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Assessing the sustainability of brocket deer hunting in the Tamshiyacu-Tahuayo Communal Reserve, northeastern Peru

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Abstract

Since the 1800s, brocket deer have been an important source of meat and income for subsistence and professional hunters in the Peruvian Amazon. Today, local people continue to hunt brocket deer for subsistence meat and for sale in local meat markets. Although brocket deer are not hunted as frequently as peccaries, they make a significant contribution to rural household economies. This study assessed the sustainability of hunting of brocket deer by local communities in the Tamshiyacu Tahuayo Communal Reserve (TTCR), northeastern Peru. We analyzed data from 1991 to 1999 using density comparisons, hunting pressures, an age structure model, and a harvest model comparing results between heavily hunted, slightly hunted, and non-hunted sites. The four approaches agreed that brocket deer are harvested sustainably. The sustainability of brocket deer hunting will depend on the continued presence of other valuable wildlife species (e.g. peccaries and large rodents), which are more preferred due to their ease of hunting and higher rates of encounters. Gross productivity indicates that brocket deer are showing resilience in the form of density dependent reproductive adjustments in the TTCR, but they may still be vulnerable to overhunting. Consequently, current levels of harvesting may be continued until further ecological and biological information on the species' population trends assist in defining more reliable sustainable offtake levels.

Keywords: *Mazama americana*; *Mazama gouazoubira*; Brocket deer; Sustainability of hunting; Peruvian Amazon

1. Introduction

Sustainable use of wildlife implies that people can use species for subsistence without destroying the possibility that future generations can use these resources in similar ways (Allen and Edwards, 1995; Robinson and Bennet, 2000). This strategy is based on the assumption that the economic value of wild resources can gradually improve user's well being and consequently positively affect the conservation of species and habitats (Balmford et al., 1992; Noonan et al., 1982). However, this requires combined efforts of social and natural scientists to provide the technical information and assistance to people who make decisions on resource use (Western and Wright, 1994). In this paper, we use a case study to examine the relationship between rural people and subsistence hunting of brocket deer.

Red brocket deer (*Mazama americana*) and gray brocket deer (*M. gouazoubira*) are the most abundant and widely distributed cervids in Neotropical forests (Eisenberg and Redford, 1999). These species are usually sympatric in the Amazon basin, but differ in their habitat use (Bodmer, 1989). Red and gray brocket deer are two of the most preferred game species throughout the Amazon basin (Robinson and Redford, 1991a; Robinson and Bennet, 2000), providing a complementary source of revenue to rural households (Bodmer, 1994). Due to their relatively high reproductive rates, brocket deer are thought to be less susceptible to overharvesting than tapirs and primates (Bodmer, 1995). Studies on the preferences for wildlife meat in the Peruvian Amazon have shown that rural hunters prefer both peccaries and brocket deer (Bodmer et al., 1997a). Nevertheless, hunters concentrate their hunting efforts mainly on peccaries, agoutis, and pacas because they

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represent easier targets in contrast to brocket deer. Additionally, many indigenous groups have taboos for brocket deer, especially for gray brocket deer, and believe that their ancestors live through brocket deer spirits.

In this paper, we use data from a long-term field project to determine whether brocket deer are unsustainably harvested in the Tamshiyacu Tahuayo Communal Reserve, northeastern Peruvian Amazon. We used (a) comparisons of hunting pressures and densities of brocket deer populations between heavily hunted, slightly hunted, and non-hunted sites in the reserve, (b) an age-structure model to examine if changes in age distribution of brocket deer populations indicate overuse, and (c) a harvest model to provide a further measure of sustainability.

2. Methods

2.1. Study design

The Tamshiyacu-Tahuayo Communal Reserve (TTCR) is located in northeastern Peru in the department of Loreto and covers approximately 322,500 ha (Fig. 1). The reserve is mostly upland habitats of terra firme forests. Hunting, fishing, non-timber plant extraction, and shifting agriculture are among the main activities for rural people who live along the boundaries of the reserve (Coomes, 1992). The TTCR has three zones: (1) a permanent settlement zone, where all the people live; (2) a subsistence use zone, which has been designated for the sustainable use of natural resources, and (3) a fully protected zone, where hunting and extractive activities are not allowed. Rural inhabitants of the region are detribalized people known as ‘‘*Ribereños*.’’ These people have diverse origins. These include colonists from the Andes, varied mixtures of Peruvian and Brazilian Amazon Indians, Europeans, and Africans (Lima, 1991).

