87
Trogon melanurus	8	0.017	147.76	0.32
Ramphastos cuvieri	8	0.017	147.76	0.32
Cephalopterus ornatus	3	0.006	55.41	0.12

during periods from 2 to 45 days, ranged from 3 to 117 individual animals and from 6 to 544 kg of biomass. As explained above, major contributions to this variation were the different sampling durations and different numbers of people at each depot. Daily and *per capita* rates tell a different story (Table 1). Mean number of prey harvested daily by depot averaged 1.24 ind/day (range= 0.11-2.6, sd= 0.844) while mean daily harvested biomass per depot averaged 5.63 kg/day (range=0.45-12.08, sd= 4.596) across the 18 depots. *Per capita* harvest rates averaged 0.139 ind/person/day/depot (range= 0.004-0.833, sd= 0.189) and 0.541 kg/person/day/depot (range= 0.024-2.362, sd= 0.536). The per capita averages and their wide variation decreased to 0.072 ind/pers/day (sd=0.036) and 0.367 kg/pers/day (sd= 0.241) when the four depots monitored 8 days or less were excluded from the analysis.

Not surprisingly, across 14 depots total daily harvest was positively related to total number of people at the depot. Nevertheless, number of people per depot explained only 48% of the variance on number of animals taken daily (R^2=0.48; F=11.36; df=1, 13; P=0.006; Fig. 2 and 29% of the variance on biomass harvested per day (R^2=0.288; F=4.86; df=1, 13; P=0.048; Fig 3). In Figs. 2-3 is also obvious a strong influence of the Barraca (a large population and harvest [leverage between 0.5 and 0.8 in the regressions]) and two small depots (a few people and a small harvest) on the regression slope, while the eleven medium size depots (with 10-20 people) were more variable and unpredictable in their harvest. The number of hunters per depot, however, was a better predictor of daily harvest of individual prey (R^2=0.73; F=33.09; df=1, 13; P<0.001; Fig 4) and biomass (R^2=0.53; F=13.67; df=1, 13; P=0.003; Fig 5), suggesting that number of guns or able hunters was a more important determinant of total harvest than was consumer population size. A strong positive correlation existed between the number of game individuals and biomass harvested (r_s=0.84; df=13; P<0.001).

Comparing Game Harvest at Depots Near and Far from the Barraca

Bush meat consumption seemed similar among the 14 best-monitored depots since the *per capita* harvest rate medians for individuals and biomass were not significantly different between "near" and "far" depots (U=20; df=1, 12; P=0.60, and U=21; df=1, 12; P=0.70, respectively; Table 1). However, species groups known to be vulnerable to hunting, such as primates, cracids and psittacids, were harvested at lower rates near the Barraca than in more remote depots (U=4; df=1, 12; P=0.008; U=4.5; df=1, 12; P=0.011; U=10.5, P=0.078, respectively; Table 2) suggesting they were rarer or more difficult to hunt in the more heavily impacted area. The more resilient rodents, on the contrary, did not show differences in the median harvest rates between depot groups (U=19; df=1, 12; P=0.52). It should be pointed out that rodents were hunted at all 14 depots, while primates were bagged only in 2 out of the 6 depots near the Barraca. The only hunted spider monkey *Ateles paniscus*, a highly preferred and vulnerable game species, came from a depot 35 km away from the Barraca. Other vulnerable species, such as tapirs *Tapirus terrestris* and curassows *Mitu tuberosa* were only captured at a distance of 18 km or more away.

Hunting Techniques and Success

The hunters consisted of 68 male workers (mostly around 30 yr of age or younger), 37 of whom harvested 85% of the sample, killing between 4 and 29 animals each. The hunters used 0.22-caliber rifles for 62% of the kills, and 16-gauge shotguns for 34%. A few animals were trapped, killed with machetes or captured bare handed. Active hunting provided 63.6% of the kills: 55.3% through searches along paths and 8.3% by stalking. Casual encounters resulted in 36.1% of kills and trapping in 1.3%.

