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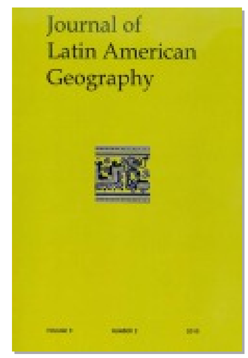

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Abstract
Hunting remains an important subsistence activity for many indigenous peoples of the Neotropics. This paper describes indigenous hunting patterns using a mixed-methods approach in southern Guyana from a space and place perspective that takes into account both biophysical and cultural/spiritual factors. Findings confirm those of others, that distance from community, mediated by characteristics of the biophysical environment, impacts where hunters go. Mapping of the spiritual landscape, however, demonstrates that sense of place is also important. This paper argues that researchers and managers should be careful to incorporate both the local environmental and cultural/spiritual contexts in studies that inform biodiversity and sustainable resource-use management.
Keywords: *indigenous hunting, place, Makushi, geographic information systems*

Resumen
La cacería persiste como una actividad importante de subsistencia para muchos pueblos indígenas de los neotrópicos. Aquí describimos los patrones de cacería en el sur de Guyana usando un método mixto, desde una perspectiva del espacio y lugar que toma en

cuenta factores biofísicos y culturales. Nuestros resultados coinciden con los de otros investigadores, en que la distancia del pueblo, mediada por la característica del ambiente físico, afecta las zonas donde actúan los cazadores. Nuestro mapeo del paisaje cultural, demuestra que el 'sentido de lugar' también es importante. Argumentamos que los investigadores y los que manejan estos territorios deben incluir, no solamente el ambiente físico, sino el contexto cultural que forma parte de la biodiversidad y el manejo y uso de los recursos sustentables.

Palabras clave: *cacería indígena, lugar, Makushi, sistemas de información geográficos*

Introduction

The livelihoods of many indigenous peoples of Amazonia continue to be subsistence-oriented, being largely dependent on both swidden agriculture and resources found in the surrounding landscape, including plants, fish, and wildlife. As well as representing a major source of protein, hunting activities and game animals are intimately linked to the cosmologies of these cultures. In attempting to understand patterns of hunting on the landscape, it is important not only to consider influencing factors that relate to the biophysical environment in space and time, such as species abundances and logistical factors (i.e., the amount of effort required to bring home a kill), but also cultural factors, such as meat preferences, taboos, and other proscriptions and prescriptions that affect how people interact with, and relate to, those spaces, that is, the meaning that humans give to the landscape. This latter aspect refers to the much discussed notion of a "sense of place" (Tuan, 1975; Pred, 1984; Massey, 1994). Directly or indirectly, the concept of place has influenced studies of the interface between human and natural systems, such as Forbes-Boyte's 1988 study that looked at notions of place in North American indigenous cultures. Despite Fragoso *et al.* (2000), Whitehead (2003:60), and Silvius (2004) all advocating the need for researchers to take into account how resource use by indigenous peoples is governed by their cultural and spiritual understandings in addition to ecological factors, few, if any, have attempted to analyze hunting patterns in neotropical indigenous populations based on both space and place.

There exists a wide literature on indigenous hunting that deals with either biophysical or cultural aspects. Some of the key factors that have been identified as influencing where people hunt include the degree of effort involved with respect to gains, ease of accessibility, animal ecologies, whether the hunting activity is opportunistic, such as occurs when someone stumbles across an animal usually during a primary activity such as fishing or walking to a farm, or part of a planned trip, and cultural factors, such as rules that control resource-use areas or the targeting or avoidance of sacred sites (Dunn, 2004). These factors all have implications for sustainability of hunting and the conservation of wildlife populations.

Ecological studies that have examined the impacts of hunting on wildlife include those focusing on hunting effort and harvest rates (Alvard *et al.*, 1997; Souza-Mazurek *et al.*, 2000), impacts of hunting on encounter rates (Hill et al., 1997; Fragoso *et al.*, 2000) and animal density estimates (Levi *et al.*, 2009). While many, but not all, of these studies analyze patterns of hunting as they relate to biophysical characteristics (type of habitat/vegetation, distance from village, or access through roads or rivers; Smith, 2008; Dunn, 2004), much of the research in the neotropics investigating cultural, and specifically spiritual, factors has tended to focus on the aspatial aspects of hunting, such as food taboos (including what and when certain animals can or cannot be eaten) and importance in festivals (Hill and Hawkes, 1983; Redford and Robinson, 1987; Silvius, 2004). This may be due to the challenges inherent in mapping cultural versus biophysical components of landscapes – or place as opposed to space. And yet, all factors that affect human decisions of where to hunt will have important implications for the dynamics of animal populations (Fragoso *et al.*, 2000; Novaro *et al.*, 2000; Naranjo and Bodmer, 2007) and therefore for hunting sustainability, and must be incorporated into analyses of hunting patterns (Dudley *et al.*, 2009). To the authors' knowledge, only one study (Dunn, 2004) has analyzed indigenous hunting patterns in the neotropics through combining both biophysical and cosmological factors in a spatial analytical environment. This study contributes to the incorporation of spiritual factors into hunting studies by mapping the locations of sites in an indigenous landscape and assessing the influence of these sites, among other factors, on hunting kill locations over a three-year study period.

Physical factors affecting hunting patterns

The distance that hunters travel to a hunting site is seen as an important indicator of a number of factors relating to hunting systems (Fragoso *et al.*, 2000; Peres, 2000). Distance is often used as an approximation of the amount of effort that a hunter can or will invest in order to successfully forage. It is assumed that hunters will stay close to their community or point of access to a hunting area if the animals are present. For example, Broseth and Pedersen (2000), studying ptarmigan (*Lagopus lagopus*) hunting in Norway, found that hunting intensity (activity) decreased with distance from the start point, with 82 percent of hunting pressure occurring within 2.5 km of the start point. Likewise, Smith (2008), working in western Panama, found that hunting was concentrated within 2 km of indigenous peoples' homes, and Hill *et al.* (1997), working in Paraguay with the Aché Indians, found that distance was a good indicator of hunting pressure, with hunters staying close to access points and the frequency of hunter signs (such as disturbed vegetation, hunting camps or hideouts, litter, foot or horse tracks etc.) approaching zero no more than 10 km from the nearest access point. Many researchers use this relationship between distance and hunting pressure to examine the sustainability of hunting systems and the existence of source-sink animal population dynamics; for example, relating the distance that hunters will travel to measures of animal encounters, animal densities, or hunting yields, has provided some evidence of local depletion of commonly-hunted animals around population centers (Fragoso, 1991; Hill *et al.*, 1997; Fragoso *et al.*, 2000; Souza-Mazurek *et al.*, 2000; Siren *et al.* 2004; Naranjo and Bodmer, 2007; Zapata-Rios *et al.* 2009; Endo *et al.* 2010).

Accessibility is another important factor that influences hunting activities. Accessibility and distance are related, and rivers, roads, and modes of transport can impact how far hunters will go. For example, Souza-Mazurek *et al.* (2000) suggest that the Waimiri Atroari of central Brazilian Amazonia experience higher hunting yields than other groups, as a result of increased access to distant sites via roads and trucks. Natural phenomena such as topography and seasonal flooding are also likely to have an impact on ease of access and where hunters may be active.

Animal habitats also influence patterns of hunting (Hill *et al.*, 1997); for instance deep forest, early successional stages/fallow areas, or swidden gardens all attract different animal species (Wadley and Colfer, 2004). Dunn (2004), working in Honduras, found 65 percent of indigenous hunting yield to derive from mature forest habitat, but also found garden hunting to be important. Gardens attract and support wildlife and can help to keep animal densities high (Jorgenson, 2000), thus hunting in gardens is common, not only as a planned activity but also opportunistically, with the added advantage that it also serves as pest control and can occur alongside other activities such as tending crops (Naughton-Treves *et al.*, 2003; Smith, 2005; Parry *et al.*, 2009). Abandoned garden sites continue to be visited by semi-nomadic indigenous peoples for hunting as well as for gathering of perennial crops that persist after cessation of active cultivation; these form part of a mosaic anthropogenic landscape that influences where hunting takes place (Good, 1989).

Cultural and spiritual factors affecting hunting patterns

Indigenous societies often have strong ties to spiritual worlds that shape how they interact with the environment (Ulloa *et al.*, 1996; Colding and Folke, 2001; Kawamura, 2004; Silvius, 2004). Many studies have addressed the relevance of including spiritual and indigenous knowledges in studies of indigenous resource use alongside other forms of knowledge (Ulloa *et al.*, 1996; Silvius, 2004; Pandya, 2007; Watson and Huntington, 2008; Berkes, 2009; Peloquin and Berkes, 2009; Roth, 2009). Cultural and spiritual 'rules' of behavior control such aspects of life as location of resource use areas (Redford and Robinson, 1987; Silvius, 2004; Ulloa *et al.*, 2004), food taboos (Ross, 1978; Silvius, 2004), and timing of specific activities. This study focuses on the importance of such 'rules' in influencing hunting-use areas.

Aside from territorial rules of resource use that often dictate boundaries of specific resource uses between different communities, hunting activities are often regulated through rules, such as when and where to hunt, how to hunt, and who can hunt. These rules include segment taboos (restricted to a certain segment or demographic of society), temporal taboos, method taboos, habitat taboos, species taboos, and life-history taboos (Colding and Folke, 2001). For example, species taboos exist in many societies which limit hunting of defined species (Henfrey, 2002; Dunn, 2004; Silvius, 2004; Ulloa *et al.*, 2004), or forest spirits can be angered for inappropriate forms of hunting (Silvius *et al.*, 2004; Aisher, 2007). It is the meanings and connections to the local environment that represent conceptions of *place* (Tuan, 1979; Pred, 1984; Massey, 1994). As Tuan (1977:136) states, "Space is transformed into place as it acquires definition and meaning", and he referred to the spiritual connection to the land as *geopiety* (Tuan, 1975). Thus, resource and habitat taboos that regulate the location of hunting may be considered an aspect of place (Colding and Folke, 2001), and are among the factors that influence the distribution of hunting activity on the landscape.

