

NATURAL LICKS AS KEYSTONE RESOURCES FOR WILDLIFE AND PEOPLE IN
AMAZONIA

By

OLGA LUCIA MONTENEGRO

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by

Olga Lucía Montenegro

This dissertation is dedicated to the memory of my father, José J. Montenegro, from whom I inherited his curiosity for animals, his love for nature and his spirit of adventure;

to my mother Blanca Lilia who, together with my father, gave me all the values that guide my life;

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Olga Lucia Montenegro

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Natural licks are particular sites in some types of habitats often visited by a number of wild animals with the purpose of licking or consuming soil (a behavior known as geophagy). Several studies associate geophagy with the nutritional ecology and/or health of the animals that use them. Therefore, the existence of natural licks in a particular habitat may reduce the costs of obtaining adequate nutrition, and/or maintaining health; and thus may be fundamental to population persistence. One of the habitats where natural licks exist is the Amazon forest. Many Amazonian wildlife species, including large birds and herbivorous mammals, are users of natural licks. Natural licks also may be important for rural communities that rely on wildlife for their subsistence. This is particularly important for Amazonian human communities, because one of the most common hunting techniques in those forests is waiting for game animals at natural licks.

Our study addressed the importance of natural licks for both wildlife and humans in the Yavari-Miri River valley in the northeastern Peruvian Amazon. A relatively large group of mammalian and large bird species frequently visited natural licks during 2001. The most frequent lick visitors were lowland tapirs. Natural licks found in the Yavari-Miri River valley had higher concentration of several minerals (Na, Ca, Mg, P, Cu, S, and B) compared to non-lick samples. Those differences were constant throughout the year; suggesting that natural licks are in fact, a source of minerals for wildlife in the Yavari-Miri River valley. The diet of the most-frequent lick visitor (the lowland tapir) was examined for mineral content. Results showed that combined foods eaten by lowland tapirs are of good quality regarding mineral content, except for Na, P, Cu and Zn. We suggest that tapirs supplement their mineral intake by consuming mineral-rich soils at natural licks in the Yavari-Miri River valley. The above results suggest that natural licks are a key resources for several Amazonian species because they represent a natural mineral source in the humid forest of western Amazonia.

To assess the importance of natural licks for Amazonian human communities, subsistence-hunting patterns were examined at the Nueva Esperanza village, in the Yavari-Miri River valley. Over 30% of total biomass hunted during 2001 was harvested at licks, and was heavily represented by lowland tapirs. Hunters of Nueva Esperanza village use more than 40 natural licks located along the Esperanza Creek and the middle and lower Yavari-Miri River. We recommend regulation of hunting at licks by temporal rotation of use. Also, we suggest that natural licks should be an attribute of habitat quality when selecting areas for wildlife conservation in western Amazonia.

CHAPTER 1 INTRODUCTION

In wildlife ecology, a resource has been simply described as “something an animal needs” (Caughley & Sinclair 1994:46). The conservation biology discipline has introduced the term keystone resources to refer to those resources that are critical or limiting in particular habitats, but are crucial for many species in a community (Primack 1993). The above concept is an extension of the keystone term used in other contexts. The term keystone was first used in ecology to refer to a predator species of exceptional importance because of its critical effect on prey populations in maintaining the structure of its community (Paine 1969). Since then, the concept of a keystone species has been extended to many species across trophic levels, and has been categorized according to their function and community importance (keystone predator, prey, mutualist, host, modifier; Mills *et al.* 1993). Power *et al.* (1996:609) proposed a refined definition for the keystone as “a species whose impact on its community or ecosystem is large, and disproportionately large relative to its abundance”. The keystone role has been extended not only to species (both plants and animals), but also to critical limiting resources that “occupy only a small area of the habitat, and yet are critical to many species in the community” (Primack 1993:48).

Natural licks are listed among those keystone resources (Primack 1993). Natural licks are particular sites in some types of habitats often visited by a number of wild animals with the purpose of licking or consuming soil. This behavior, known as geophagy, is common among many mammals (ungulates, primates, rodents) and several

species of birds. Geophagy has been reported in many geographical locations throughout the world.

Because ingested soils usually have a high content of one or several minerals and/or a higher clay content compared to non-eaten soils, several benefits of geophagy have been proposed. One hypothesis is that minerals in lick soil compensate for mineral deficiencies or imbalances (Jones & Hanson 1985). This is why researchers usually refer to geophagy sites as mineral licks or salt licks. Another hypothesis is that the clay in eaten soil has beneficial effects on decreasing acidosis, secondary plant compounds, intestinal infections or parasites (Mahaney 1993; Mahaney *et al.* 1996, 1997; Gilardi *et al.* 1999). Those studies refer to the licks as clay licks.

These hypotheses may not be mutually exclusive. Comparing data across studies is difficult because of the different research questions and methods used in each case (reviews in Kreulen 1985; Klaus & Schmid 1998; Diamond *et al.* 1999; Krishnamani & Mahaney 2000). The overall conclusion of those reviews is that geophagy has different functions for different animal species, and/or different functions for the same species under different situations. However, all proposed reasons for soil consumption at natural licks (as are called hereafter) seem related to the nutritional ecology and/or health of the animals that use them. Therefore, the existence of natural licks in a particular habitat may reduce the costs of obtaining adequate nutrition, and/or maintaining health; and thus may be fundamental to population persistence.

One of the habitats where natural licks exist is the Amazon forest, particularly in western Amazonia. Many wildlife species (mainly ungulates, primates, and rodents, and some birds species) are users of natural licks. Preliminary research in the Peruvian

Amazon indicated that during the dry season in the southern Peruvian Amazon, lowland tapirs and other ungulates are frequent lick users (Montenegro 1998). However, it is poorly known whether the use of licks is constant through the year, or occurs mainly during dryer seasons. Also, in that pilot study, further research on dietary mineral contents of lowland tapir food was suggested to better examine the mineral-intake hypothesis for tapirs in the Amazon forest.

Natural licks also may be important for rural communities that rely on wildlife for their subsistence. For many Amazonian rural communities, wildlife hunting continues to be one of the most important subsistence sources (Robinson & Bodmer 1999). A potential keystone role of natural licks for local hunters could be hypothesized, since one of the most common hunting techniques in the Amazon forest is waiting for game animals at natural licks. At the Tamshiyacu-Tahuayo Communal Reserve (RCTT) in the Peruvian Amazon, the presence of natural licks, known as *colpas*, is often an indispensable condition for establishing hunting sites (Puertas 1999). One important hunting strategy used by local hunters at the RCTT is going to the *colpas* at night looking for tapirs, deer and pacas (Puertas 1999). Moreover, Puertas (1999) provided one example of a hunter strategically placing food in *colpas* to accustom animals to supplied fruits. This practice allowed the hunter to rotate hunting sites over time.

Although the use of natural licks as hunting sites is commonly reported, few studies have quantified the relative importance of those places in terms of the amount of game obtained in relation to total hunting. The few published studies on this subject involve use of licks by native groups. In the Colombian Amazon, for example, indigenous communities of the Miriti-Parana River obtain about 25% of consumed meat from natural

licks (Walshburger & Hildebrand 1988). No other estimations of hunting return from natural licks are published, and the real importance of licks as hunting sites is generally poorly known in Amazonian hunting systems.

Over-hunting at natural licks was apparently controlled by social and ritual practices in many indigenous communities. For many Amazonian communities, however, such restrictions are no longer practiced, or are not part of their culture, especially for settlers who migrated from other regions. As a result, hunting at natural licks is usually uncontrolled. Often hunters report that a natural lick has been damaged when animals, as a consequence of excessive hunting, no longer visit it.

Intensive hunting at natural licks drives animals away, probably affecting their nutrition and health. Over-exploitation of many wildlife species also is contributing to declines in their populations. This is particularly true for ungulates such as lowland tapirs and large primates (Bodmer *et al.* 1993, 1997b). At the same time, over-exploitation of wildlife at natural licks may threaten subsistence of rural communities that depend on wildlife as their main source of subsistence. For the above reasons, a better understanding of the importance of natural licks as a resource for Amazonian wildlife, and for rural communities in the Amazon is needed in order to design effective wildlife-management programs that take into account both rural communities' subsistence and long-term wildlife persistence.

From the above background, these questions arise: how important are natural licks for both wildlife and people in western Amazonia? Can they be considered as a keystone resource in that habitat? Peres (2000) proposed that 4 ecological attributes could be examined in order to help identifying putative keystone resources: (1) degree of

consumer specificity, (2) temporal redundancy, (3) reliability, and (4) abundance. From the consumer's perspective, a keystone resource is one with low redundancy (available when alternative sources are not), is consumed by a large proportion of the species assemblage, is highly reliable, and has low abundance.