Of the 68 hunters, 53 reported the duration of (or were registered completing) 231 successful journeys of active hunting (searches and stalking). Since unsuccessful trips

could not be confidently recorded, only journeys with at least one animal harvested were used to estimate the rate of success. Hunting trips averaged 6.98 hrs in length (range 1-44 hr) and yielded a mean of 1.53 animals per hunter per trip or 0.22 animals per hour. Number of prey per hunter per trip was not correlated with mean trip length for each hunter.

The area impacted by hunting during this 45-day "jornaleo" period was estimated at 467 km^2, which represented 73% of the 639 km^2 property.

DISCUSSION

Wildlife Harvesting Patterns and Declining Game Populations

Although the most widely hunted taxa tend to be consistent throughout lowland Neotropical forests (Ojasti 1993), the composition of the harvest varies with cultural differences among hunters and among the ecological conditions of sites (Redford and Robinson 1987, Vickers 1984). For example, colonist hunters tend to be more selective than their indigenous counterparts, consuming fewer arboreal animals, while native hunters usually show greater harvest rates and a long list of prey taxa (Redford and Robinson 1987). Cultural and biological factors, as well as the physical, social and economic context of the sites have been also described as affecting the sustainability of hunting (Bennett and Robinson 2000).

In the present study, the harvest by these non-indigenous hunters consisted of 61 prey species, including some with small body size: squirrels, tamarins, and birds. The composition of this harvest (26 species of mammals, 29 of birds and 6 reptiles) was more diverse than that of the harvest recorded in Santa Cruz (Rumiz *et al*. 2001) during a corporate timber operation (19, 8 and 3 species, respectively) and in one study of indigenous subsistence hunting (27, 8 and 3 spp). In the Beni savanna-forest ecosystem, Townsend (1996) reported a similar prey spectrum (26, 33, and 7 species) during her long-term study on the indigenous Siriono. The diverse harvest of our study may reflect the high species richness of Pando's Amazonian forests but may also result from the high protein needs of the workers. Beef or canned foods are difficult to obtain in places as remote as these depots, or if available are very costly for the local workers. Although the "castañeros" we interviewed stated preferences for a few game species (*Tayassu, Mazama, Agouti,* large monkeys), these were often unavailable. Therefore, they had to subsist on smaller and less preferred food species.

Hunting has been practiced for years on this Brazil nut property, and there is evidence that hunting pressure on some species has not been sustainable. The comparison of hunting rates on selected species between near and remote depots indicates that vulnerable groups such as primates were depleted near the Barraca while less sensitive species such as large rodents were still hunted at a constant rate in the more intensively-used area.

In our study, number of prey/hunter/trip was not associated with mean trip length of each hunter probably because of wide variation in hunting ability among group members. Mean number of animals harvested per hunting trip (1.53 ind) or per hour (0.22 ind) resembles the hunting success of loggers in other Bolivian forest with little prior hunting pressure (1.03 ind./trip, 0.30 ind/hour, based on successful trips only, Solar 1996). However, due to the lesser mean prey weight (5.45 kg *vs* 18.6 kg) and the longer trips (6.98 hr *vs* 3.46 hr) on our study, biomass yields per hour of active hunting (1.20 kg/h *vs* 5.53 kg/h) were lesser than in the logging site study (Solar 1996). Hunting by the Huaorani in Ecuador (Mena *et al*. 2000) also showed greater returns (2.8 kg/hr or 0.48 ind/hr) than in the "castañeros" case. Longer times to kill a prey and lesser returns in harvested biomass may be signs of declining game populations. This agrees with our interviews to hunters, who frequently mentioned that some years ago it was easier to find game.