A common manifestation of sense of place among indigenous groups is the identification of sites of spiritual significance in their landscapes. Such sites may be small and represent natural features such as rocks, mountains, and lakes (Dudley *et al.*, 2009), but can sometimes be very extensive in area, from 100 to thousands of hectares (Fragoso *et al.* 2000: 49; Silvius 2004: 46; Fragoso *pers. obs.*). In some instances, spiritual sites represent places to be avoided (either by a subset of the community, or by all individuals), or they can be reserved for specific activities (Forbes-Boyte, 1998; Colding and Folke, 2001). They often, but not always (see Wadley and Colfer, 2004), represent places where hunting is not permitted, and have been hypothesized to contribute to biodiversity conservation through restricting hunting and providing safe refuges for animals (Gadgil *et al.*, 1993; Fragoso *et al.*, 2000; Silvius, 2004; Dudley *et al.*, 2009). Gadgil and Chandran (1992) show how sacred forests associated with particular deities have played a significant role in preserving portions of India's threatened forests, and in Africa, sacred places have been documented as acting in the protection of the few remaining tracts of closed canopy forest (Wilson, 1993). Such social taboos rely on cultural norms and do not depend on national governments for promulgation or enforcement; however, they may function similarly to formal institutions for nature conservation (Ulloa *et al.*, 1996; Posner and Rasmusen, 1999; Colding and Folke, 2001; Ulloa *et al.*, 2004).

These nuanced understandings of place are not readily obvious and generally have been undervalued (Peloquin and Berkes, 2009; Roth, 2009), particularly when researchers assess the biophysical dimensions of hunting. Failing to involve hunters' perceptions of the landscape can result in inaccurate or incomplete assumptions about the factors affecting the distribution of hunting in the landscape. Thus, understanding this distribution requires the inclusion and careful mapping of such phenomena (Rundstrom, 1993).

Goals and description

The goal of this study is to describe indigenous hunting patterns across a landscape from a space and place perspective that takes into account both biophysical and spiritual factors. The locations of animal kills are tracked and their position with respect to distance from the hunter's community and directional trend, proximity to roads and rivers, elevation, major vegetation type (forest/savanna), and proximity to spiritual sites are analyzed. Distance from community is used as a proxy for effort. In accordance with other studies of hunting and site accessibility (Broseth and Pedersen, 2000, Fragoso *et al.*, 2000), it was posited that hunting effort and therefore intensity would decrease with increasing distance from communities. Accessibility is here measured by proximity of kill sites to roads and navigable rivers, and elevation of kill sites. It was hypothesized that locations with easy access would correspond with higher hunting intensities compared to locations that were more difficult to access. In order to determine whether habitat type influences where people hunt, the type of vegetation at a coarse scale (forest or savanna) where hunting occurs was assessed. It was expected that hunting intensity would be highest in vegetation known to harbor most game animals (forest) than those with fewer game animals (savanna). Finally, the proximity of kill sites to spiritual places was measured to determine whether hunters preferentially avoid those sites when hunting. In addition the modes of transport used by hunters to get to their hunting sites, and whether the animal kill was opportunistic or part of a planned hunting activity are also examined.

The mixed methods approach to analyzing space and place involved the use of geographic information systems (GIS), satellite remote sensing of vegetation/habitat, surveys with hunters on their hunting activities, key informant interviews on spiritual places, and the collation and creation of environmental and cultural features GIS layers. Data collection methods in which technicians were recruited from collaborating communities and trained in biological and social data collection, including administering hunting and spiritual site surveys were relied upon. Other researchers have reported success with this type of survey methodology in the past (Smith, 2003; Jones *et al.*, 2008). Information gained from informal interviews with community members was used to inform interpretation of findings from GIS-based analyses. No attempt to assess sustainability of the system was involved, in terms of biodiversity or culturally, nor is there an attempt to describe the territory or area required by communities to fulfill their hunting needs. Moreover, this paper makes no claim to contribute to understandings of the possible roles political spaces play, whether at national or local indigenous levels, primarily due to lack of access to spatial data on such spaces.

The research was carried out over a span of three years in a predominantly indigenous area of the Guyanese Amazon (Figure 1). The Rupununi of southern Guyana is situated on the Guiana Shield and represents part of the northern South American savannas and transition forest-savanna biome. The area is home to several groups of indigenous peoples which span southern Guyana, northern Brazil, and Venezuela. In the Rupununi, most inhabitants are of the Makushi[1] and Wapishana[2] indigenous groups, which primarily follow subsistence-oriented livelihoods, including small-scale swidden agriculture, with many households relying heavily on hunting and fishing. Twenty-one communities participated in this study, spanning those located primarily in either savanna or forest, or close to the forest-savanna boundary.

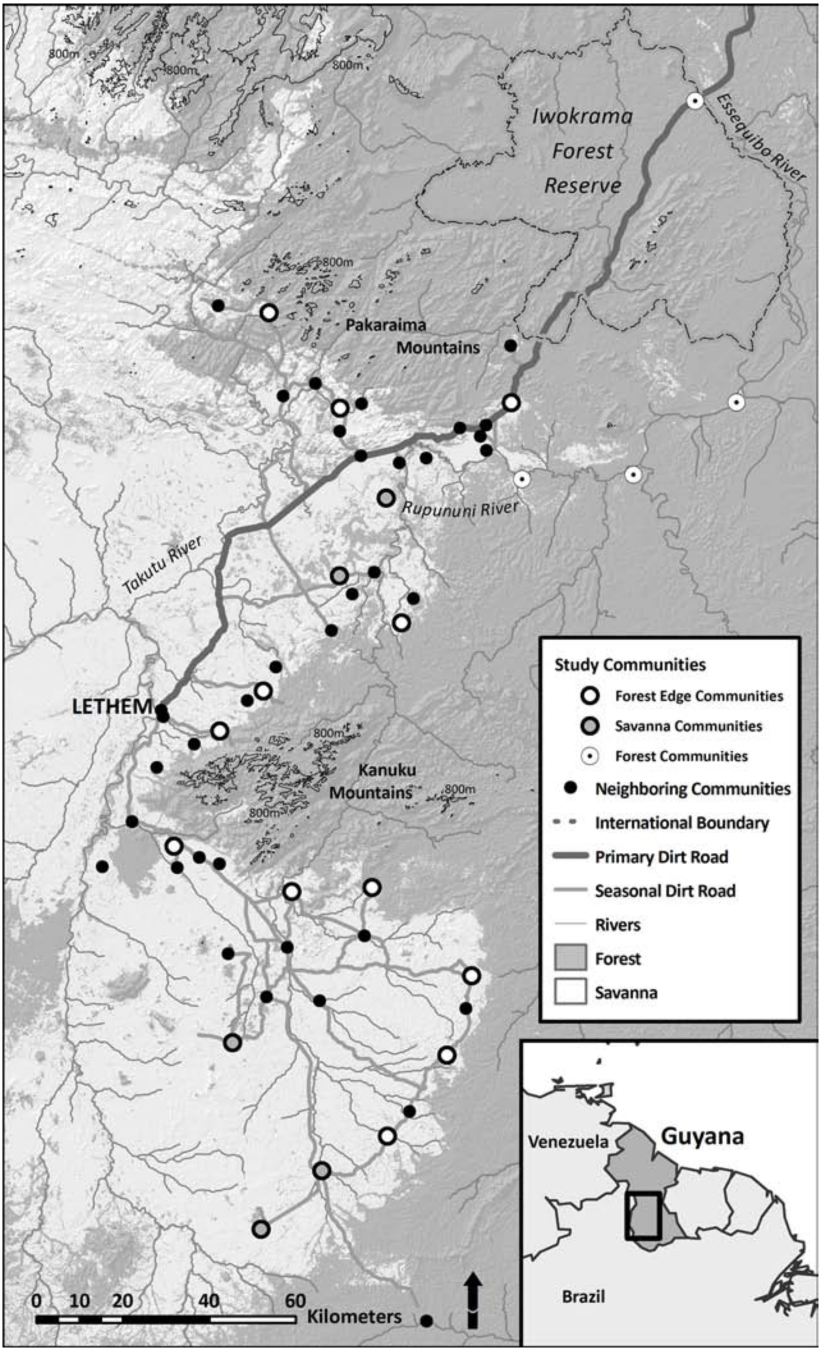

Figure 1: Study site.

The Rupununi of Central and Southern Guyana

The study area (48,000 km^2) is characterized by rolling savannas (upland and seasonally-flooded), forest islands and gallery forest, as well as areas of unbroken old growth forest, and is bordered by mountains to the north and south east that are generally covered by dry and moist forests. Elevation ranges from around 1,100 m. in the Pakaraima mountains, to 30 m. in lowland savanna and swamp areas (Figure 1). Rainfall is received predominantly during two rainy seasons—a longer May-August season, and a briefer season in December-January during most years (Hydromet, 2006). Major game animals such as the white-lipped and collared peccaries (*Tayassu pecari and Tayassu tajacu*, respectively), lowland tapir (*Tapirus terrestris*), red brocket deer (*Mazama americana*), several species of armadillo (*Cabassous unicinctus, Dasypus kappleri, Priodontes maximus*), paca (*Cuniculus paca*), and agoutis (*Dasyprocta leporina*), live only in forests, while white-tailed deer (*Odocoileus virginianus*) and nine-banded armadillo (*Dasypus novemcinctus*) prefer open savanna (Eisenberg, 1989).