We used three different sites with three levels of hunting for this study: heavily hunted, slightly hunted, and non-hunted, which are situated along the Yavari-Miri and Blanco Rivers (Fig. 1). The Yavari-Miri and Blanco sites are separated by 180 km of continuous forests with no major rivers splitting the area. The hunted and non-hunted sites have similar fauna and flora. In a recent comparison of vegetation structure, leaf litter cover, and fruit abundance, no major differences were found among these areas (Begazo, 1999). The study site along the Tahuayo/Blanco River has a 600-km^2 catchment area of heavy hunting pressure (2.7 mammals hunted/ km^2 /year; Bodmer, 1994). The other study site along the lower Yavari-Miri River has a 1300 km^2 catchment area that is infrequently hunted (1.1 mammals hunted/ km^2 /year; Bodmer, 1994).

We assessed the harvesting of red and gray brocket deer using the following approaches: (1) population

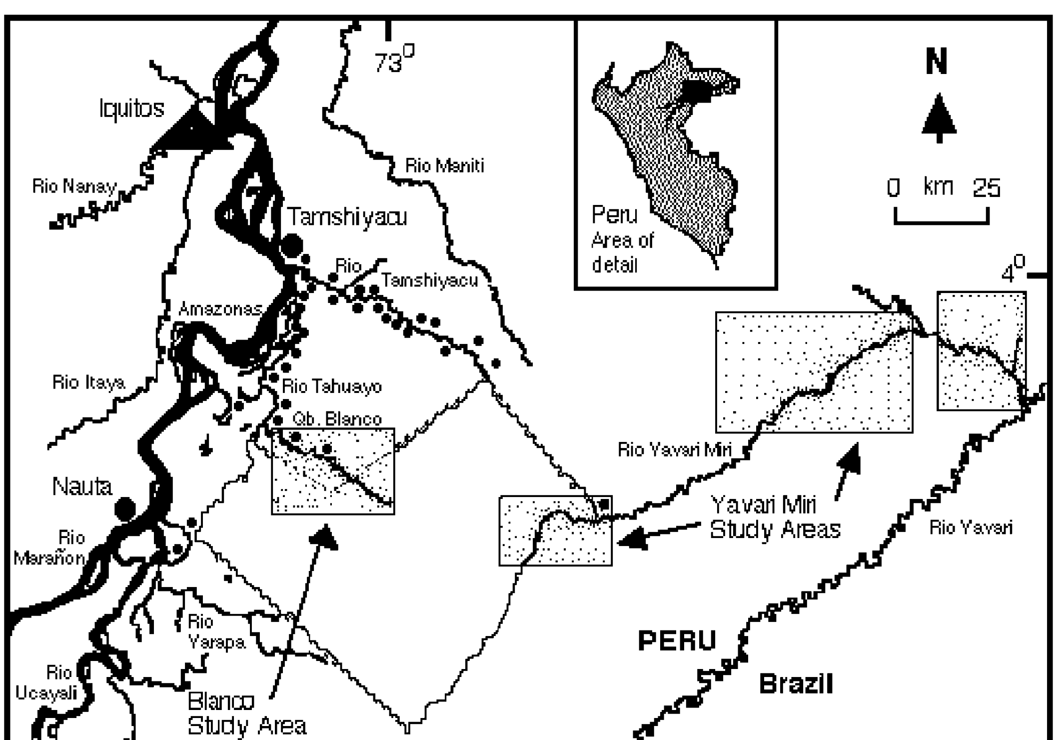

Fig. 1. Map of the Blanco and Yavari-Miri study areas at the Tamshiyacu-Tahuayo Communal Reserve, Northeastern Peru. Dots represent communities in and around the reserve.

density comparisons between heavily hunted, slightly hunted, and non-hunted sites; (2) age-class comparisons in red and gray brocket deer between the heavily and slightly hunted sites; (3) hunting pressure (number of individuals annually harvested); and, (4) a harvest model that compares production with a known harvest in a specified catchment area and provides a direct measure of overhunting.