Annual Cycle at the Property and Sustainability of Game Harvest

Based on the number of people living on the property during three seasonal periods of 1997/1998 (682, 30, and 172 people, during 132, 105, and 105 days, for the "zafra", transitional and "jornaleo", respectively), we estimated the annual impact to be 111,234 person-days, or about 18.5 times our "jornaleo" sample of 6,035 person-days. Among these periods, the zafra would produce the more intensive impact (90,024 person-days or 15 times our sample). Assuming that the *per capita* harvest rates we measured are maintained along the year and at different worker population levels, we extrapolated the harvest for selected mammal and bird game species to a hypothetical (342-day long) annual period of worker activity at the property (Table 3). These indices, based on a dry season sample, should be considered with caution since several species may vary seasonally in their chance to be harvested. Also, it may not be realistic to expect that a four-fold enlarged population of workers during the "zafra" will maintain the same *per capita* harvest rate as during the low population season. Although the validity of these assumptions will be tested in the near future with new data from two "zafra"operations, we used these indices in order to identify species that possibly are being harvested at unsustainable levels and will need further attention.

We compared the annual indices of hunting pressure (hpi, expressed as number of individuals hunted per km^2) with Robinson and Redford's (1991) potential maximum sustainable harvest rates (ph) proposed for some Neotropical mammals. Unfortunately, we could not estimate the harvest sustainability for birds since models similar to the ones for mammals are not available.

Species such as the red howler monkey (*A. seniculus*) (hpi=0.51, ph=0.39), the brown capuchin (*C. apella*)(hpi= 0.99, ph= 0.18), the white lipped-peccary (*T. pecari*)(hpi= 0.91, ph= 0.83), and the paca (*A. paca*)(hpi= 2.81, ph= 1.31) seemed to have been harvested above Robinson and Redford's sustainability levels. In the case of the paca, however,

it is possible that our dry season sample overestimated the annual harvest (since this animal might be more difficult to hunt during the wet season), and then its populations may be not threatened by hunting. Tapirs (*T. terrestris*)(hpi=0.04, ph= 0.03) and spider monkeys (*A. paniscus*)(hpi= 0.04, ph= 0.16) were rarely harvested (only one individual of each in our sample) despite being a preferred prey. Consistently with interviews to hunters, this indicates that tapirs and spider monkeys existed at very low densities on the property, and therefore, almost any level of harvest would be unsustainable at present time. Species such as agoutis, squirrels, armadillos, brocket deer and collared peccary seem all to be enduring harvest below critical levels and might still tolerate current hunting pressures. Although it may be surprising that species such as brown capuchins and white-lipped peccaries were still abundantly harvested, we need to confirm if hunting levels have been constant during the last decades at the property and if animals could have been coming from less-hunted "source" areas in the surroundings. We finally warn readers against considering these extrapolations as harvest rates for a whole year until our estimates are corrected with sampling during the "zafra" season.

Hunting and Sustainable Forest Management

Whether or not it poses a threat to wildlife populations, hunting associated with forestry operations is currently prohibited by Bolivian laws (DS 22641 Ley de Veda General Indefinida, Ley Forestal 1700). Although these laws are ambivalent with regard to indigenous communities, their right to practice subsistence hunting within their communal territories, is recognized elsewhere. The issue is addressed by the national standards for forest management certification, in which guidelines are intended to mitigate environmental impacts of logging and subsistence hunting in production forests (CFV 2000). Still, the legal definition of subsistence hunting does not apply to employees of forest concessions or properties. Such workers should ideally be supplied with enough food so that they need not hunt for bush meat. Extraction of Brazil nuts is a forest activity often labeled as "sustainable" and having a "low environmental impact" because only the fallen seeds of an abundant tree species are extracted. Nevertheless, the current practice of hunting to provide food for field workers appears uncontrolled with a marked impact on some wildlife populations. New management practices should be adopted to reduce this environmental impact, to improve working conditions of nut harvesters, and to allow the promotion of the Brazil nut as a certified forest product (CFV 2001). These practices should focus initially on the protection of threatened animal species (giant armadillos, spider monkeys, tapirs, white-lipped peccaries, cracids), a general reduction of hunting (control of harvest for pets, trade of wildlife products, entry of guns and ammunition), and the use of alternative sources of food protein.