The study region encompasses most of the territory occupied by the Caribanspeaking Makushi and the Arawakan-speaking Wapishana people of Guyana (Census 2002). Approximately 40 communities are scattered across the study area, ranging in population from around 60 to 1,200, and predominantly located in lowland savanna close (<5 km) to the forest edge (Figure 1). The main population center is Lethem, located on the Brazil-Guyana border, with an ethnically-diverse population of 1,158 (Census 2002). The surrounding communities all have as a minimum a government-built community center and primary school, with households spaced typically 100 m or more from each other (although some can be spaced closer, especially if they constitute close family). Fishing is an important source of protein, especially during the dry seasons when fish are concentrated in shallows and game animals are more dispersed. During the rainy seasons, when much of the lower areas are flooded, hunting becomes more important and easier as the animals are concentrated on higher ground. Domesticated animals also provide an occasional protein source for most households. Farming areas, most ranging between 0.5-1 ha per household, are usually cleared from forest, with cassava, bananas, and, in some cases, peanuts as key crops. Hunters continue to rely primarily on the bow and arrow and machetes, though some hunting is done with firearms and traps for catching live birds for the pet trade. Access is usually by foot, horse, or canoe, although use of bicycles is now common.

While the Guyana Ministry of Amerindian Affairs has recognized the majority of the study communities with legal title to lands to date (L.C.D.S., 2010), communities have long had their own agreed-upon, or customary (Davis, 2006), "rules" of land use that control where houses can be built, and where farming, logging, fishing, and hunting activities are permitted. The Iwokrama Forest Reserve lies within the study area (Figure 1) and is divided into management areas that differentially restrict certain activities; however, local indigenous people are permitted to carry out non-commercial traditional uses, which include hunting for household use (Iwokrama International Centre for Rain Forest Conservation and Development, 2007).

Methodology

Collection of hunting data

Survey data on hunting activities and animal kills by hunters in twenty-one communities over a period of 32 months during 2007-2009 were gathered. The communities were selected based on their distribution in the study area, their representative location with respect to vegetation type and topographic characteristics, proximity to other communities, and willingness of the community members to participate in the project. Study communities in many cases are interspersed with non-study communities whose presence and activities could potentially influence the hunting and other behaviors of the study communities, and it is important to take these communities into consideration when interpreting findings of the research. The number of months of data collection per community varies depending on when a community was included in the study, with a maximum of 32 and minimum of 12 months. Surveys were conducted weekly to ensure that hunters did not have to remember details of their hunting activities over long periods of time. They were administered to every household in each community by locally-recruited indigenous technicians who were residents of each community and trained by the project researchers. Hunting surveys have been used successfully in other studies, both by university-trained researchers (e.g. Townsend, 1995; Alvard *et al.*, 1997; Naranjo and Bodmer, 2007), and by local technicians under supervision of a university-trained field team (Souza-Mazurek, 2000; Noss *et al.*, 2005; Smith 2008).

Hunting survey questions included: Was it a planned hunting trip? Where did you hunt? How did you get there? Name of animal killed or caught? The hunters were asked to mark an 'X' of the location of each kill on a hardcopy topographic map (1:50,000) or printed Landsat-TM satellite image centered on their community. The maps also had identifying features marked to help orient the hunters, such as rivers, location of the center of the community, and/or the eight 4-km long wildlife transects that are part of this larger research project and distributed within a 12 km zone around each community, clearly-marked on the ground, and well-known to the hunters. No attempt was made to verify locations or assess the accuracy of kill site locations on the ground; however a conservative estimate, based on the detail of the maps/images, the scale of the data, and hunters' knowledge of the area and ability to read maps/images (witnessed during four years of working in the field with community members and hunters), is that the majority of points would have been accurate to within 500 m. depending on distance away from the community and familiarity with the site. Locations of hunt kill sites were digitized and stored in GIS format; locations of unsuccessful hunts were not recorded or mapped.

Collection of spiritual sites data

General information and stories about spirituality were gathered through informal conversations with community members that took place over three years of fieldwork. However, to better understand local conceptions of places associated with the communities' belief systems and the locations of these places (hereafter referred to as *spiritual sites* to distinguish them from other sites of cultural significance), data were also gathered through formal interviews and surveys. First, one-time surveys with the principal hunters of each community (as identified by the community leaders) were administered by local technicians or the project anthropologist. Questions were asked about places that hunters avoided or in which they had to use extra caution. Second, interviews were conducted with knowledgeable members of each community including the elderly, *toshao* (community leader), and/or *piaiman* (shaman) about places generally known to be sacred and/or dangerous. Details and locations of such sites were determined and mapped based on information gathered from the surveys and interviews, as well as from supplementary information provided by project technicians. Locations of sites were marked on topographic or hardcopy satellite images and later digitized and stored in GIS format as points.

Collection of environmental data

Two Landsat Thematic Mapper images acquired 1st October 2005 and covering the extent of the study area were georeferenced, converted to reflectances, mosaiced, merged with 30 m Aster Global Digital Elevation Model data (GDEM), and classified using a hybrid unsupervised-supervised classification to identify areas of forest and savanna. Forest was classified as areas of continuous tree cover, and included small forest islands in the savanna. A GIS data layer of major rivers was generated from the 2000 Shuttle Radar Topography Mission data (SRTM30) and edited using the Guyana Integrated Natural Resources Information System rivers dataset. GPS locations of community 'centers' were taken, usually at the front of the primary school where possible, and mapped in GIS format. Similarly, commonly-used roads were mapped using GPS and classified as either the primary dirt road, which runs from Lethem to Georgetown, or seasonal dirt road (all others).

Spatial analyses

Straight-line distances from kill sites to a) community centers, b) the nearest road or river, and c) the closest spiritual site were calculated. It was not possible to track the actual paths of the hunters due to logistical constraints as a result of the size of the study area, time-frame, and number of communities and hunters involved. While it is acknowledged that hunters are unlikely to walk in a straight line to kill sites, the straight-line distances still yield useful information about spatial patterns of kill sites in relation to select landscape features (communities, rivers, roads, spiritual sites). Data on elevation and vegetation (forest/savanna) were extracted for each kill site using GIS overlays with the 30 m Aster GDEM and satellite image vegetation classification, respectively. The distribution of hunting patterns (kill sites) to find the mean center of a community's hunting activity were assessed, and standard distance analyses were conducted to determine the directional trend of that activity. The mean center provides information about the location of the center of hunting kills, which can be compared with the location of the community center in terms of distance away and direction from the center. In addition, the shape and size of the ellipse adds spatial information about the variation (clustering or dispersion) in both x- and y-directions in the spread of distribution of kill sites. A circular ellipse centered on the community would indicate that distance alone may be a good indicator of kill site patterns, while any departures from that would indicate that other factors may be influencing the distribution. Directional ellipses were mapped, using 1 standard deviation (representing 68 percent of the points) from the mean center in the x- and y-directions to define the axes of the ellipse.

Distance from kill sites to spiritual sites gives a useful measure to show whether kills occur on or close to spiritual sites, however it does not indicate whether hunters are actively avoiding those sites or not, since the spiritual sites might not be in areas where hunters normally go. To help determine whether spiritual sites were just as likely to be places where kills occurred or not, elevation and vegetation characteristics of kill sites were assessed and then compared with those of the spiritual sites. To do this, a density surface of hunt kill locations was calculated based on a quadratic kernel function (that is, the area was divided into 90 m x 90 m pixels, and the density of kill sites around each pixel using a circular search radius of 12 km was calculated). The surface was then classified into five classes ranging from lowest to highest kill density based on natural breaks in the data. The density classes were overlaid separately on the SRTM digital elevation model and vegetation classification of the area, descriptive statistics of elevation and percent forest/savanna for each density class were extracted, and they were then compared to those of the spiritual sites. In this way it was possible to assess whether areas of high kill density had specific characteristics, and if so, whether those characteristics differed from those of the spiritual sites.

Results and Discussion

Hunting surveys from 21 communities and 496 survey months of data collection identified 6,449 successful kills occurring during 5,558 hunting events (whether planned or opportunistic). Most hunts (80 percent) took one-day or less, with just under 20 percent lasting from two to seven days. Hunters were men who mostly (56 percent of hunts) hunted in small groups of 2-5 people, or alone (38 percent of hunts). The majority of kills (58 percent) were with bow and arrows, with 24 percent using shotguns, 8 percent using cutlasses (machetes) and the remainder with traps or a variety of tools.

Kill sites tend to cluster around each community (Figure 2), demonstrating that hunters usually do not need to venture far from their community when hunting. It is important to note that only locations of successful hunt kill sites were mapped, and it is assumed that these are representative of all hunting locations. The greater number of kills by hunters from the southern communities is a reflection of the significantly ($P<0.001$) larger community populations in the south than the north. Because this study did not work with all communities in the area, and because they varied by population size and number of months of data collection, here no attempt is made to quantify per capita hunting or infer information on wildlife populations; moreover, the data cannot be used to infer potential impacts of adjacent community 'territories'. We assume that hunters will only hunt within the permitted resource-use areas for their community, and that those areas will not encroach upon those of other communities, thus the clustering of kill sites around each community likely reflects the rules of resource-use in addition to other factors. Within the Iwokrama Forest Reserve, kills only occurred in the north, primarily along the river, with no kills occurring within the wilderness areas.

A total of 107 animal species were identified as killed, eight of which represented 69 percent of all reported kills, with the next highest percentage of kills for any species accounting for only 3 percent of kills (Table 1). Six of the eight most-commonly hunted animals are primarily forest-dwellers, with nine-banded armadillo and white-tailed deer preferring savanna habitats. Agoutis (approx. weight from 2-5 kg; Silvius and Fragoso, 2003) and paca (approx. weight 10 kg; Eisenberg, 1989) are rodents that eat seeds, fruits and nuts and are commonly found in moist habitats at low elevations. White-lipped peccaries (approx. weight 25-50 kg), named for their white lower jaw, move in large groups (to 400 or more individuals) over extensive areas, foraging for palm nuts and seeds, roots, fruits, and tubers (Eisenberg, 1989; Fragoso, 2004). Collared peccaries are smaller than the white-lipped peccary (range from 16 to 25 kg) and have a white collar around the neck (Eisenberg, 1989; Fragoso, 1999). They generally move in small herds of approximately eight individuals and prefer to eat fallen fruits and palm nuts. The red brocket deer is a small, solitary, and secretive deer that is active mostly in the evening, night, and early morning hours. It occurs in montane and lowland forests and tree savanna. The white-tailed deer, a medium-sized deer named for the white underside of its tail, on the other hand, prefers a more open savanna environment with trees to allow for grazing as well as browsing, and the nine-banded armadillo prefers low elevations and a range of habitats but is commonly found in savannas in the study site where it forages for insect larvae and ants mostly (Eisenberg, 1989).