2.2. Sample collection

From December 1991 to June 1998, hunters living in the TTCR collected reproductive tracts of does and skulls of both sexes of red and gray brocket deer as part of a participatory community-based wildlife management program. Heads are usually part of the hunters' diet. Hunters boiled, cleaned, sun dried, labeled, and stored the skulls for this study. Hunters labeled and preserved reproductive tracts in 10% formalin. Reproductive tracts included ovaries, uterus, cervix, and the cranial portion of the vagina. Labels included an individual code, date hunted, location, and name of hunter. Biological materials were stored at the Museo de Zoología de la Universidad de la Amazonia Peruana.

2.3. Data analyses

We estimated densities censusing deer during mornings and evenings using newly opened line transects, measuring perpendicular distances of the sighted animals to the trail, and estimating densities using DISTANCE (Buckland et al., 1993). Data to estimate densities came from the Tahuayo/Blanco (heavily hunted), the Lower Yavari-Miri (slightly hunted), and the Upper Yavari-Miri (non-hunted) sites, which had 923, 889, and 941 km of line, transects censused; respectively, for a total of 2753 km of census. Censuses were carried out from 1991 to 1999.

We categorized the skulls of brocket deer by age classes following methods adapted from Severinghaus (1949). This method uses similar approaches for tooth development classification, specifically for white-tailed deer (*Odocoileus virginianus*) and has been widely used for similar studies (e.g. Branan and Marchinton, 1987; Stallings, 1986; Townsend, 1995). We divided skulls into four different classes (classes I, II, III, IV), assuming 2-year intervals for each class (e.g. Class I is considered to fall between 0 and 2 years).

To calculate number of animals harvested/km^2 we used harvest data that came from (1) skulls of red and gray brocket deer collected between 1994 to 2000 and (2) written records of every animal hunters hunted since 1994. We added a 10% error to the total number of skulls. This error was estimated through informal interviews with local hunters and incorporates skulls that were missed or not collected. The total estimated catchment area is 650 km^2 for the Tahuayo/Blanco (heavily hunted site) and 1300 km^2 for Yavari-Miri (slightly hunted site).

Reproductive productivity analyses in brocket deer were adapted from Bodmer et al.'s (1997b) studies of peccaries. Age determination of fetuses was adapted from Armstrong (1950). Reproductive tracts of red brocket deer ($n = 60$) and gray brocket deer ($n = 20$) were analyzed by gross anatomical examination. We recorded pregnancy and the litter size. A doe was considered pregnant when an embryo or fetus was found in her reproductive tract. Gross examination of brocket deer reproductive tracts can usually determine pregnancy after 24 days of conception. The sex of each fetus was also noted when it was possible to differentiate. Information on pregnancy permitted an estimation of: (1) pregnancy rate (number of females pregnant/total number of females examined); (2) average litter size (number of fetuses/number of pregnant females); (3) gross productivity (number of fetuses per number of females); (4) fecundity, (number of female fetuses per total number of females examined); and, (5) fetal sex ratio (number of male fetuses/number of female fetuses)

We used a harvest model developed by Bodmer et al. (1997a,b) to compare harvest and production of brocket deer in hunted sites to help predict overhunting. The model uses production estimates derived from reproductive productivity and population density. The model assumes that the sex ratio for brocket deer is 1:1 and we considered that red and gray brocket deer had an average of 1.7 gestations per year (Muller and Duarte, 1992). The impact of hunting of brocket deer populations was determined by comparing harvest with production, calculating the proportion of production that was harvested. The proportion of production (P) that can be harvested sustainably for short-lived species is 40% (for explanation see Robinson and Redford, 1991b). The harvest model is explained mathematically as follows: $P = (0.5D)\ (Y * g)$. Where Y is the number of young recorded per female, g is the average number of gestations per year, and $0.5D$ is the population density discounted by 50% (please refer to Robinson and Bodmer, 1999; for the assumptions of the model).