The Bolivian government is promoting the sustainable use of fauna by local communities through current programs aimed to harvest wool from wild vicugnas and skins from wild caimans. The apparent abundance of certain game species in Pando, despite extensive hunting, suggests the possibility of using some of them sustainably, thus, enhancing the economic value and conservation of forests.

On biological grounds, we can propose some forest dwelling species as subject for sustainable harvest from natural populations in Bolivia (highly productive, robust wildlife species such as long-nosed armadillos, agoutis, pacas, brocket deer and collared peccaries). However, such a harvest still needs definitions on aspects of legal framework, social context, administrative control, and wildlife monitoring responsibilities before being implemented.

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Appendix A. Mammals, birds and reptiles (species, number of individuals, weight, and percent contribution) harvested by field workers at a Brazil nut collecting property in northern Bolivia.

	Local Name	Number of Individuals	Mean Weight (kg)	Harvested Biomass (kg)	Percent Number of Individuals	Percent Weight
MAMMALS						
Marsupialia		1		1.25	0.41	0.06
Didelphis sp.	carachupa	1	1.25[a]	1.25	0.41	0.06
Xenarthra		11		111.70	4.48	5.18
Tamandua tetradactyla	oso hormiga	1	4.32[b]	4.32	0.41	0.20
Cabassous unicinctus	mete	1	2.00	2.00	0.41	0.09
Dasypus novencinctus	tatu 9 bandas	1	2.50	2.50	0.41	0.12
Dasypus kappleri	tatu quince kilos	8	12.86	102.88	3.25	4.77
Primates		62		173.00	25.21	8.02
Saguinus fuscicollis	mono leoncito	7	0.50	3.50	2.85	0.16
Callicebus moloch	lucachi	8	0.91	7.28	3.25	0.34
Saimiri sciurus	chichilo	4	0.93	3.72	1.63	0.17
Cebus apella	silbador	25	2.85	71.25	10.16	3.30
Cebus albifrons	toranso	4	2.92	11.68	1.63	0.54
Alouatta seniculus	manechi colorado	13	4.89	63.57	5.28	2.95
Ateles paniscus	marimono	1	12.00	12.00	0.41	0.56
Carnivora		15		151.00	6.10	7.01
Nasua nasua	tejón	9	4.50	40.50	3.66	1.88
Potos flavus	wichi	2	2.00[b]	4.00	0.81	0.19
Felis pardalis	tigrecillo	2	13.00[b]	26.00	0.81	1.21
Felis wiedi	gato del monte	1	6.00[c]	6.00	0.41	0.28
Felis concolor	león	1	74.50[c]	74.50	0.41	3.45
Perissodactyla		1		90.00	0.41	4.17
Tapirus terrestris	anta	1	90.00	90.00	0.41	4.17
Artiodactyla		49		1,147.39	19.92	53.20
Tayassu pecari	chancho de tropa	23	30.82	708.86	9.35	32.86
Pecari tajacu	taitetú	9	19.33	173.97	3.66	8.07
Mazama americana	huaso	3	25.00	75.00	1.63	3.48
Mazama guazoupira	hurina	14	13.54	189.56		8.79
Rodentia		107		482.56	43.49	22.38
Sciurus spadiceus	ardilla roja	16	0.59	410.38	28.86	19.03
Sciurus ignitus?	ardilla marrón	2	0.23[c]	62.28	7.32	2.89
Agouti paca	jochi pintado	71	5.78	9.44	6.50	0.44
Dasyprocta variegata	jochi colorado	18	3.46	0.46	0.81	0.02
Subtotal		246		2,156.90	100	100
BIRDS						
Tinamidae		33		30.46	18.53	18.69
Tinamus tao	perdiz azul	2	1.50	3.00	1.12	1.84
Tinamus major	perdiz cab. choca	6	1.50	9.00	3.37	5.52
Tinamus guttatus	perdiz urucú	15	0.83	12.45	8.43	7.64
Crypturellus cinereus	perdiz cocinera	7	0.63	4.41	3.93	2.71
Crypturellus soui	perdiz uiriri	2	0.30	0.60	1.12	0.37
NI	perdiz juan juan	1	1.00	1.00	0.56	0.61
Falconidae		2			1.12	
Ictinia plumbea	chuvi	1			0.56	
NI	chuvi	1			0.56	
Cracidae		55		74.75	30.90	45.87
Ortalis motmot	huaracachi	1	0.50	0.50	0.56	0.31
Penelope jacquacu	pava coto rojo	51	1.25	63.75	28.65	39.12
Mitu tuberosa	pava mutum	3	3.50	10.50	1.69	6.44
Phasianidae		2		0.60	1.12	0.37
Odontophorus guyanensis	uabucuru	2	0.30	0.60	1.12	0.37
Psophidae		8		9.12	4.49	5.60
Psophia leucoptera	yacami	8	1.14	9.12	4.49	5.60
Columbidae		7		2.00	3.93	1.23
Columba speciosa	torcaza	1	0.50	0.50	0.56	0.31
Columba cayanensis	torcaza	1	0.50	0.50	0.56	0.31
Zenaida auriculata	torcaza	5	0.20	1.00	2.81	0.61