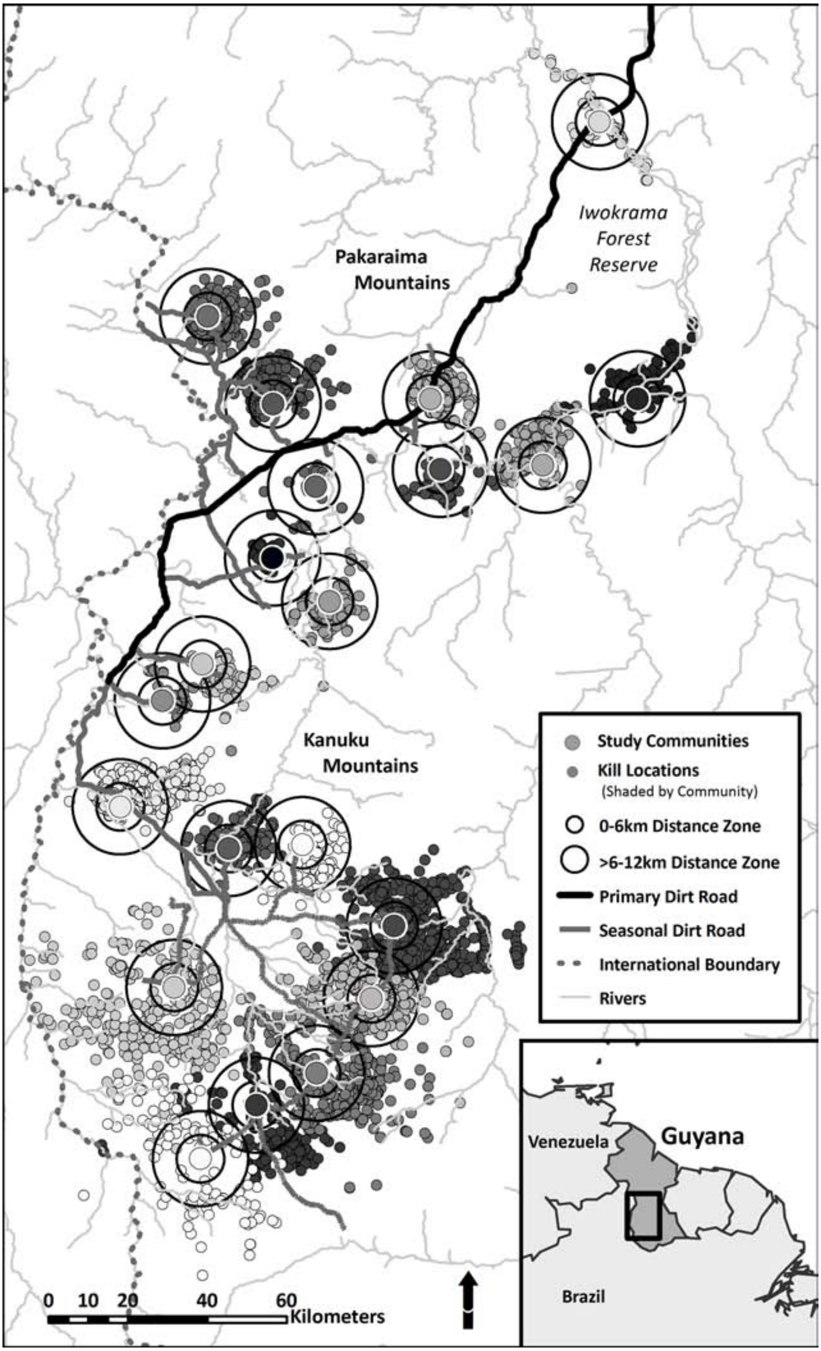

Figure 2: Hunt kill locations.

Table 1: Kill site characteristics for all animal species combined and the top eight most-hunted animals

Animal Species	**# of kills**	**Elevation**				**% of kills in forest**
		minimum	maximum	mean	standard deviation	
All animals	6449	38m	919m	179m	113m	70
Paca	899	48m	907m	182m	119m	78
Agouti	821	38m	883m	165m	102m	79
White-Lipped Peccary	803	40m	758m	142m	87m	80
Collared Peccary	632	62m	919m	204m	128m	89
Red Brocket Deer	339	71m	880m	228m	164m	80
Nine-Banded Armadillo	336	70m	788m	175m	66m	49
Red Footed Tortoise	317	65m	727m	203m	123m	61
White-Tailed Deer	304	55m	737m	162m	70m	17

Distance from community, accessibility, and habitat

The average straight-line distance from a hunter's community center to a kill site is 9 km (Table 2), with a minimum distance close to zero (i.e. within the community) and maximum of 76 km. The majority of animal kills (38 percent) occurred in a zone 6 – 12 km from the community center,[3] with 36 percent occurring up to 6 km away, and 26 percentoccurring greater than 12 km away (Figure 3a). This distribution might be interpreted as an indicator of a slight local reduction in numbers of animals closer to the communities as a result of hunting pressure, or it could be explained by the fact that most communities are located at the forest edge in savanna several kilometers away from forest, which is home to fewer species of game animals than forest habitats. This latter point is confirmed when the communities are separated into groups (forest, forest-edge, and savanna) based on where they were located; a clear pattern emerges showing that hunters from forest communities travelled on average less (5.5 km) than hunters from forest edge (9.5 km) and savanna (12.5 km) communities (Figure 3b, c, d). Moreover, the overall number of kill sites in forest communities declined with distance from the community (Figure 3b), and indeed of the eight most-hunted species, all were killed more often (or equally in the case of white-tailed deer) within 0 – 6 km of the community compared to 6 – 12 km away. Whereas in the forest edge communities (Figure 3c) the greatest number of kills occurred in the 6 – 12 km zone, presumably because hunters have to travel farther to reach forest. Number of kills increased with distance from savanna communities, and this could be interpreted either as hunters having to travel farther to find suitable (forest) habitat or that the animals are more dispersed (Figure 3d). As would be expected, the importance of savanna species (white-tailed deer and nine-banded armadillo) was greater in the savanna communities than the forest or forest edge communities. These results imply that local depletion of animals has not occurred within the forest and that hunters prefer to hunt closer to home, and will do so when game is available. These findings indicate that the local environmental context (i.e., the type of habitat in which a community is located) does matter, and that it is not possible to assign a "one distance fits all communities" model. This has important implications for quantitative modeling and management decisions.

Table 2: Kill site characteristics for all communities combined and six selected communities

Community	**# of kills**	**Mean distance (km) and standard deviation of kill sites from:**			**% of kills in forest**
		community center	nearest sacred site	nearest road or river	
All	6,449	9.0 (6.5)	16.5 (16.1)	2.0 (2.0)	70
River	348	5.0 (4.6)	10.0 (2.9)	1.0 (1.4)	99
Road	261	5.0 (3.6)	3.5 (2.2)	2.5 (1.6)	80
Forest-River	222	6.5 (5.7)	62.0 (7.4)	0.5 (0.5)	100
Savanna	291	16.0 (7.7)	11.5 (6.7)	3.0 (2.3)	7
Forest edge	1,328	12.5 (6.1)	4.0 (7.7)	3.0 (1.9)	80
Mountain	245	5.5 (3.1)	4.5 (2.9)	3.0 (2.2)	93

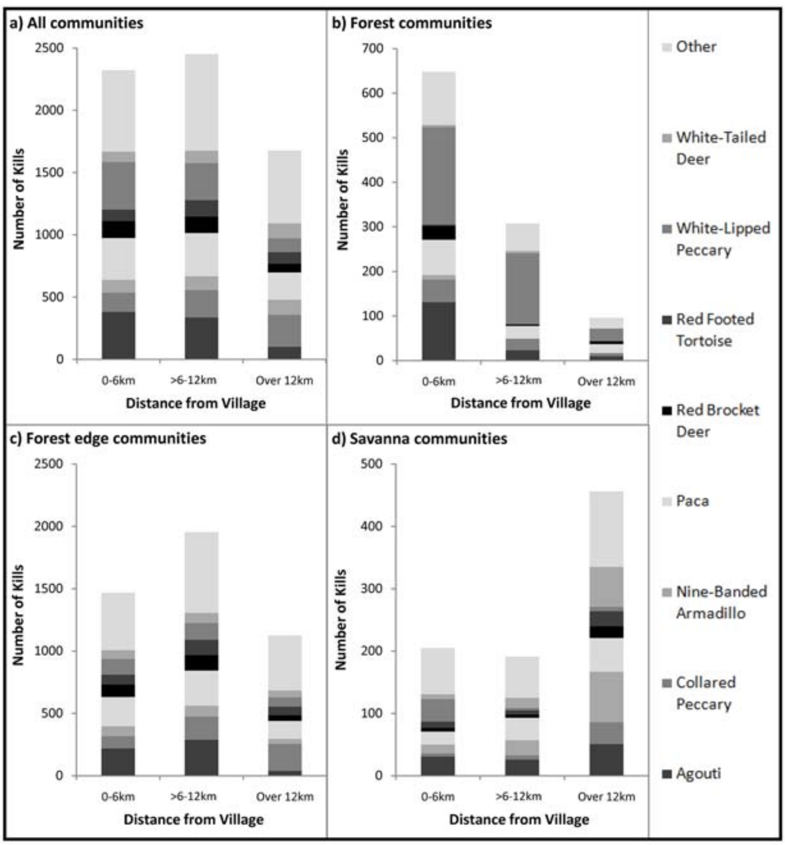

Figure 3: Number of kills by distance zone from community center for the top eight most-hunted animals for: a) all communities, b) forest communities, c) forest edge communities, d) savanna communities.