Although Peres (2000) proposed these attributes to identify putative keystone plant resources, they appear useful to examine the potential keystone role of other resources. For this reason, the above attributes are used here as a framework to examine the importance of natural licks in western Amazonia. If natural licks can be considered a keystone resource for both wildlife and people in western Amazonia, the following results would be expected: (1) a high number of lick users (both wildlife and people) visit the licks, (2) natural licks provide something to their users that is in short supply and is not easily substitutable (low redundancy), (3) natural licks are a reliable resource (are available when users need them), and (4) area occupied by natural licks in the habitat is small relative to its effect on its users.

Our study addressed the importance of natural licks for both wildlife and humans in a site of western Amazonia, the Yavari-Miri River valley of northeastern Peru. The study is presented in 4 components addressing the following objectives:

- **Objective 1:** To identify the wildlife species that are the most frequent licks users, to describe their pattern of visitation through the year, and to examine whether they visit licks in proportion to their abundance in the Yavari-Miri River valley in northeastern Peruvian Amazon.
- **Objective 2:** To evaluate natural licks as a source of minerals for Amazonian herbivores, and to describe the licks in terms of their size and location in the Yavari-Miri River valley.
- **Objective 3:** To examine the mineral intake hypothesis for lowland tapirs by determining the mineral content of tapir food and tapir feces.

- **Objective 4:** To examine the importance of natural licks for subsistence hunting in an Amazonian rural community, and its implications for management and conservation.

The following hypotheses were tested:

- **Hypothesis 1:** A relatively large number of species use licks, at least during part of the year.
- **Hypothesis 2:** For at least for some species, their use of natural licks is higher than expected from their abundance in the area.
- **Hypothesis 3:** Soils at natural licks have higher mineral concentrations (at least for one or more minerals) than non-lick soils.
- **Hypothesis 4:** Lowland tapir food is limited in one or more mineral nutrients in the Yavari-Miri River valley and such limitation is constant through the year.
- **Hypothesis 5:** Excretion of limited minerals (at least for some minerals) is low in tapir feces.
- **Hypothesis 6:** Hunting at natural licks provides a higher contribution to the overall harvest, at least for some species, as compared to other hunting sites.
- **Hypothesis 7:** Most rural hunters in a community of western Amazonia use natural licks as hunting sites

Chapter 2 addresses hypotheses 1 and 2, examining the pattern of natural lick use by Amazonian wildlife in the Yavari-Miri River region. Chapter 3 deals with the properties of consumed soils at natural licks, to examine hypothesis 3. Chapter 4 discusses browse and fruit as sources of minerals for lowland tapir, and mineral fecal excretion, to address hypotheses 4 and 5. Chapter 5 describes the use on natural licks by a rural community in the Yavari-Miri River, addressing hypotheses 6 and 7. Finally, Chapter 6 presents a synthesis of results and its implications for wildlife conservation in the Yavari-Miri River valley.

CHAPTER 2
NATURAL LICK USE BY AMAZONIAN WILDLIFE IN NORTHERN PERU

Introduction

Wildlife species around the world use natural licks. Many of those species are either mammals (Klaus & Schmid 1998; Krishanmani & Mahaney 2000) or birds (Diamond *et al.* 1999; Gilardi *et al.* 1999). Among mammals, ungulates visit natural licks in diverse habitat types. Muskox and caribou in tundra (Calef & Lortie 1975; Klein & Thing 1989), moose in boreal forests (Fraser & Hristieko 1981; Tankersley & Gasaway 1983; Couturier & Barrete 1987; Miller & Livitatis 1992), and white-tailed deer in many locations in North America (Weeks & Kirkpatrick 1976, Atwood & Weeks 2002) are some examples of ungulates using licks in temperate regions. For tropical areas, information on lick use exists mainly for areas of the Old World. African elephants (Holdo *et al.* 2002) and seven other ungulate species in savannas and woodlands (Henshaw & Ayeni 1971), Asian elephant and other ungulates in tropical forest of Thailand, and babirusa in Indonesia (Clayton & MacDonald 1999) are some large mammals using natural licks in the tropics. Besides ungulates, more than ten species of Old World primates are reported to eat soil from licks or the forest floor (Krishnamani & Mahaney 2000).

Much less is known about natural lick use in the Neotropics. Few publications exist, other than occasional reports of primates using licks (Heymann & Hartmann 1991; Izawa 1993; Ferrari 1995; Müller *et al.* 1997), tapir observations at a few sites (Peña *et*

al. 1996, Montenegro 1998, Lizcano & Cavelier 2000), and a study on the physiological significance of geophagy for some species of birds (Gilardi *et al.* 1999).

In both temperate and tropical regions, research dealing with natural lick use has addressed soil consumption (or geophagy), and its physiological significance to the animals. Several non-exclusive hypotheses transcend geographic areas and/or species (Kreulen 1985; Klaus & Schmid 1998; Diamond *et al.* 1999; Krishnamani & Mahaney 2000). The overall view is that soil consumption at natural licks is linked to the nutritional ecology (Chapter 4) and/or health of the lick users. Besides the benefits for the animals' nutrition and/or health, licks may also function as animal-gathering places, facilitating social encounters (Couturier & Barrete 1987, Ruggiero & Fay 1994).

Since natural licks may have more than one function for wildlife species, and those functions may vary across species, licks may represent a resource whose ecological importance goes beyond the particular benefits for individual species. As suggested by Klaus & Schmid (1998), presence of natural licks in some habitats may have an effect on population densities and structure, and may influence the carrying capacity of areas with lick sites. Studies rarely discuss natural lick use at a community-wide level with a broader ecological perspective. The ecological importance of natural licks could thus be overlooked.

We need to know which species in a given region use licks, how often they use them, and whether that use differs among species to assess the significance of licks as a resource for wildlife in that region. In the Amazon rainforest, this knowledge is limited, but it may have ecological and conservation implications.

This chapter examines the use of natural licks by wildlife species in the Yavari-Miri River valley in the northeastern Peruvian Amazon. The following questions were addressed:

- **Question 1.** Which species use natural licks in the Yavari-Miri River valley?
- **Question 2.** Do all species use licks with the same frequency, and does that frequency vary through the year?
- **Question 3.** Do the species use licks in proportion to their abundance in the area?

These questions were addressed by inventorying all lick visitors, by comparing lick visitation rates among species throughout the year, and by relating lick-visitation rates to available data on species abundance. If natural licks are a resource of community-wide importance in the Amazon forest, it is expected that a variety of species use licks, at least during part of the year, and that at least for some species, their use of the licks is higher than expected from their abundance in the area.

Study Area

The study area was located along the Yavari-Mirí River, a tributary of the Yavari River (Yavari District), Mariscal Ramón Castilla Province, Department of Loreto, in northeastern Peru. Fieldwork was conducted throughout the middle course of the Yavari-Mirí River, in the area between 4°30.23'S, 72°26.69W and 4°24.77'S, 72°09.76'W (Figure 2-1). Weather stations on this river do not exist, but the area's climate conditions were approximated from the closest stations in and around Iquitos (Marengo 1998), about 170 km northwest of the middle course of the Yavari-Miri River. The region is warm and humid. Mean annual temperature is 26°C, with monthly mean maximum temperatures ranging from 28 to 30°C, and monthly mean minimum temperatures from 17 to 20°C. Temperature drops below the minimum average for 3 to 5 days during *friagem*, an event

occurring between May and September, in which cold dry air masses coming from the South Pole arrive in the Amazon basin (Marengo 1984). Mean annual precipitation ranges from 2400 to 3100 mm (Marengo 1998), with the highest monthly rainfall occurring from February to April (as high as 350 mm), and the lowest from June to September (as low as 180 mm). Despite these monthly differences, there is no real dry season (unlike more southern regions of the Peruvian Amazon). Monthly rainfall differences are reflected in the Yavari-Mirí and Yavari River water levels and discharge. Water levels are lowest during the months of less rainfall (June to September), when sand beaches appear along the riverbanks. The Yavari-Mirí is a relatively narrow black-water river, and could appear very shallow during the least-rainy months.

The Yavari region harbors remarkable plant diversity. Although vegetation in the study site is still poorly known, about 1,600 plant species were identified during a recent rapid biological inventory in the Yavari basin. Estimated total plant diversity in the region is as high as 2,500 to 3,500 species (Pitman *et al.* 2003). This high diversity has led the whole area to be considered as one of the centers of plant diversity (CPD) in South America (Smithsonian Institute 2003). The three main geomorphic units in the study area are terraces, alluvial plains, and sedimentary surfaces (Figure 2-1). Main habitat types in the area are upland forests and flooded forests. Upland forests cover most of the area, and exist on terraces and sedimentary surfaces. They are not uniform through the area, with changes in plant composition occurring because of soil heterogeneity, somewhat similar to the upland forest around Iquitos (Ruokolainen & Tuomisto 1998; Pitman *et al.* 2003). Flooded forests exist on the alluvial plains of the Yavari-Mirí and Yavari rivers. Swamp forests (a type of flooded forest) are common along these rivers,

covering 25-50% of the flood plains (Pitman *et al.* 2003), and occur also on poorly drained upland soils.