Appendix A. (Continued).

	Local Name	Number of Ind.ividuals	Mean Weight (kg)	Harvested Biomass (kg)	Percent Number of Individuals	Percent Weight
Psittasidae		43		38.99	24.16	23.92
Ara macao	paraba 7 colores	11	1.19	13.09	6.18	8.03
Ara chloropthera	paraba	3	1.03	3.09	1.69	1.90
Brotogeris cyanoptera	pacula	2			1.12	
Amazona ochrocephala	loro frente amarilla	5	0.69	3.45	2.81	2.12
Amazona farinosa	loro cenizo	22	0.88	19.36	12.36	11.88
Trogonidae		8		0.80	4.49	0.49
Trogon melanurus	aurora	8	0.10	0.80	4.49	0.49
Bucconidae		5			2.81	
Nystalus chacuru?	bati bati	5			2.81	
Ramphastidae		11		5.45	6.17	3.34
Pteroglossus castanotis?	tucancillo	1	0.20	0.20	0.56	0.12
Pteroglossus beauharhaesii	tucancilllo	1	0.20	0.20	0.56	0.12
Ramphastos cuvieri	tucán	8	0.60	4.80	4.49	2.95
NI	tucancillo	1	0.25	0.25	0.56	0.15
Cotingidae		3		0.60	0.56	0.37
Cephalopterus ornatus	pajaro toro	3	0.20	0.60	1.69	0.37
Icteridae		1		0.20	0.56	0.12
Psaracolius bifasciatus	tojo	1	0.20	0.20	0.56	0.12
Subtotal		178		162.97	100	100
REPTILES						
Pelomedusidae						
Podocnemis unifilis	peta de agua	9	2.97[b]	26.73	42.90	24.75
Testudinidae						
Chelonoidis denticulata	peta del seco	4	5.19[b]	20.76	19.00	19.22
Chelidae						
Phrynops sp	galápago	1	1.00	1.00	4.80	0.93
Aligatoridae						
Caiman crocodilus	lagarto	4	14.88	59.52	19.00	55.11
Boidae						
Boa constrictor	boye	1	nc[d]		4.80	
Viperidae						
Lachesis muta	pucarara	2	nc[d]		9.50	
Subtotal		21		108.01	100.00	100.00

[a]Silva and Strahl (1996)
[b]Townsend (1996)
[c]Emmons and Feer (1990)
[d]nc- not consumed