It is assumed that hunters will take the easiest route to access a hunting site, thus if a road or river provides faster and easier access the hunter will take it. Kill sites were located on average 2 km from either the nearest river or road (Table 2), which might suggest that these access routes are important; however, without mapping the actual path that hunters took, it is difficult to speculate on the importance of these access routes. There appears to be little effect of roads on location of kill sites (i.e., kill sites do not appear to cluster around or along roads; Figure 2), and the majority of the roads pass through savanna, which may explain fewer kill sites in close proximity. Rivers may be more influential, however. Kill sites along rivers are evident in the eastern-most communities, where they show linear patterns following rivers (Figure 2). Additionally, many opportunistic kills occur along rivers (Figure 4), which reflect the fact that rivers serve as sources of water for fishing as well as wildlife, and thus provide opportunities for coming across animals while on fishing trips.

Elevation of kill sites ranged from 38 to 919 m above sea level (Table 1; Figure 5), however, of the most-hunted species, all were killed mainly at the lower elevations (mean < 228 m) with little variation between species of where the kills occurred. It is assumed that higher elevations mean more difficult access and steeper terrain; however, whereas the majority of kills occurred at lower elevations, no clear relationship with respect to elevation and distance was evident, even after the data were log-transformed. Absolute differences in elevation between kill sites and communities were also plotted to determine whether the two communities at elevations over 200 m were influencing the results, but no trend was found. It may be that because hunters stay within a zone around their community, they have little choice when it comes to elevation, and in some cases the higher elevations tend to be the best habitat (i.e., forest) within reasonable distance to find animals. A relative relief measure was calculated for each community based on a radius of 12 km and determined using the coefficient of variation of elevation for each community; forest edge communities, which see the majority of kills occurring at intermediate distances (> 6 – 12 km from the community center; Figure 3) had significantly ($P < 0.05$) more variation in relief than either the forest or savanna communities, confirming that elevation and distance alone cannot explain hunting patterns. More complexity is added to the analysis when the varied components of transport to the hunting sites are analyzed (Figure 6). Whereas walking is by far the most common form of transport (used to access 73 percent of kill sites), with bicycles (15 percent), boats with no engine (8 percent), and horses (3 percent) used to a much lesser extent, it is clear that mode of transport differs depending on location. For example, horses and bicycles are common modes of transport in the southern savanna communities, which tend to be more dispersed with hunters going greater distances than in the northern communities. Likewise, the river communities in the north make greater use of non-motorized canoes.

Directional ellipses showing the standard distribution (1 standard deviation in x and y directions) of kills demonstrate substantial variation among communities (Figure 7). They provide some sense of the size of the area where hunting occurs most intensively. The center of the ellipse is the mean center of the distribution of kill sites and can be compared with the location of the community center to give additional information on how far hunters will go from the community. Ellipses for the southern communities, which are mostly located in savanna with isolated forest patches, are noticeably larger than those for the northern communities, and show a higher mean distance from kill site to community than other communities located in or near large areas of forest.

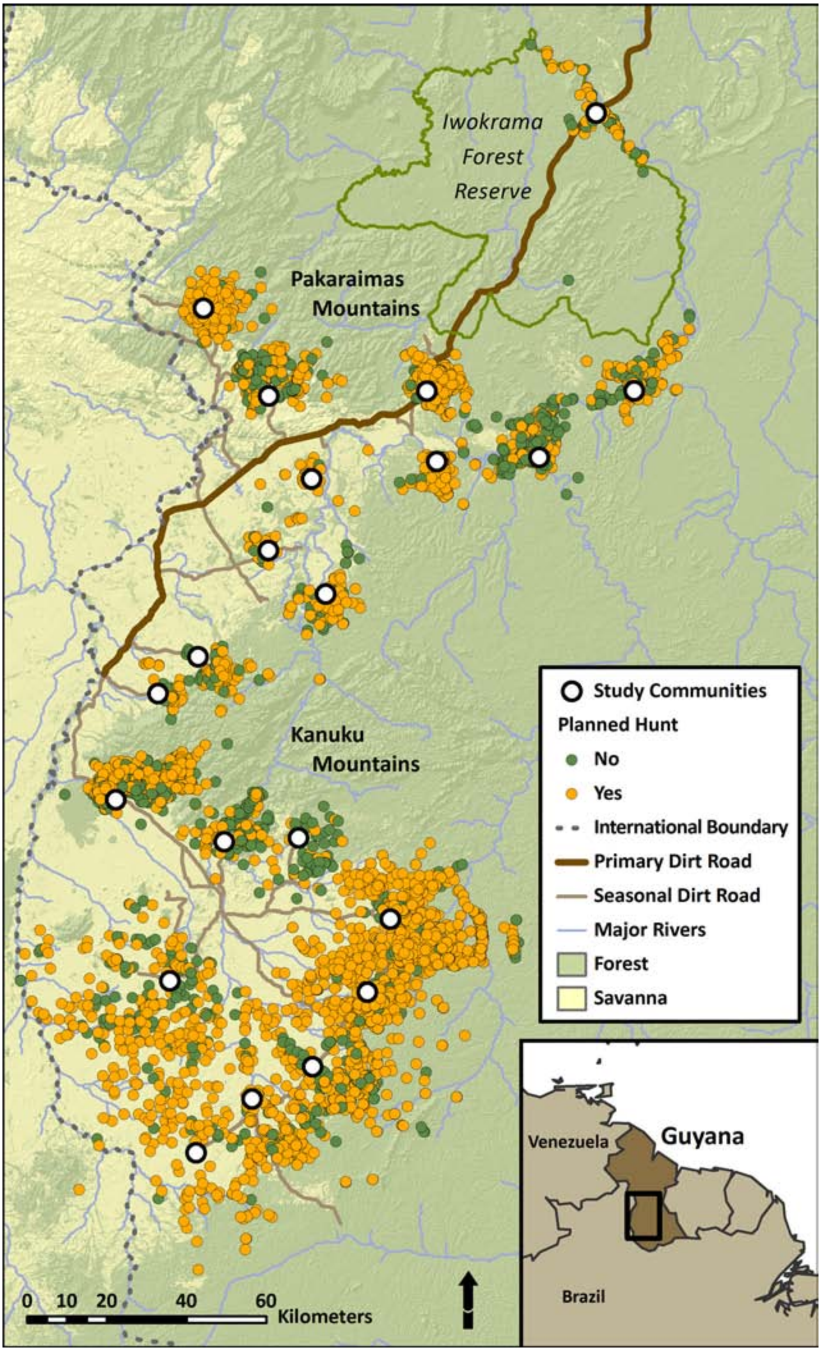

Figure 4: Planned versus unplanned (opportunistic) hunts.

This could be explained by a number of reasons: that communities are more dispersed and thus distances that community members travel generally are greater; that the distance hunters must travel to reach areas of relatively high game abundance in the forest patches is greater; that movement is easier in the savanna, especially with horses and bicycles, which makes covering larger distances easier; and animals are more dispersed/have lower abundances in the savanna, thereby necessitating covering more ground when hunting, or that the households themselves are more dispersed with hunters still hunting closer to their homes but with these dispersed over a greater area. Communities close to the savanna-forest boundary have kill site distributions that trend in an easterly direction, generally into neighboring forest and presumably reflecting the greater presence of animals in this vegetation type. Strong directional trends are evident in river communities, where hunters often travel by boat.

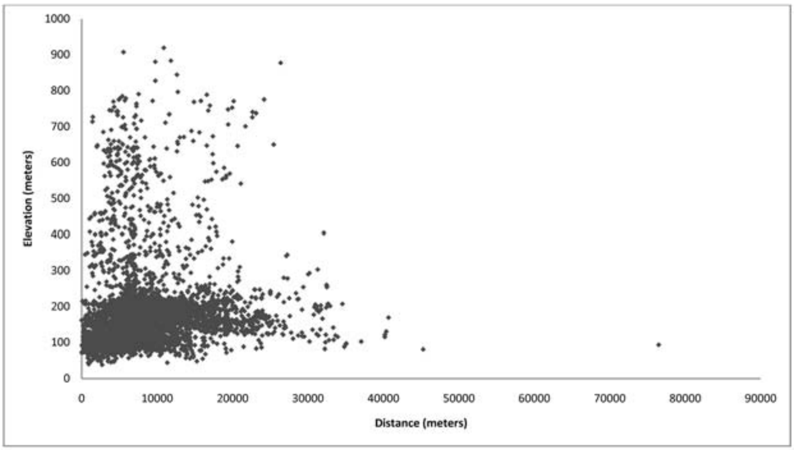

Figure 5: Scatter graph showing relationship between distance from community and elevation for all kill sites.

Vegetation type is closely related to the presence and abundance of many game species. As expected, the majority (70 percent) of kill sites were located in forest, and of the most-hunted species, only white-tailed deer and armadillo kills occurred primarily (> 50 percent) in savanna (Table 1), where both species are commonly found (Eisenberg, 1989).

Most kills (73 percent) occurred as planned activities (whether in conjunction with other activities or as specific hunting trips) rather than opportunistically; the majority of unplanned kills occurred close to communities (Figure 4), as expected given that daily activities take place as people move between locations in the communities and their forest gardens or fishing locations. Farming provides an opportunity for unplanned hunting of important game species that are also pests on gardens—e.g. paca, agouti, red brocket deer and lowland tapir. These results are similar to Smith's (2008) findings in Panama, whereby he found that 20 percent of kills were opportunistic and the remainder planned either as formal hunting trips or as hunting in anthropogenic areas often combined with other activities close to the community.