Animal diversity in the area is also high, especially for mammals, causing some to consider the Yavari valley as one of the mammalian diversity hotspots of Peru (Valqui 1999, 2001; Salovaara *et al.* 2003). Although there is some hunting in the area, it is slight compared to other sites in the Peruvian Amazon (Bodmer & Puertas 1999; Bodmer *et al.* 2003), and many wildlife species are still abundant. Lowland tapirs and other ungulates, for instance, have healthy populations at the Yavari-Miri River (Salovaara *et al.* 2003).

Methods

An intense search for natural licks was conducted in the Yavari-Miri River valley from January to March 2001. This search occurred along 66 km of trails opened on both sides of the river. Trails were cut using predetermined bearings, based on characteristics of the terrain observed from a satellite image. Areas around the trails were checked carefully, especially when numerous tapir tracks were found, since they often indicate the proximity of natural licks. Once a natural lick was found, its geographical coordinates were taken with a global positioning system (GPS), and marked on a 1:100,000-scale map.

This search yielded 21 licks, most of them found on the north side of the Yavari-Miri River. Another 3 licks were found in July during a parallel study at the Yavari-Miri River (Salovaara, in prep.), and were included in our study. All 24 licks were located on the map (Figure 2-1). We monitored 7 to 24 licks from February to early December 2001 (except August), using 3 methods: camera trapping, direct observation, and examining tracks.

Camera Trapping

Automatic 35-mm cameras triggered by a passive infrared motion detector were set at selected licks. From March to July, three Buckshot® passive infrared system cameras (Buckshot35, Louisiana, USA) were used. From September to early December, two additional CamTrakker® (CamTrak South, Inc, Georgia, USA) cameras were available, for a total of 5 cameras used in our study. Cameras were located at the entrance trails and/or in front of the most-used sites of the licks, to increase the chance of every lick visitor to be detected and photographed. Locations of the cameras were changed on average of every 2 weeks to allow sampling of several licks. A total of 14 licks was surveyed with 5 cameras (Table 2-1).

Direct Observation

At 7 licks, observation platforms (and sometimes blinds) were built to allow observation without being seen by the animals. The area of platforms was 2.2 x 2.2 m, and they were built 3 to 7 meters above the most-used sites of the licks. Palm leaves were put around the platforms, to make them less visible. Those licks were monitored from February or March through early December 2001 (except August). An additional lick was added for direct observations from September, but no platform was built there. Instead, observations were made from a hammock tied 10 m above the lick. With the latter, a total of 8 licks was sampled by direct observation.

On average, 3 licks were observed per month (range, 1 to 7). Diurnal and nocturnal observations were made at the licks. Total hours of observation were 796, of which 544 (68.3%) were nocturnal and 252 (31.7%) were diurnal. Total average observation time per lick was 68 h at night (range, 12 to 144 h), and 31.5 h during the day (range, 7 to 69 h) (Table 2-1). Diurnal observations were made with binoculars. Nocturnal observations

were made with an ITT night vision scope. In some cases, a video camera was used to record animals visiting the licks. For each individual entering the lick, we hand-recorded species identity, time of arrival and departure, and activity during the visit.

Examining Tracks

On average, 8 licks (range 5 to 13) were checked for tracks every month from January to November 2001, except in June (when only 1 lick was checked) and August (when I was absent from the study site) (Table 2-1). We used this method to determine the proportion of licks used every month by large terrestrial species. When the same lick was checked for tracks more than once in the same month, we only used data for the first day of checking. Species identity was established from the animals' tracks. Only fresh tracks inside the licks were recorded at the time of checking. This method is not suitable for arboreal animals (birds and arboreal mammals), and smaller terrestrial mammals (such as pacas and agouties); they are likely to be underrepresented, especially when other larger animals step on the same entrance paths.

Data Analyses

Lick visitors

An inventory of lick visitors was obtained by combining data from the three detection methods (camera trapping, direct observation and tracks).

Frequency of natural-lick use

Data from camera traps, direct observations and tracks were analyzed separately to describe the use of natural licks by wildlife species.

Camera traps. Frequency of lick visitation, as shown by camera trapping, was estimated as the number of captures (photos) per 100 trap-nights (trapping success). A

trap-night is defined as each 24-hour period in which cameras were operational. Overall trapping success was compared among species for the whole study period.

Direct observation. Frequency of lick visitation for each species (as shown by direct observation) was estimated as the number of sightings per 100 h of observation (sighting rate). Overall sighting rates were compared among species for the whole study period. Comparisons were done separately for bird and mammal species. Among mammals, comparisons were done for diurnal and nocturnal species separately. Also, for species with more than 10 observations, comparisons of lick visitation rates among seasons were done. Although, as mentioned above, seasonality in the study area is not strong (a true dry season does not occur), the differences in rainfall and river levels led us to define three seasons: heavy rainy season (from February to May), low rainy season (from June to September), and moderate rainy season (from October to December). Since the sampling effort was not exactly the same for each season (Table 2-2), for each analyzed species, the expected frequency of lick visits was estimated by multiplying the total number of visits by the proportions of sampling effort from each season (weighted-count).

Tracks. For species detected with this method, the monthly rate of track occurrences was estimated as the ratio between the number of licks with tracks present over the total number of licks checked every month.

Within each data set (camera trapping and direct observation), comparisons of lick visitation rates among species and/or among seasons were done with chi-square goodness-of-fit tests. For all comparisons, a p -value ≤ 0.05 was considered significant.

When comparing only two categories (species), Yate's correction for continuity was used (Zar 1974).

Lick-visitation rate and species abundance

To test the null hypothesis that wildlife species visit natural licks in proportion to their abundance in the area, we used published information on abundance and density of large mammals coming from a 1,827-km line transect censuses conducted in the Yavari-Miri region from 1992 to 1999 (Bodmer *et al.* 2003, Salovaara *et al.* 2003). Data are available for several primates, ungulates and large rodent species. A chi-square test of homogeneity of proportions was used to compare the total number of sightings of mammal species (using only direct observation data), relative to their density in the area. Expected values for the test were obtained by multiplying the number of counts per species by the proportion of their density in the area. Birds were not included in this section because density data for most bird species are not available, except for large game species (Begazo 1999).

Results

Lick Visitors

At least 7 species of birds and 15 species of mammals (a total of 21 species) were detected at the licks by camera traps, direct observation and tracks (Table 2-3). Birds found using the licks were medium to large species and included 1 species of rail, 1 species of curassow, 2 species of guans, 1 species of pigeon, and 2 species of parakeets. Among mammals, lick visitors included 2 species of large primates, 4 species of ungulates, 4 species of medium to large rodents, 2 species of cats (jaguar and ocelot), and members of at least 2 families of bats. The cameras also captured a tail of an unidentified mammal (possibly a bushdog), which was excluded from analyses.

Frequency of Natural-Lick Use

Camera traps

Sampling effort with camera traps totaled 412 trap-nights. That trapping effort provided 87 photographs of animals at 14 natural licks from March to early December 2001. Photos recorded at least 17 species entering the licks (Table 2-3). Half of the photographs (43) were bats captured at 2 licks (Table 2-4). Bats were common visitors in most licks year-round (from direct observation). However, at the beginning of the study we noticed that they excessively triggered the cameras, reducing the time cameras were operational (on a single night a complete roll of film could be spent in only couple of hours). Cameras were moved away from high bat-traffic areas, and thus bats may be underrepresented in camera trapping for the rest of the year. Use of licks by bats is mentioned in general, in the discussion below, but they were excluded from statistical comparisons. Most bats at the licks were leaf-nose bats (Family Phyllostomidae), and at least 23% of the bat pictures were of fruit bats (Subfamily Stenodermatidae).

Other than bats, the remaining 44 photographs showed 14 species visiting the licks (Figure 2-2). The overall lick-visitation rate (detected by camera trapping) was not the same across species ($\chi^2 = 23.7$, $df = 13$, $p < 0.05$). These differences in lick visitation hold when comparing only among mammals ($\chi^2 = 15.5$, $df = 8$, $p < 0.05$), but do not hold when comparing only among birds ($\chi^2 = 2.1$, $df = 4$, $p > 0.05$).

Excluding bats, lowland tapir (*Tapirus terrestris*) was the most frequent species captured by the camera traps (10 photos in 412 trap-nights). Exclusive of pictures of the same individual, at least 8 different tapirs were photographed at the licks. Tapir photos come from 5 of the 14 licks sampled with camera traps, which are located in the middle and upper Yavari-Mirin valley (Figure 2-1). Peccaries (*Tayassu pecari* and *Pecari*

tajacu), deer (*Mazama americana*), pacas (*Agouti paca*), and ocelots (*Leopardus pardalis*) were captured 4 times at the licks, and the remaining species were registered only 1-2 times with camera traps.