3. Results

Red brocket deer are more abundant than gray brocket deer in the TTCR. The density comparisons between the treatment (hunted) and control areas (non-hunted) showed that red brocket deer have similar population densities in the heavily hunted sites (1.16 ± 0.29 individuals/km^2) and non-hunted sites (1.14 ± 0.44 individuals/km^2; Fig. 2). Gray brocket deer, however, exhibit an increase in their population density in the heavily hunted site (0.39 ± 0.07 individuals/km^2)

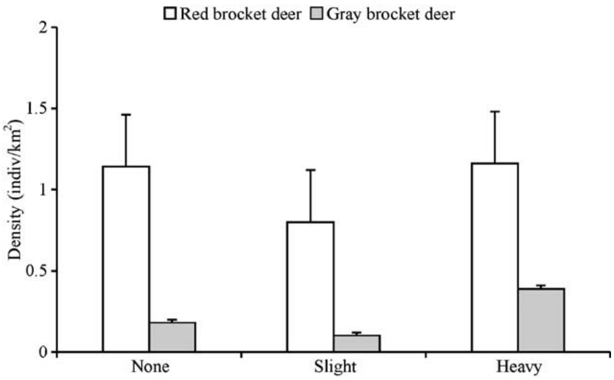

Fig. 2. Densities of red and gray brocket deer according to different hunting pressures in the TTCR. Total length of walked transects were 941 km for non-hunted, 889.5 km for slightly and 923 km for heavily hunted areas.

compared to the non-hunted sites (0.18 ± 0.09 individuals/km^2; Fig. 2).

In the heavily hunted site at the Tahuayo/Blanco, 152 red brocket deer and 39 gray brocket deer were harvested in three consecutive years (1994,1995, and 1996). The hunting pressure resulted in the extraction of 4785 kg of red brocket deer biomass and 760 kg of gray brocket deer biomass. There were 0.17 red brocket deer/km^2 and 0.04 gray brocket deer/km^2 harvested during those years. In contrast, in the slightly hunted area only 76 red brocket deer and 5 gray brocket deer were hunted from 1994 to 1996. A total of 2392 kg red brocket deer biomass and 97.4 kg gray brocket deer biomass was harvested, resulting in a hunting pressure of 0.06 red brocket deer/km^2 and 0.004 gray brocket deer/km^2 (Table 1).

The age structure of red brocket deer at Tahuayo/Blanco did not differ significantly from the Yavari-Miri site ($D = 0.58$, $P > 0.9$, Kolmogorov Smirnov; Fig. 3). In the case of gray brocket deer, the age structure of the harvested populations appears to be normally distributed between younger categories (Fig. 4). It was not possible to compare age structure between heavily and slightly hunted sites, due to number of skulls available for age determination in the latter site.

Table 1
Hunting pressure for red and gray brocket deer in the heavily and slightly hunting sites at the TTCR during 1994–1996

Hunting pressure	Heavy	Slight
Red brocket deer		
Total individuals hunted	152	76
Biomass extracted (kg)	4785	2392
Individuals hunted/ km^2	0.17	0.06
Gray brocket deer		
Total Individuals hunted	39	5
Biomass extracted (kg)	760	97.4
Individuals hunted/ km^2	0.04	0.004

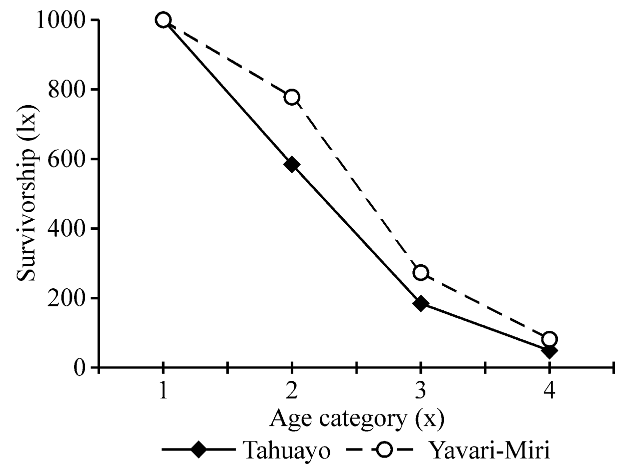

Fig. 3. Age structure of red brocket deer from Tahuayo/Blanco ($n = 245$) and Yavari-Miri ($n = 99$) at the TTCR.