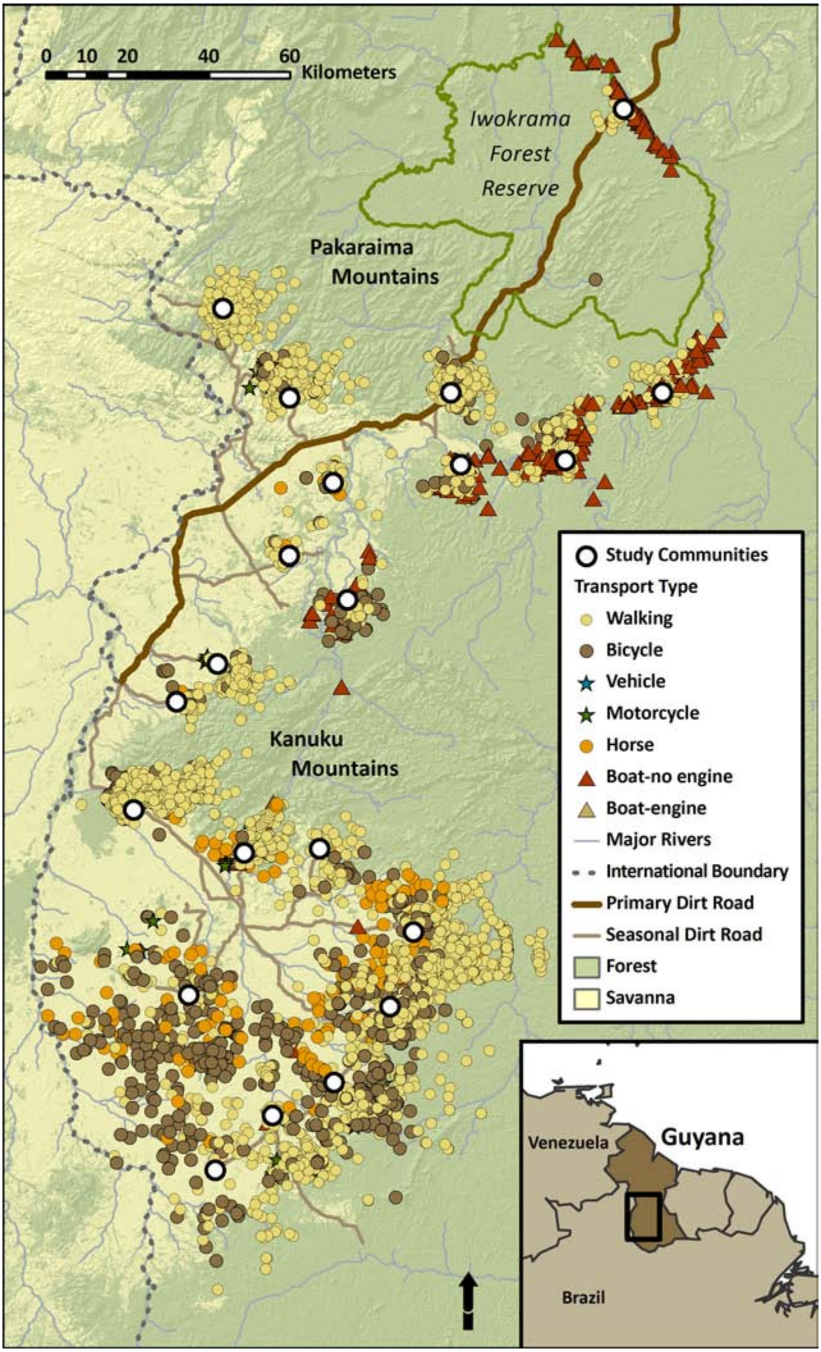

Figure 6: Modes of transport to kill sites.

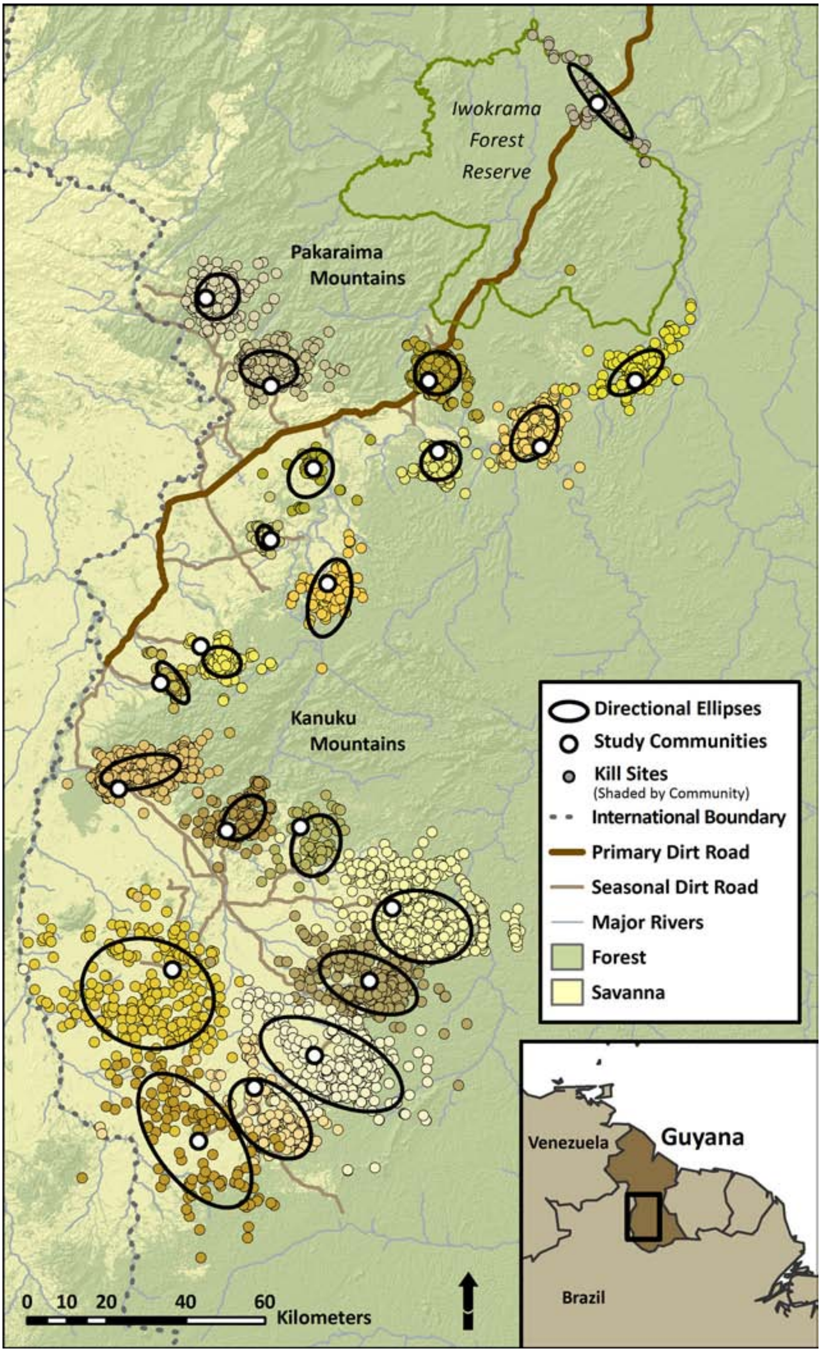

Figure 7: Directional ellipses for all study communities.

Spiritual sites

The Makushi and Wapishana people have a strong sense of place (David, 2006), in that many landscape features, including ponds, streams, rocks, and mountains have cultural significance and are often associated with spiritual guardians and associated stories (Whitehead, 2003). Three types of spatial taboos, not necessarily mutually exclusive, in the study area were identified from the data: a) features/places avoided by all community members, b) features/places avoided by certain segments of the community, and c) avoidance of specific activities at a feature or in a specific place. Such features or places range in size from rocks, that should not be disturbed, or ponds, that have creatures that can cause harm, to mountains, with dangerous creatures or special powers. Some sites used to be dangerous but are no longer, and others have stories attached to them that have no taboos.

Spiritual places in the study area are often associated with specific prescriptions and/or proscriptions, most of which preclude certain human activities such as cooking, hunting or fishing, or establishing a household residence. Moreover, these places are generally associated with cautionary tales, telling of individuals who suffered some misfortune or death because they did not act according to the rules. Such stories often, but not always, occur in 'mythic time', and generally hold relevance for common human activities. Personal experience with a particular place may reinforce notions of place. For example, a hunter who enters an area known widely to hold spiritual dangers and who later contracts a sickness such as malaria might have his belief reinforced. In other cases, indirect experience may suffice: stories of those who tested a site and faced consequences also reinforce respect for the site. For instance, in one Wapishana community, a tale is commonly told about a rock outside the community that must never be interfered with. A man once decided to test the belief and struck the rock with a stick. Shortly thereafter, he suffered a stroke, leaving him partially paralyzed. In another community, a resident shaman tells a tale when he himself decided to climb a small mountain purported to have a dangerous spiritual being locked inside and that is generally avoided by all community members; he was forced to turn back when the mountain began to tremble as he approached the summit.

A total of 61 spiritual sites, that included rivers, lakes, ponds, mountains, and rocks were identified and mapped (Figure 8). The sites are generally distributed throughout the study area, although there are some clusters around communities in the foothills of the Kanuku mountains, as well as around the Pakaraima mountains and their foothills. Fewer exist in the south than in the north. Sixty percent of the sites are characterized by some form of danger and avoidance by people in general, including hunters. Others are dangerous under certain conditions, for instance if fire is set or pepper (*Capsicum spp.*) is 'burned', which might deter people from setting camp and cooking in those locations. Only three of the mapped sites specifically refer to hunting taboos. No animal kill occurred on a spiritual site. The mean distance of kill sites from spiritual sites is 16.5 km, ranging from the shortest distance of <500 m to a maximum of 81 km. Kills that occurred within 500 m of a 'dangerous' spiritual site represented only 0.6 percent of total kills.

It is possible that these data are the result not of hunters avoiding spiritual sites due to spiritual reasons, but that sites simply do not represent good places to hunt based on habitat or elevation. In an attempt to assess whether spiritual sites have different characteristics to sites where people hunt, vegetation and elevation distributions were analyzed for five kill density classes (ranging from low to high kill densities) and spiritual sites.