Direct observation

A total of 119 animals were detected at the 8 licks sampled from observation platforms. Fifteen of the 21 species found at licks were seen with this method (Table 2-3). Eighty-three animals were observed during day hours, and 36 animals were seen at night (Table 2-5). Overall sighting rate was not equal across species ($\chi^2 = 88.3$, $df = 14$, $p < 0.05$). Differences among species hold when comparing sighting rates among bird species ($\chi^2 = 42.4$, $df = 5$, $p < 0.05$), and among mammal species ($\chi^2 = 42.5$, $df = 8$, $p < 0.05$), separately. Among birds, pigeons (*Columba subvinacea*), parakeets (*Pyrrhura picta* and *Pionopsitta barrabandi*), and blue-throated piping guans (*Pipile cumanensis*) were the most frequent species at the licks, with sighting rates of 9.5, 4.7 and 4.3 sightings per 100 observation hours respectively (Figure 2-3.). Among diurnal mammals, black spider monkeys (*Ateles paniscus*) were the most frequent visitors, with a sighting rate of 5.1 sightings/100 diurnal-observation hours. Howler monkeys and the two species of peccaries and agoutis were seen also, but with less frequency (Figure 2-4.). Nocturnal visitors to the licks were tapirs, pacas, red-brocket deer, and in one occasion a porcupine. Red-brocket deer have both diurnal and nocturnal activity, but they were grouped within the nocturnal mammals because they were seen at the licks only at night. Overall, tapirs were the most frequent visitors to the licks across nocturnal species, with a rate of 3.8 sightings/100 nocturnal-observation hours (Figure 2-5).

Examining tracks

A total of 24 licks were checked for tracks throughout the year. Tracks of lowland tapir (*Tapirus terrestris*), white-lipped peccary (*Tayassu pecari*), collared peccary (*Pecari tajacu*), and red-brocket deer (*Mazama americana*) were found at the licks almost all year-around (Figure 2-6). However, rates of track occurrences were higher for lowland tapirs, except in January. Data from June, although it is displayed, is excluded from this pattern because only one lick was checked for tracks that month. Track data indicate that even though all ungulates use licks during the year, tapirs visit a higher number of licks as compared to the other 3 species detected with this method.

Variation in Lick Use through the Year

Variation in lick use across the 3 seasons was determined only for the three most frequently observed bird species (pigeons, parakeets and piping guans) and the two most frequent mammals (spider monkeys and lowland tapirs). Although number of observations seemed higher after June, that was the result of an increase in the sampling effort. As a consequence, no significant differences were found when comparing the number of sightings in proportion to the hours of observation across seasons for any of the species tested (Table 2-6).

Lick-Visitation Rates and Species Abundance

Density estimations in the Yavari-Miri River valley were available for the following mammalian species (Bodmer *et al.* 2003, Salovaara *et al.* 2003): spider monkey (*Ateles paniscus*), red-hower monkey (*Alouatta seniculus*), lowland tapir (*Tapirus terrestris*), white-lipped peccary (*Tayassu pecari*), collared peccary (*Pecari tajacu*), red-brocket deer (*Mazama americana*), and black agouti (*Dasyprocta fuliginosa*). Comparisons among species indicate that these mammals did not visit the licks in

proportion to their abundances in the area ($\chi^2 = 795.15$, $df = 6$, $p < 0.05$). Three patterns emerged from this comparisons: (a) species with low density and high visitation rate, such as tapirs, spider monkeys and howler monkeys (Figure 2-7); (b) species with higher densities and lower lick visitation rate, such as the 2 peccary species; and (3) species with both low densities and low lick visitation rate, such as the red-brocket deer and the black agouti (Figure 2-7).

Discussion

Lick Visitors

Birds. The Yavari-Miri region harbors a large diversity of birds (Lane *et al.* 2003). The 7 bird species found visiting licks in the Yavari Miri River valley belong to 2 families of large birds (Rallidae and Cracidae) and 2 medium size birds (Columbidae and Psittacidae). Among the large birds, the family Cracidae was the most common at the licks. Three of the 4 species of Cracidae inhabiting the Yavari region (*Crax salvini*, *Penelope jacquacu* and *Pipile cumanensis*) (Lane *et al.* 2003; Begazo 1999) were seen at the licks, and represent 75% of the species of this family in the area. They are large birds (>1.5 Kg) that use primarily interior forest habitats (Begazo 1999). Among the medium-size birds visiting the licks, the most common (in fact the most frequent bird at the licks) was the pigeon (*Columba subvinacea*), one of the 6 species of the family Columbidae (16%) reported for this area (Lane *et al.* 2003). The other 2 bird species visiting the licks were 2 species of parakeets (*Pyrrhura picta* and *Pionopsitta barrabandi*), which are medium to small parrots, and account for the 10% of the parrot species reported in the Yavari region (20 species) (Lane *et al.* 2003). Large parrots and macaws were not observed at the licks, although they are reported using licks in other locations in the Amazon. That is also the case for large parrots of the genus *Amazona* and at least 3

species of macaws (*Ara severa*, *A. chloroptera* and *A. macao*), seen at a natural lick along the riverbank of Manu River (Gilardi *et al.* 1999, Emmons & Stark 1979) and Madre de Dios River (personal observation) in southern Peruvian Amazon. Most of these species are present in the Yavari-Miri region (Lane *et al.* 2003, personal observation), but they were not sighted in the licks studied. An explanation for their absence in those licks is that large parrots are more common in open areas such as river pathways (Begazo 1999) and above forest canopy (Gilardi & Munn 1998), while the licks studied were all found more than 1 kilometer inside the forest. The high cliffs along riverbanks of several Amazonian rivers, such as the Manu or Madre de Dios River, are not seen to the same extent on the smaller Yavari-Miri River. In contrast, use of licks by the Cracidae (guans) seems less common in the riverbank licks, than in the interior licks studied. This is expected since those cracid species prefer interior forest (Begazo 1999).

All bird species observed at the licks were engaged in geophagy, but the reasons for this behavior are not well understood. The several hypotheses proposed to explain geophagy in birds have been examined for parrots (Gilardi *et al.* 1999), with evidence in favor of the detoxification hypothesis, and secondary, the mineral supplementation hypothesis. No information is available for the other bird species in regard to geophagy. However, all the species at the licks have in common that they are frugivore (parakeets) or frugivore/omnivore (Stotz *et al.* 1996), and may use licks for similar reasons.

Independent of the specific benefits for the species, licks seem important for at least a set of large and medium bird species in the Amazon. Those species, especially the cracids, although less diverse than other bird groups, constitute a significant part of the

standing biomass of bird communities in the Neotropics (Terborgh 1986), and are important seed dispersers (Levey 1994).

Mammals. The Yavari region is also home for a large diversity of mammals; probably the highest recorded in any Amazon location, and possibly even the entire Neotropics (Valqui 2001, Bodmer *et al* 2003, Salovaara *et al* 2003). Among the mammals, the most common lick visitors were 2 species of primates, along with most ungulates and large rodents. Although 13 species of primates exist in the Yavari-Miri valley, most of them are medium to small size primates, and only 3 species are large primates: the red-howler monkey (*Alouatta seniculus*), black spider monkey (*Ateles paniscus*), and the woolly monkey *Lagothrix lagothricha*). Except for the latter, the largest primates were the ones seen at the licks in this study. Although woolly monkeys are mentioned in one study as lick users (Bicca-Marquez & Calegario-Marquez 1994), and at the study area were seen close to the licks on many occasions, they never actually came down to eat soil, as observed for howler and spider monkeys. Smaller primates such tamarins have been also reported eating soil (Heymann & Hartmann 1991), but more from termite mounds than natural licks. Several species of howler monkeys and spider monkeys also are reported regularly visiting licks in other tropical forest of Colombia (Izawa 1993), French Guiana (Julliot & Sabatier 1993) and Brazil (Bicca-Marquez & Calegario-Marques 1994). *Ateles paniscus* is a frugivorous primate, while *Alouatta seniculus* is more folivore species, although it includes fruits and other food items in its diet. In general, no single reason for geophagy in primate species has been found (Krishnamani & Mahaney 2000), or for these two genera of large Neotropical primates in particular

(Isawa 1993, Souza *et al.* 2002), but all hypotheses suggest nutritional or medicinal benefits.

All ungulates living in the Yavari-Miri valley were seen at the licks, except for the gray-brocket deer (*Mazama gouazoubira*). Local inhabitants, however, report that this species is also a lick visitor, but their lower abundance compared to the other ungulates may explain why they were not detected during the study period. Deer and tapirs are browser/frugivore (Bodmer 1989), collared peccaries are frugivore/omnivore, and white-lipped peccary are omnivore. Among rodents, the 2 large terrestrial rodents (paca and agouti) and one arboreal species (porcupine) use licks. The terrestrial rodents (paca and agouti) are also frugivores, and the arboreal one (porcupine) is a herbivore/frugivore. For ungulates it is suggested that use of licks is related to their nutrition or health. The nutritional benefit hypothesis is examined in Chapter 3 and 4 for lowland tapir. Use of licks by other South American ungulates also is reported in other locations. For example, the Chacoan peccary also regularly visits licks (Sowls 1997), although its diet differs somewhat from the Amazonian species (Taber 1993).