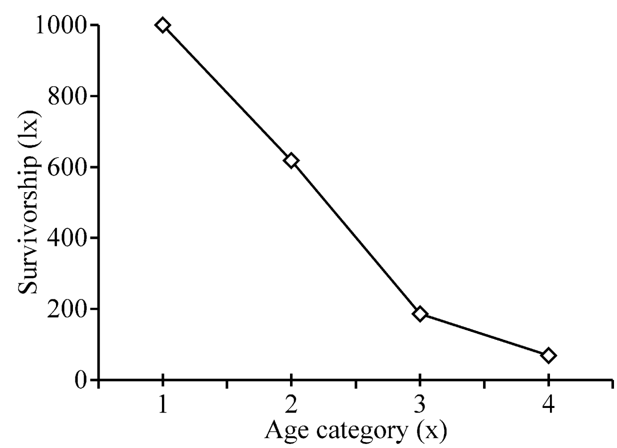

Fig. 4. Age structure of gray brocket deer ($n = 102$) from the hunted sites at the RCTT.

Gross productivity was higher for red and gray brocket deer in the heavily hunted site (0.71 fetuses/ females and 0.54 fetuses/ females, respectively) than in the slightly hunted site (0.35 fetuses/ females and 0.43 fetuses/ females, respectively). The harvest model indicated that the percentage of production taken by hunters was 24% in the heavily hunted and 18% in the slightly hunted site for red brocket deer and 22% in the heavily hunted and 6% in the slightly hunted site for gray brocket deer (Table 2).

4. Discussion

Our results suggest that red and gray brocket deer harvests are sustainable at current offtake levels in the Tamshiyacu-Tahuayo Communal Reserve. However, it is important to consider that the models we used to measure sustainability work under a number of assumptions involving the population dynamics of wildlife species (Robinson and Bodmer, 1999). The

Table 2
Calculated harvest model for red and gray brocket deer in the heavily and slightly hunting sites at the TTCR[a]

Species	Red brocket deer		Gray brocket deer	
Hunting sites	Blanco	Yavari-Miri	Blanco	Yavari-Miri
Gross productivity	0.71	0.35	0.54	0.43
Gestations/year	1.7	1.7	1.7	1.7
0.5 * Density	0.58±0.15	0.4±0.13	0.2±0.03	0.09±0.05
Annual production	0.70	0.24	0.18	0.07
Hunting pressure	0.17	0.06	0.04	0.004
% Production harvested	24%	25%	22%	6%

[a] 0.5 * Density is expressed as the mean±S.D.

density comparisons do not include density-dependent responses, the age models assume age structure responses to overhunting and the harvest model assumes a closed population and factors in natural mortality as a variable in the limit of sustainability. Thus, we acknowledge that the results are not conclusive, but taken in aggregate lessen the probability of an incorrect deduction.