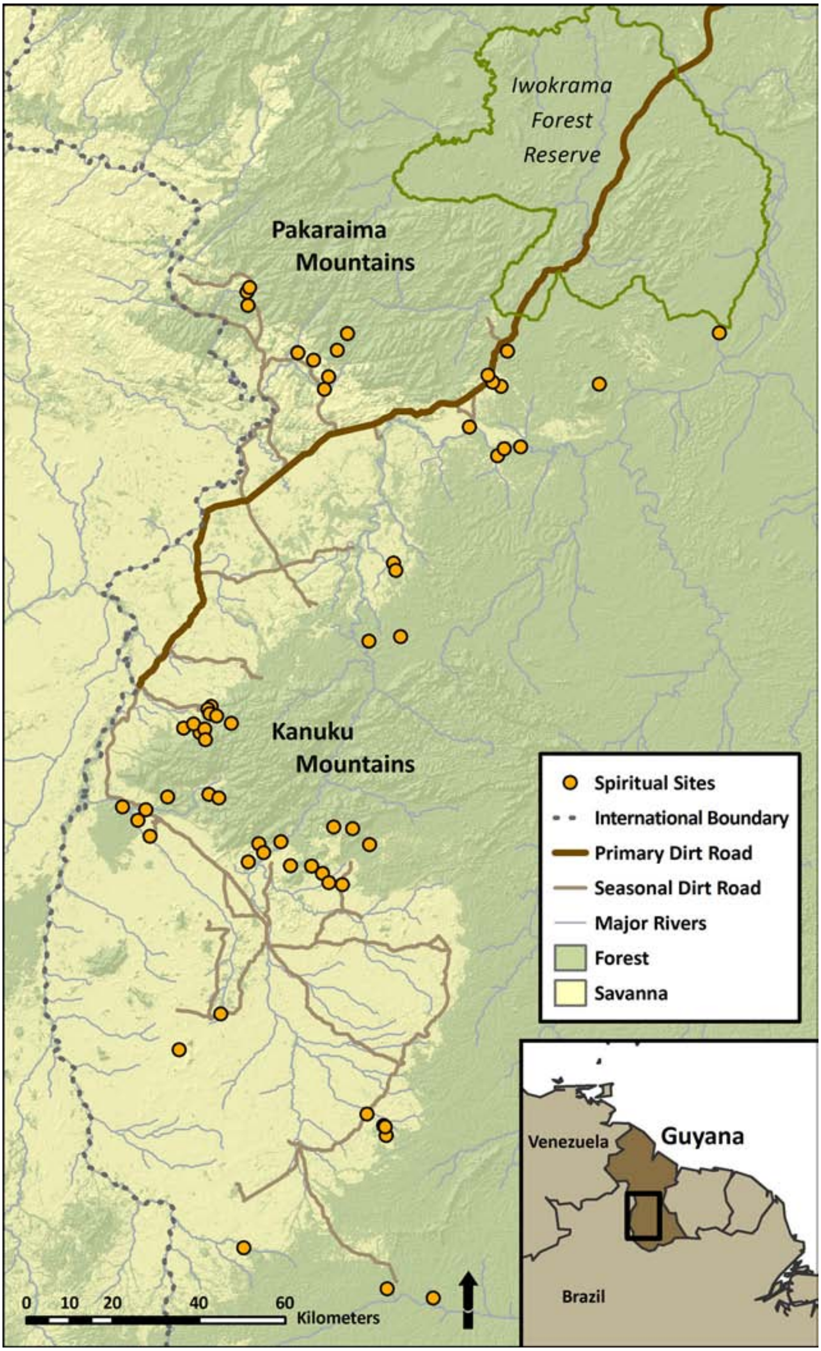

Figure 8: Location of spiritual sites.

Significantly more kills occurred in forest than savanna regardless of whether the kills occurred in a high or low density kill area, and likewise, more spiritual sites occurred in forest than savanna (two-sample difference test: $P < 0.01$).

In other words, the areas where most kills occur do not have different vegetation characteristics (percent forest vs. savanna) from areas where low density of kills occurred, and likewise they do not appear to be different from the spiritual sites. Similarly, mean elevation does not show a positive or negative relationship with kill density (Figure 9), indicating that areas of high kill density do not appear to be different from areas of low kill density with respect to elevation; however, mean elevation of spiritual sites is higher than those for the kill density classes, albeit with a large standard deviation. These results suggest that hunters avoid spiritual sites at elevations where they normally hunt, but that some sites may be at elevations where hunters would not normally go. Overall, these data do not suggest that the kill density classes have substantially different elevation and vegetation characteristics than the spiritual sites, and while not presenting definitive proof, the authors suggest that it is likely that hunters deliberately avoid those sites based on spiritual grounds. Some authors (Wadley and Colfer, 2004; Bhagwat and Rutte, 2006; Dudley *et al.*, 2009) have suggested that such avoidance could have biodiversity conservation value through serving as protection from hunting of these areas, which in turn could represent animal population source areas.

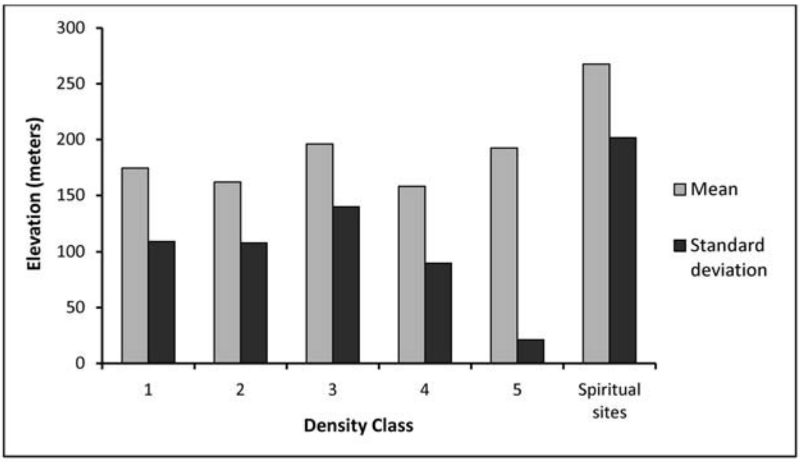

Figure 9: Mean elevation for five kill density classes (1=lowest; 5= highest) and spiritual sites.

Local complexity

To examine the spatial patterning in hunting and the local environmental context in more detail, six communities representative of the range of communities in the study site are evaluated. They include communities located along the main dirt road (*road*), on a river and only accessible via river (*river*), at higher elevation in the Pakaraima Mountains (*mountain*), in lowland savanna close to the forest edge (*forest edge*), in lowland savanna far from large extents of forest (*savanna*), and in forest but with road and river access (*forest-river*).

The river community lies in lowland forest with no mountains or savannas nearby. Access is via river only. Hunters travel on average the shortest distance of the six communities, primarily by non-engine boat or on foot (Table 2). The directional ellipse, an indicator of the size of the hunting zone around a community, is small relative to many other communities, and shows a strong trend along the route of the river, with the mean center downriver from the community (Figure 10a). With the exception of collared peccaries, kill sites for the five most-hunted species (all forest dwelling animals) also show a strong trend downriver. The existence of another community 30 km upriver may explain why hunters from this community seek game in the opposite direction. Ninety-nine percent of kills occurred in forest (Table 2). Kills sites were on average almost 10 km from the nearest spiritual site (Table 2). Some 42 percent of successful hunting trips were unplanned, with many reported to have occurred near the hunter's house, in the garden/farm, or during a fishing trip.

The road community lies in lowland savanna, close to the forest edge with mountains to the north. Hunters generally do not venture far (mean distance to kill site 5 km) despite having road access to forests to the north-east (Table 2), while 80 percent of the kills occurred in forest. The directional ellipse trends along the road from the community center, but is almost circular, indicating that while hunters move north along the road to hunt, that they then move laterally into the forest in either direction (Figure 10a). The average distance to the nearest road or river from kill sites was 2.5 km, thus these access avenues do not appear to be important as hunting locations per se, although they may be important as a means of access to forest father away. Four of the top five most-hunted species show similar directional trends; yellow-footed tortoise had a large kill area that contrasts with that of the other species, but examination of the data show that three of the far kills were unplanned and occurred while the hunters were cutting a trail (Figure 10a).

The savanna community lies in the south of the study area, in savanna with some forest patches to the south and west. The distance ellipse is relatively round in shape (i.e., little directionality) and the largest of all 21 communities studied, indicating that hunters use a large area which can be explained by the reasons listed previously (Figure 10a). The mean center of kill sites lies to the south-west of the community center, suggesting that the forest patches may be important animal habitat, although the top five most-hunted species were all savanna species (Figure 10a), white-lipped peccaries and tapir (generally forest-dwelling species) were not recorded as killed, and 93 percent of kills occurred in savanna. Thus, it appears that the longer distances travelled to kill sites in the savanna is a function of ease of travel through savanna or more dispersed animal populations, rather than striving to reach distant forest patches.

The mountain community lies in the Pakaraima mountains at approximately 300 m. The community exists in a savanna patch, but is surrounded by forest. Curassows (*Crax alector*) rank among the top five most-hunted animals (Figure 10b). The ellipse is relatively round in shape, with a weak trend to the northeast. The mean distance to kill site is 5.5 km – a relatively short distance, presumably due to difficulty of access far from the community owing to difficult terrain. Ninety-three percent of kills occurred in forest.

The forest edge community lies in savanna approximately 3-4 km from the forest edge. The mean distance from the community center to kill site is 12.5 km (Table 2). The directional ellipse is likewise relatively large, with the predominant trend to the east of the community center in the direction of the forest (Figure 10b). Eighty percent of kills occurred in forest, although white-lipped peccaries did not rank in the top five most-hunted species. The majority of kills took place on planned hunting trips, with the farthest kills located along rivers approximately 23 and 31 km to the east, which the hunters accessed on foot.