Other mammalian lick visitors were bats, mainly fruit-eating bats. These species were very common all year-around at the licks. Little is known about the use of natural licks by fruit bats. Some information is available on bat mineral nutrition, but mainly for the Old World bats (Nelson 2003). Potential nutritional benefits could be expected for the fruit-bat species observed in this study, and deserves more attention in future research. The family Phyllostomidae is the most diverse and common in the Neotropics, and a substantial number of species are fruit-eating bats. Their role in the tropical forest as seed disperser is well known (Fleming 1988).

Other than primary consumers at the licks, carnivores such as jaguars (*Panthera onca*) and ocelots (*Leopardus pardalis*) were also detected visiting these sites. There is no record of any carnivore eating soil, and the purpose of their visits is probably related to their prey, rather than a direct use of the soils at the licks. Jaguars eat a variety of prey, including peccaries, pacas, agouties, and deer among other animals (Emmons 1987; Sunquist & Sunquist 2002). Ocelots eat smaller prey, weighing less than a kilogram such as spiny rats (*Proechimys* spp.). Also, although not prominent in their diet, ocelots may occasionally kill agouties, deer and peccaries (Sunquist & Sunquist 2002). All these prey species are lick visitors which may offer an opportunity for easy hunting to these predators.

In summary, a relatively large group of mammalian species and large bird species are lick visitors. Most of them are frugivore or frugivore/herbivore species, and may obtain different benefits from the licks. Indirect benefits for non-herbivorous species are proposed for carnivores, since they may reduce their cost of foraging, by visiting the licks where prey may be concentrated. As a consequence, the use of licks also represents a cost for their herbivore users, since the risk of predation is high inside the licks. All these factors reveal that licks are an important component of Amazon forest for a relative large number of species, and across the food guilds.

Frequency of Lick Use

From all the three methods used in this study, the consistent pattern regarding differences in licks visitation rate indicate that lowland tapir and spider monkeys, among mammals, and pigeons, parakeets and guans, among birds, are the most frequent lick users. No seasonality was found in their use of licks. This result contrasts with more seasonality in lick use reported in other sites, such as eastern Brazilian Amazon (Ayres &

Ayres 1979) and southern Peruvian Amazon (Montenegro 1998). Those sites are clearly more seasonal in terms of rainfall where differences between dry and wet season are stronger. Compared to those other sites, the Yavari-Miri River valley showed lower visitation rates, at least for species with some information. For example, at the Madre de Dios River in Southern Peruvian Amazon, where seasonality is very strong, a very high visitation rate to the licks was recorded for lowland tapir during the dry season (Montenegro 1998), and red-brocket deer (Montenegro, unpublished data). In that study, almost 200 observations of lowland tapir were obtained in about 3 months, whereas in the Yavari-Miri valley, just over 20 direct observations were recorded during almost a year. Several factors may explain these differences. Besides the differences in seasonality, at the Madre de Dios River, the location of the study was at an ecotourism site where tapirs were already habituated to human presence. At the Yavari-Miri River, tapirs were in general more difficult to see, and the higher number of sightings occurred at those licks further inside the forest. Also, although hunting it is slight compared to other locations in Peru, licks are one of the preferred sites to hung tapirs (Chapter 5). Tapirs in the Yavari-Miri valley seem to be more cautious when visiting licks, and may even return to their trail before entering a lick when an observer is present. This behavior depends on the individual, and is probably influenced by the previous experience of tapirs at licks used by hunters.

Despite these differences, the common pattern in licks observed at Yavari-Miri and Madre de Dios Rivers, is the relatively high number of lick users, with a higher visitation rate by the lowland tapir, over other species. Spider monkeys also used licks in Madre de Dios, but they seemed to prefer another lick, and since only one lick was regularly

monitored in that site, comparisons with Yavari-Miri are difficult. In summary, the most frequent lick visitors overall are the lowland tapirs, and their use of licks is constant through the year in the Yavari-Miri region.

Lick-Visitation Rate and Species Abundance

Wildlife species in the Yavari-Miri region did not use licks in proportion to their abundance. Lowland tapirs had the lowest density, and yet, were the most frequent lick visitors. Low density but high lick use was also observed by the spider monkeys and secondarily by howler monkeys. Interestingly, peccaries are very abundant in the area, especially white-lipped peccary, and even though peccaries use the licks, they do it with less frequency compared to tapirs. White-lipped peccaries seem to perceive their habitat at a different scale than collared peccaries (Fragoso 1998, 1999). They might be using other licks, located farther away in the forest.

Overall, natural lick visitors comprise a relatively large set of species. The most frequent visitors, both birds and mammals, are mainly large species that comprise a substantial part of the standing biomass in the Amazon forest. Many of them are frugivores or frugivore/herbivores that play an important role in the forest structure through seed dispersion. Although the benefits for the species may vary, licks are an important resource for a large number of species, and should be considered an indicator of habitat quality for those species, and a key element in western Amazonian forests

Summary and Conclusions

A relative large number of Amazonian animals visit natural licks in the Yavari-Miri River valley, in the northern Peruvian Amazon. Most species were large birds and mammals. The most frequent species visiting the licks was the lowland tapir. No strong seasonality in lick use was observed in the study area, as seems to occur in other tropical

forest. Species did not visit licks in proportion to their abundance in the area. Lowland tapirs have low density compared to the other ungulates in the Yavari-Miri River valley, and yet, they were the most frequent visitor of natural licks.

Table 2-1. Sampling effort used in three detection methods to determine the frequency of natural-lick use by wildlife in the Yavari-Miri River Valley, during year 2001.

Month	Camera trapping ¹	Direct observation ²		Examining Tracks ³
		Diurnal	Nocturnal	
January	---	---	---	5.0
February	---	2.0	38.0	7.0
March	29.0	8.0	61.0	7.0
April	1.0	5.5	0.0	6.0
May	7.0	5.0	73.0	11.0
June	9.0	12.5	24.0	1.0
July	21.0	36.5	60.0	9.0
September	108.0	64.0	84.0	6.0
October	141.0	49.0	72.0	10.0
November	98.0	62.0	120.0	13.0
December	2.0	7.5	12.0	---
Total	412.0	252.0	544.0	24.0 ⁴

¹ Number of trap-nights (number of 24-hour periods when cameras were operational).

² Number of hours spent at observation platforms.

³ Number of licks checked for tracks.

⁴ Cumulative number of licks checked at the end of the study period.

Table 2-2. Sampling effort used in direct observation per season.

Season	Direct observation	
	Day (h)	Night (h)
Heavy rainy (Feb-May)	21	172
Low rainy (Jun-Sep)	113	168
Moderate rainy (Oct-Dec)	118	204
Total	252	544

h = cumulative hours of observation.

Table 2-3. Species detected at natural licks by camera trapping, direct observations and tracks in the Yavari-Miri River valley, Peruvian Amazon.

Species	English name	Local name	Camera traps	Direct observation	Tracks
BIRDS					
GRUIFORMES					
Family Rallidae					
<i>Aramides cajanea</i>	Grey-necked wood-rail		X		
CRACIFORMES					
Family Cracidae					
<i>Crax salvini</i>	Salvin's curassow	Paujil	X	X	
<i>Penelope jacquacu</i>	Spix's guan	Pucacunga	X	X	
<i>Pipile cumanensis</i>	Blue-throated piping-guan	Pava negra	X	X	
COLUMBIFORMES					
Family Columbidae					
<i>Columba subvinacea</i>	Ruddy pigeon	Paloma	X	X	
PSITTACIFORMES					
Family Psittacidae					
<i>Pyrrhura picta</i>	Painted parakeet	Lorito		X	
<i>Pionopsitta barrabandi</i>	Orange-cheeked parrot	Lorito		X	
MAMMALS					
CHIROPTERA					
Subfamily.					
Stenodermatidae					
	Fruit-bats	Mashu	X		
Other Phyllostomidae					
	Bats	Mashu	X	X	
PRIMATES					
Family Cebidae					
<i>Alouatta seniculus</i>	Red howler monkey	Coto		X	
<i>Ateles paniscus</i>	Black spider monkey	Maquisapa		X	
CARNIVORA					
Family Canidae					
<i>Speothos venaticus*</i>	Bushdog		X		
Family Felidae					
<i>Leopardus pardalis</i>	Ocelot	Tigrillo	X		
<i>Panthera onca</i>	Jaguar	Otorongo	X		
PERISSODACTYLA					
<i>Tapirus terrestris</i>	Lowland tapir	Sachavaca	X	X	X
ARTIODACTYLA					
Family Tayassuidae					
<i>Tayassu pecari</i>	White-lipped peccary	Huangana	X	X	X
<i>Pecari tajacu</i>	Collared peccary	Sajino	X	X	X
Family Cervidae					
<i>Mazama Americana</i>	Red-broket deer	Venado rojo	X		X

Table 2-3 (continued)

Species	English name	Local name	Camera traps	Direct observation	Tracks
RODENTIA					
Family Erethizontidae					
<i>Coendou prehensilis</i>	Porcupine	Erizo		X	
Family Agoutidae					
<i>Agouti paca</i>	Paca	Majás	X	X	X
Family Dasyproctidae					
<i>Dasyprocta fuliginosa</i>	Black agouti	Añuje	X	X	
Family Echimididae					
<i>Proechimys sp.</i>	Spiny rat	Sachacuy	X		

* Probable.