The results can help rural communities in developing guidelines for the management of brocket deer in the Peruvian Amazon. Most of the studies that have analyzed sustainability of hunting of wildlife species across the neotropics also reported that brocket deer harvests are within sustainable limits (Alvard, 1993; Ascorra, 1997; Bodmer, 1995; Hill and Padwe, 2000; Leeuwenberg and Robinson, 2000; Mena et al,. 2000; Mitchell and Raez, 1991; Townsend, 1995). Nevertheless, not all the studies have used similar methods to deduce their results. For instance, the Ache in the Mbarayacu Reserve in Paraguay underharvest red brocket deer in comparison to their estimated density (1.7 individuals/km^2, similar to this study). Aches consider red brocket deer wary, difficult to hunt with bow and arrow and consequently unimportant and not preferred as a source of protein (Hill and Padwee, 2000). In contrast, The Piros in Madre de Dios in Peru, who have overexploited tapirs and primates around their boundaries, still are able to hunt brocket deer as frequently as they are found, and these species together with peccaries represent their most important source of protein (Alvard, 1993; Mitchell and Raez, 1991). Additionally, in the TTCR, brocket deer meat is sold for cash in rural and urban markets. Hunters kill an estimated 6000 individuals of red and gray brocket deer annually in the northeastern Peruvian Amazon alone (Bodmer and Pezo, 2000). As we can surmise from these three cases, preferences for red and gray brocket deer have different factors acting upon hunters' decision whether or not to hunt brocket deer. For some communities brocket deer might be simply unimportant, for others seems to be more valuable as a dietary component, and for others they are an essential source of income.

Brocket deer show an increase in their gross productivity and relative densities in the heavily hunted areas compared to the slightly hunted and unhunted areas in the TTCR. Results concur with previous vulnerability analyses in which Bodmer (1995) and Bodmer et al. (1997b) suggested that red and gray brocket deer are less vulnerable to overhunting because they have faster rates of reproduction and intrinsic rates of population increase in contrast to other species. These factors together with the species behavior, ability of dispersal, and difficulty of capture elucidate why some wildlife species are less susceptible to hunting (FitzGibbon et al., 1995; Peres, 1990).

The results obtained using the harvest model (Bodmer et al., 1997a,b) should be interpreted as the level at which brocket deer hunted populations must be maintained for them not to decline (Robinson and Bodmer, 1999). Additionally, the harvest model provides information of the proportion of brocket deer born each year that can be safely taken. The model requires density of individuals present in a non-hunted or slightly hunted area to be compared with the density of individuals in heavily hunted areas. Results from these comparisons are assumed to provide information on how much the population has been depleted. Moreover, the number of pregnant animals killed offers information on birth rates. As a ballpark figure, the harvest of a relatively fast breeder like brocket deer should comprise only 40% of the newborns (see Robinson & Redford 1991b) and this may help maintain sustainability.

As conservationists, we aim to minimize the risks that a population declines to extinction, and as wildlife managers, we seek to decrease, increase, or maintain current extraction levels that will not ''affect'' game species (Leopold, 1933). Hence, we must consider all the factors that may influence the sustainable use of species. For instance, the resilience that red and gray brocket deer show to hunting in the TTCR does not mean they cannot be overharvested. Although both species respond well to disturbed habitats (Jorgenson, 1993; Leeuwenberg et al., 1999; Linares, 1976), their populations can also be overexploited (Julia and Richard, 1997; Leni, 1999). Additionally, rareness of species should be considered. Estimated densities showed that gray brocket deer is less abundant than red brocket deer in the TTCR. This result is vital for conservation purposes of the species since gray brocket deer is rare in other regions of Peru as well (Ascorra, 1997; Alvard, 1993; Aquino et al., 1999; Bodmer et al., 1999). Thus, caution should be warranted when recommending levels of harvest for gray brocket deer. The sustainable use of brocket deer also relies on hunters taking the more common wildlife species sustainably. In the TTCR hunters normally concentrate on white-lipped and collared peccaries, agoutis, and pacas, which are generally easier to hunt (Bodmer, 1994).

In conclusion, the combination of the four models supports our hypothesis of sustainability of harvest of the standing populations of red and gray brocket deer in the TTCR. Moreover, current offtake rates should be maintained until new information can be incorporated in new harvest models to obtain more reliable offtake rates. We have used four different models in order to increase the confidence of interpreting sustainability. It is necessary to involve local communities in the management of their own resources and recognize the cultural value and traditional knowledge of the species and habitats. In other areas of the Peruvian Amazon, reproductive biology of brocket deer species, habitat availability, the presence of source areas and socio-economic issues must be analyzed further. Management must protect the most vulnerable species, gray brocket deer, which is less abundant, and has a more restrictive habitat than red brocket deer.

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