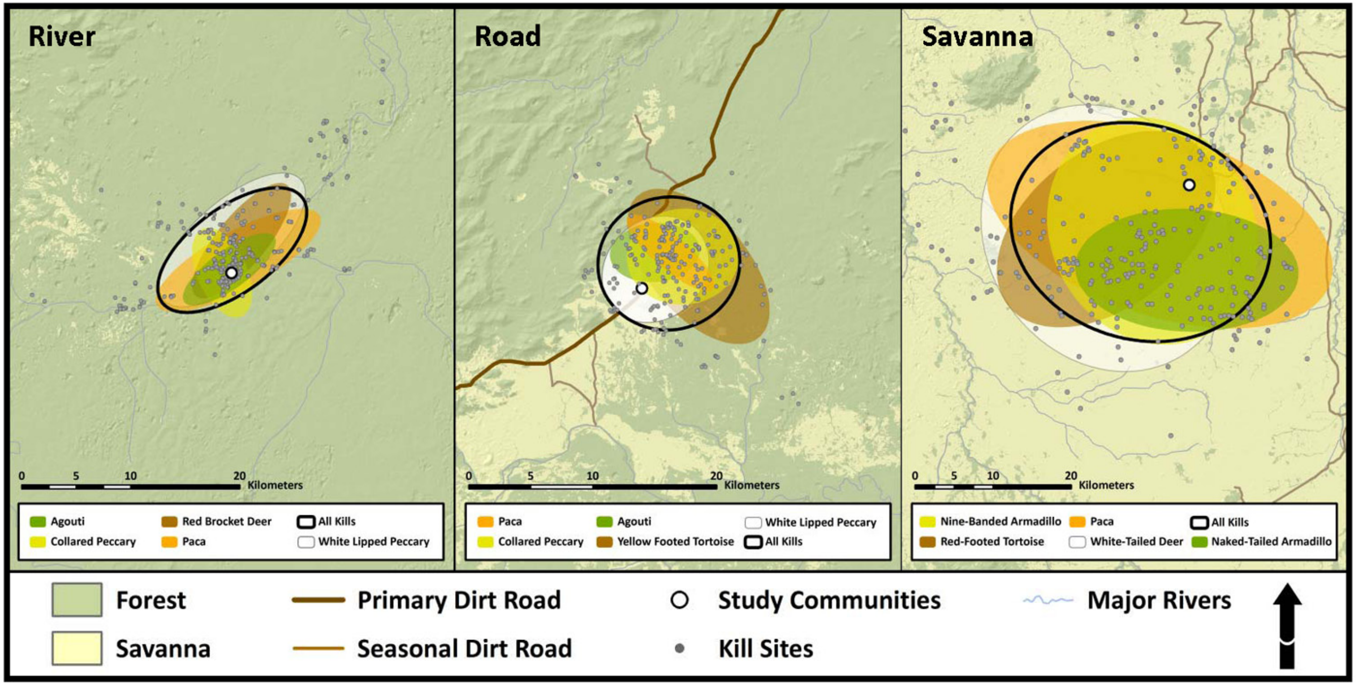

Figure 10a: Directional ellipses for the top five most-hunted species for select communities: river, road, and savanna

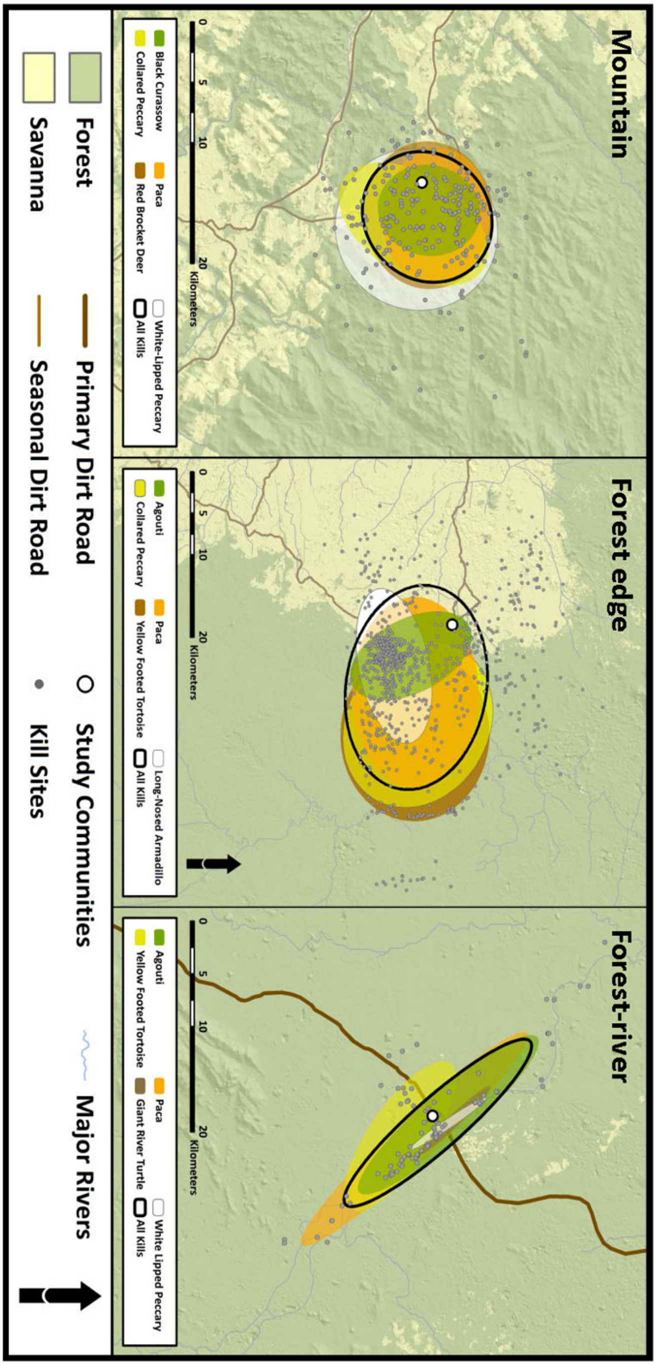

Figure 10b: Directional ellipses for the top five most-hunted species for select communities: mountain, forest edge, and forest-river.

The forest-river community is located on a major river at a road crossing in dense forest, with negligible savanna vegetation nearby. The community lies in the NE corner of a multiple-use protected area and although restrictions on traditional indigenous people hunting activities within the area do not exist, it is interesting that the only hunting that occurred was along the north boundary of the reserve along the river (Figure 10b). Almost 100 percent of kills occurred in forest; no deer were killed and giant river turtles were among the top five most-hunted animals.

Conclusions

Several studies (Ulloa *et al.*, 1996, 2004; Fragoso *et al.*, 2000; Dunn, 2004; Silvius, 2004) addressing both the biological and social limits on hunting, have shown that neotropical indigenous peoples incorporate spiritual and cultural landscape elements in their hunting practices. These studies relied on ethnographies and explanations provided by indigenous peoples. Other studies have addressed in detail the role of physical parameters (Hill *et al.* 1997, Souza-Mazurek *et al.*, 2000) and anthropogenic landscapes (Good 1989; Parry *et al.* 2009) in influencing hunting. By incorporating the identification of spiritual sites into the research design and data analysis, this study attempted to more explicitly address the impact of such sites. By plotting animal kill locations, the spatial distribution of hunting activity across the landscape with reference to major factors known or hypothesized to influence the distribution of hunting is examined. Specifically, this study goes beyond other studies by incorporating the location of spiritual sites into a GIS database, thus enabling one to visually examine the role of special culturally-defined places in shaping hunting activity. In this way, it is possible to better understand how certain cultural norms (Posner and Rasmusen, 1999; Colding and Folke, 2001) affect patterns of resource use.

Several aspects of the physical and cultural environments play a role in creating patterns of higher and lower hunting intensity. These findings confirm those of other authors (Hill *et al.*, 1997; Broseth and Pedersen, 2000; Fragoso *et al.*, 2000; Peres, 2000; Smith, 2008) that the influence of distance that a hunter will travel from his community is important, but is also impacted variably by aspects of the physical environment. Moreover, mode of transport to hunting areas (Souza-Mazurek *et al.*, 2000), as well as whether the hunting activity was planned or opportunistic (Naughton-Treves *et al.*, 2003; Smith, 2005; Parry *et al.*, 2009), are cultural factors that affect the location and habitat in which a kill may occur. Most importantly for this research, we found some evidence that spiritual landscape elements influence where people hunt at the local scale, and can lead to avoidance of specific portions of the landscape. Given the importance of spirituality of many indigenous peoples in the region and beyond, it is evident that mapping the spiritual landscape alongside other factors and incorporating it into studies of hunting patterns may be an important step in understanding the sustainability of these systems. Other important factors seen in this study that affect hunting patterns include presence of protected areas and neighboring communities, which can impact the national and local 'rules' governing resource-use areas (Fragoso *et al.*, 2000; Silvius, 2004). For example, title to land may not only influence rules regarding resource use but also might change local conceptions of place; if a community requests and receives an extension of their titled lands, does that impact where a person may hunt through, for example, ceasing to hunt on areas of neighboring communities or increasing/extending hunting to show ownership? Thus, a key area of research lies in assessing the role of local complexity (physical, cultural, spiritual) and its interaction with regional environmental and political factors in driving patterns of hunting.

This research has implications for researchers attempting to understand indigenous resource use and impacts on wildlife populations, as well as for both indigenous communities and governments in defining policies and management plans for indigenous areas. For instance, Ulloa *et al.* (1996, 2004), Fragoso *et al.* (2000), and Silvius (2004) all discuss how wildlife managers and indigenous communities used the congruency between the indigenous concept of sacred or source sites (from where animals are released by shamans) and the western concept of protected areas to design spatially-based wildlife management systems. Thus, local conceptions of place are already valued in management; and being able to map these places can provide an even more powerful tool. While the authors acknowledge that reducing a spiritual place to a point in a GIS in and of itself cannot adequately portray meanings about a place, they believe that inclusion of these data can highlight factors that have traditionally been ignored in many studies of impacts of hunting on biodiversity and sustainable resource use, and in turn can be instrumental in informing development of more inclusive management objectives and plans for indigenous landscapes.

Notes

[1] Alternative spellings include "Macushi" in Guyana and "Macuxi" in Brazil.

[2] Alternative spellings include "Wapichan" in Guyana and "Wapixana" in Brazil.

[3] Distance zones of 0-6, >6-12, and >12 km from communities were selected to correspond with the distribution of wildlife transects that are part of the larger project from which this study comes.

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