Table 2-4. Number of monthly photo-captures at 14 licks form March to December 2001, in the Yavari-Miri River Valley, Peruvian Amazon

Species	Season									Total
	Heavy rainy			Low rainy			Moderate rainy			
	Mar	Apr	May	Jun	Jul	Sep	Oct	Nov	Dec	
BIRDS										
<i>Aramides cajanea</i>							1	1		2
<i>Crax salvini</i>							1			1
<i>Penelope jacquacu</i>						1	1			2
<i>Pipile cumanensis</i>						2	1			3
<i>Columba subvinacea</i>						4				4
MAMMALS										
Subfamiy Stenodermatidae	7							10		17
Other Phyllostomidae	16					9		1		26
<i>Leopardus pardalis</i>							3	1		4
<i>Panthera onca</i>							1			1
<i>Tapirus terrestris</i>	1			1	4	3	1			10
<i>Tayassu pecari</i>						4				4
<i>Pecari tajacu</i>						1	1			2
<i>Mazama Americana</i>							2	2		4
<i>Agouti paca</i>						4				4
<i>Dasyprocta fuliginosa</i>								1		1
<i>Proechimys sp.</i>						1				1
Number animal photos	24	0	0	0	1	30	14	17	0	86
Trapping effort (# trap-nights)	29	1	7	9	21	108	141	94	2	412

Table 2-5. Frequency of birds and mammals observed at eight natural licks from February to early December (excluding August), 2001 in the Yavari-Mirin River Valley, Peruvian Amazon.

Time of observation/Species	Feb	Mar	Apr	May	Jun	Jul	Sep	Oct	Nov	Dec	Totals
Day											
Birds											
<i>Crax salvini</i>								1.0			1.0
<i>Penelope jacquacu</i>	1.0						2.0		2		5.0
<i>Pipile cumanensis</i> * (1-5)	1.0				1.0		4.0	2.0	4		12.0
<i>Columba subvinacea</i>					2.0	5.0	5.0	8.0	4		24.0
<i>Pyrrhura picta</i> * (>50)						1.0	5.0	3.0	2		11.0
<i>Pionopsitta barrabandi</i> * (>20)								1.0			1.0
Mammals											
<i>Alouatta seniculus</i> * (5)							1.0	1.0	3		5.0
<i>Ateles paniscus</i> * (2-3)		1.00			1.0	1.0		5.0	5		13.0
<i>Tayassu pecari</i> * (>50)	1.0				1.0	1.0	1.0				4.0
<i>Pecari tajacu</i> * (2)		1.00				1.0	1.0				3.0
<i>Dasyprocta fuliginosa</i>				1			2.0	1.0			4.0
Diurnal sightings/month	3.0	2.0	0.0	1.0	5.0	9.0	21.0	22.0	20	0.0	83.0
Day hours/month	2.0	8.0	5.5	5.0	13.0	36.5	64.0	49.0	62	7.5	252.0
Sighting rate (Sights/day hours)	1.5	0.2	0.0	0.2	0.4	0.25	0.33	0.45	0.32	0.0	0.33
Nigth											
Mammals											
<i>Tapirus terrestris</i>		1.0		2.0	3.0	2.0	4.0	4.0	5		21.0
<i>Mazama Americana</i>		2.0		1.0			1.0	1.0	1		6.0
<i>Agouti paca</i>	1.0	3.0		2.0		1.0	1.0				8.0
<i>Coendou prehensilis</i>	1.0										1.0
Sightings per month	2.0	6.0	0	5.0	3.0	3.0	6.0	5.0	6	0.0	36.0
Day hours/month	38.0	61.0	0	73.0	24.0	60.0	84.0	72.0	120	12.0	544.0
Sighting rate (sights/night Hours)	0.05	0.1	0	0.07	0.1	0.05	0.07	0.07	0.05	0.0	0.07
Total sightings											119.0
Total observation hours											796.0
Overall sighting rate (total sightings/total Hours)											0.15

* Sightings of groups, not individuals (group size in parenthesis).

Table 2-6. Chi-square values for testing the null hypothesis that number of sightings is the same in the three seasons.

Species	χ^2	df	<i>p</i> -value
Birds			
<i>Columba subvinacea</i>	2.194	2	>0.05
<i>Pyrrhura picta</i>	1.152	2	>0.05
<i>Pipile cumanensis</i>	0.053	2	>0.05
Mammals			
<i>Ateles paniscus</i>	5.037	2	>0.05
<i>Lowland tapir</i>	3.131	2	>0.05

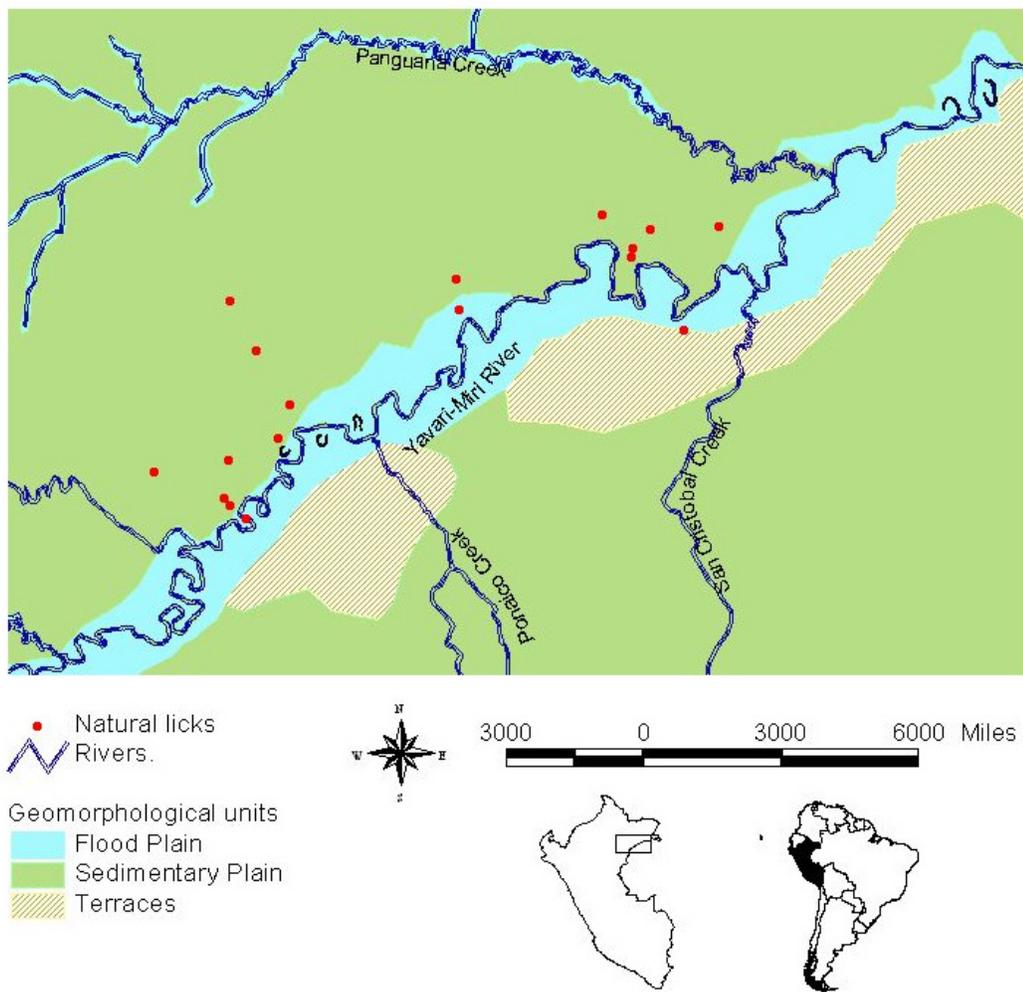


Figure 2-1. Location of 24 natural licks found in the Yavari-Miri River Valley, northeastern Peru.

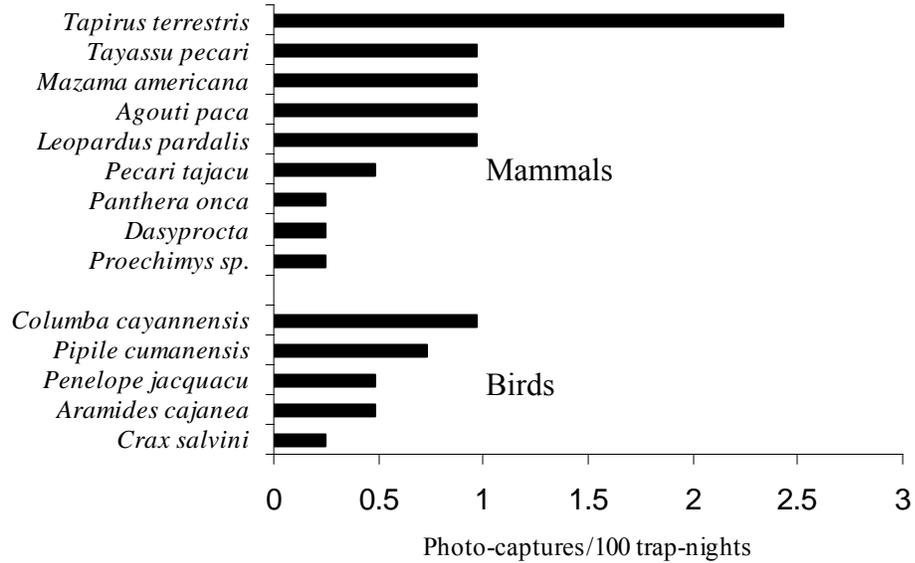


Figure 2-2. Photo-captures per 100 trap-night per species at 14 licks from March to December 2001 in the Yavari-Mirin River Valley, Peruvian Amazon (excludes bats).

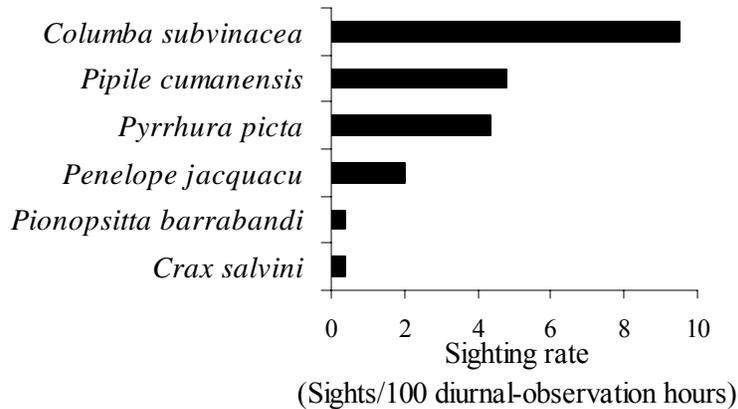


Figure 2-3. Total sighting rate of bird species at 8 licks surveyed from February to early December 2001 in the Yavari-Miri River Valley, Peru.

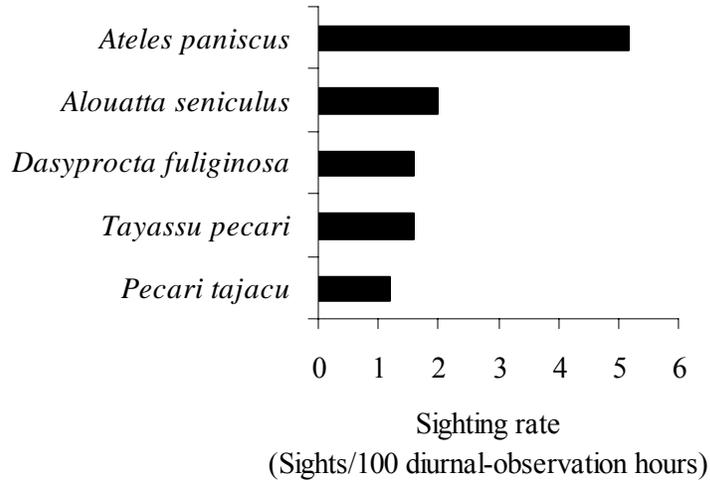


Figure 2-4. Total sighting rate of diurnal mammal species at 8 licks surveyed from February to early December 2001 in the Yavari-Miri Valley, Peru.

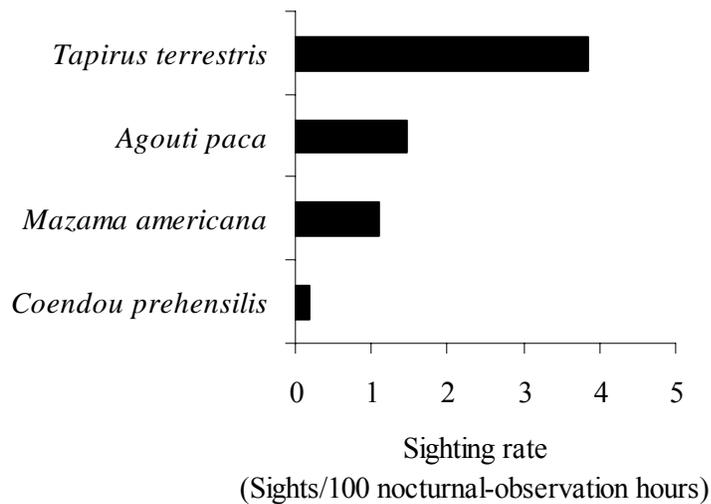


Figure 2-5. Total sighting rate of nocturnal mammal species at 8 licks surveyed from February to early December 2001 in the Yavari-Miri Valley, Peru.

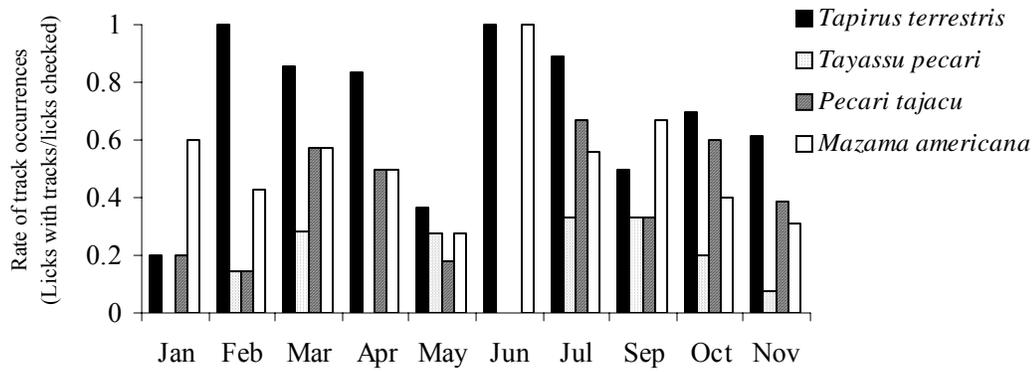


Figure 2-6. Ratio of track occurrences for tapir (*Tapirus terrestris*), white-lipped peccary (*Tayassu pecari*), collared peccary (*Pecari tajacu*), and red-brocket deer (*Mazama americana*) from January to November of 2001 in the Yavari-Miri Valley, Peruvian Amazon.

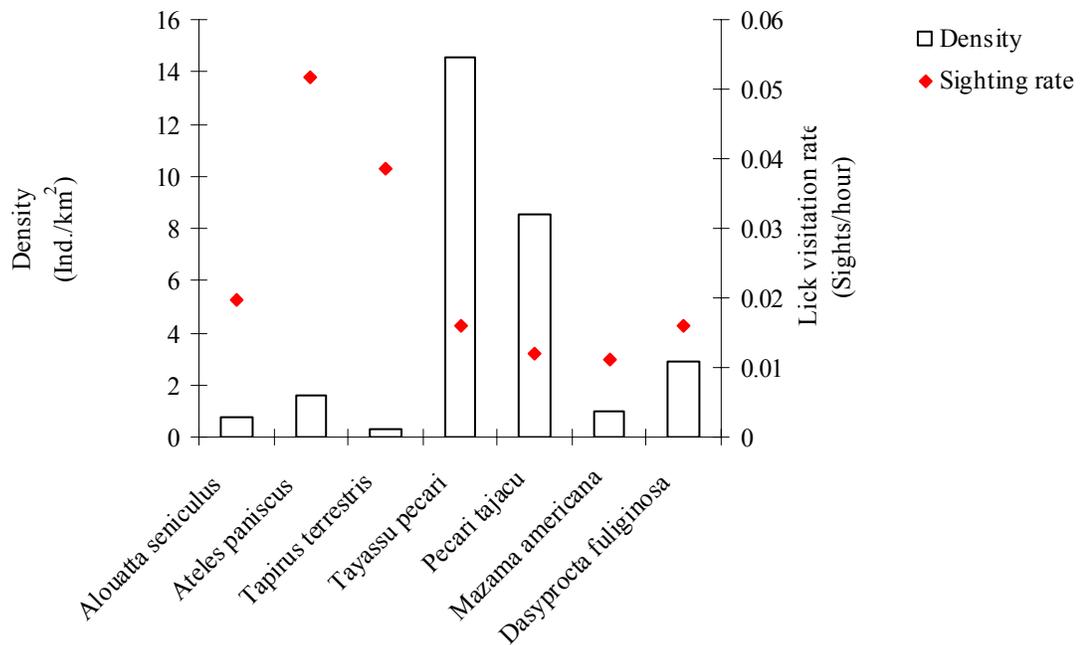


Figure 2-7. Density of selected mammals in the Yavari-Miri River valley and their overall lick-visitation rate during year 2001.

CHAPTER 3
NATURAL LICK SOILS AS SOURCE OF MINERALS FOR WILDLIFE IN THE
YAVARI-MIRI REGION

Introduction

Soils indirectly influence nutrition of herbivores through the amount and quality of plant biomass they produce. However, since many animals purposely consume or lick soil materials (a behavior known as geophagy), a more direct effect of ingested soils is also considered (McDowell 2003). Many wildlife species engage in geophagy, and diverse studies link this behavior to their mineral nutrition (Hebert & Cowan 1971; Weeks & Kirkpatrick 1976; Robbins 1983; Stark 1986; Jones & Hanson 1985; Klein & Thing 1989; Moe 1992; Kennedy *et al.* 1995; Tracy & McNaughton 1995; Holdo *et al.* 2002). Other researchers, however, associate soil ingestion with the potential benefits of clay in soils, such as buffering gastrointestinal fluids (Oates 1978), avoiding diarrhea (Mahaney 1993; Mahaney *et al.* 1996; Mahaney *et al.* 1997), or providing protection against toxic plant secondary compounds (Gilardi *et al.* 1999). The latter two benefits have been suggested due, in part, to a higher content of clay of some geophagical soils as compared to non-consumed soils.

Geophagy is usually selective, occurring in specific locations commonly termed natural, mineral, salt or clay licks, depending on the benefits attributed to soil consumption. Characterization of soils from natural licks is available for several sites of North America (Jones & Hanson 1985; Kennedy *et al.* 1995; Tracy & McNaughton 1995). In the tropics, chemical features of licks are available for Old World tropical

savanna habitats (Weir 1972; Ruggiero & Fay 1994; Holdo *et al.* 2002), and to a lesser extent, for tropical forest sites (Klaus *et al.* 1998; Moe 1993). In the Amazonian Neotropics, natural licks have been characterized for a few sites, such as southern Peru (Emmons & Stark 1979; Gilardi *et al.* 1999), a site in Brazil (Ayres & Ayres 1979) and southeastern Colombian Amazon (Narvaez & Olmos 1990; Lips & Duivenvoorden 1991).

Results from the above studies vary, and comparisons are difficult because of differences in methods (including chemical determinations), number of natural licks sampled, presence/absence of control samples and their collection site with respect to licks, types of licks studied, geographical location, animal species using the licks, and general research questions, among others. Also, natural licks around the world have different origins and characteristics, and the benefits to wildlife are obscured by regional differences in soil properties. For these reasons, it is necessary to consider not only the chemical composition of the licks, but their geocological context in order to better interpret their role in the ecology of their users.

In tropical areas with high rainfall, some elements are easily leached and usually pose a challenge for the mineral nutrition of many wildlife species (Robbins 1983). One of the regions where such limitation exists is the Amazon basin, where precipitation is high, ranging 2000-3000 mm annually (Marengo 1998). Most of the Amazon forest is characterized as having very acid soils, low in available nutrients, and high in concentrations of toxic Al. In this type of environment, herbivore species may face mineral limitations if their only source of minerals is the plant resources. If natural licks in the Amazon region provide some minerals of nutritional importance for herbivores,

they might play an important role in animal nutritional ecology and population persistence.

A region in the Amazon where natural licks occur and where many species persist in healthy populations is the Yavari-Miri River valley, in northeastern Peru (Salovaara *et al.* 2003). A relatively high number of wildlife species use natural licks in the Yavari-Miri River valley (Chapter 2), including all resident ungulates (especially lowland tapirs), two species of monkeys, large rodents and large birds. It is unknown whether all these species are attracted to the licks for the same reasons. However, it is thought that for the herbivores in particular, licks might provide some elements of nutritional importance. Also, it might be that those licks provide other, not necessarily exclusive, benefits to the animals, such as clay, as suggested for other Amazonian licks (Gilardi *et al.* 1999).

The purpose of this chapter is to describe the natural licks occurring in the middle Yavari-Miri River valley of the Peruvian Amazon in terms of their size and location along the river, and to evaluate them as a source of minerals and/or clay for Amazonian herbivores. The hypotheses examined in this study were the following:

- **Hypothesis 1.** Soils at natural licks have higher mineral concentration (for one or more minerals) than non-lick soils.
- **Hypothesis 2.** There is no difference in soil mineral content between high water and low water seasons.
- **Hypothesis 3.** Lick soils have higher clay content as compared to non-lick soils.

It is predicted that if natural licks in the Yavari-Miri River valley are a direct source of minerals, higher concentrations of one or more extractable elements will occur in lick soils as compared to non-lick soils. Also, if natural licks are a reliable source of minerals through the year, it is predicted that their mineral concentrations (at least for some

elements) do not substantially drop throughout the year. Also, if animals are attracted to the licks for their clay content, it is predicted that higher percentages of clay content will differentiate lick from non-lick soils. To test these predictions comparisons of several physical and chemical characteristics of lick and non-lick materials were conducted and analyzed within the regional geo-ecological context.

Study Site

The study was conducted along the Yavari-Miri River, a tributary of the Yavari River, in the Department of Loreto, in northeastern Peru. Fieldwork was conducted throughout the middle course of the Yavari-Miri River, in the area between 4°30.23'S, 72°26.69W and 4°24.77'S, 72°09.76'W. This area is located from San Cristobal Creek upstream to Maquisapay Creek (Figure 3-1). Elevation in the area covered in this study varies from about 90 to 120 meters above sea level. Mean annual temperature in the region is 26°C, with monthly mean maximum temperatures ranging from 28 to 30°C, and monthly mean minimum from 17 to 20°C. Mean annual precipitation ranges from 2400 to 3100 mm (Marengo 1998), with the highest monthly rainfall occurring from February to April (as high as 350 mm), and the lowest from June to September (as low as 180 mm). In spite of these monthly differences, there is no real dry season, as occurs in more southern regions of the Peruvian Amazon. Monthly rainfall differences are, however, reflected in the Yavari-Miri and Yavari river water levels and discharge. The water levels are the highest during the months of heavy rainfall (February to April), and this period will be called here the high water season. The lowest water level of the Yavari-Miri River occurs during the months of less rainfall (June to September), when sand beaches appear along some riverbanks. The Yavari-Miri is a black water river relatively narrow, and

could appear very shallow during the least rainy months. This latter period will be called here the low water season.

Geology of the Yavari-Miri valley is not known in detail, but research conducted around the Iquitos area (Räsänen *et al.* 1998), and along the Amazon River (Hoorn 1993) provides useful regional information. The main geological formation in the area is the Pebas formation, a thick layer of sediments covering a large area of northern Peru, and equivalent to sediments of northwestern Brazil and southeastern Colombia (Hoorn 1993). The area is also associated with the Iquitos Arch, an uplifted geological structure that separates the Amazon and Marañon Sedimentary basins (Hoorn 1993).

The three main geomorphic units in the study area are terraces, alluvial plains and sedimentary surfaces (Figure 3-1). Main habitat types in the area are upland forests and flooded forests. Upland forests cover most of the area, and exist on terraces and sedimentary surfaces. They are not uniform throughout the area, but change in plant composition because of soil heterogeneity, somewhat similar to the upland forest around Iquitos (Ruokolainen & Tuomisto 1998; Pitman *et al.* 2003). Flooded forests exist on the alluvial plains of the Yavarí-Miri and Yavari rivers. Swamp forests, a type of flooded forest, are common along these rivers, covering 25 to 50% of the flood plains (Pitman *et al.* 2003), and occur also on poorly drained upland soils.

Plant and animal diversity in the area is very high (Pitman *et al.* 2003). The high mammalian species richness leads some to consider the Yavari valley as one of the mammalian diversity hotspots in Peru (Valqui 1999, 2001; Salovaara *et al.* 2003). Although there is some hunting in the area, it is slight compared to other sites in the Peruvian Amazon (Bodmer & Puertas 2000; Bodmer *et al.* 2003), and many wildlife

species are still abundant. Lowland tapirs and other ungulates, for instance, have healthy populations at the Yavari-Miri River (Salovaara *et al.* 2003).

Methods

Lick Location and Description

From January to March 2001, an intensive search for natural licks was conducted along 66 km in trails on both sides of the Yavari-Miri River. Trails were cut across the 3 landscape units of the area (flood plains, terraces and sedimentary surfaces), and across an area of approximately 220 km². This search yielded 21 natural licks. Three additional licks were found in July during a parallel research project at the Yavari-Miri River (Salovaara, in prep.), for a total of 24 licks found from the San Cristobal Creek to Maquisapay Creek. Once a natural lick was found, its geographical coordinates were taken with a global positional system (GPS), and marked on a 1:100,000-scale map.

Licks were measured (length and width) and described in terms of their form, number of geophagical sites (spots where animals eat soil) and general features of vegetation cover. Location of licks was displayed on top of a satellite image of the study area using the software ArcGIS to determine their distance to the river and the physiographic unit where they occurred.

Physical and Chemical Characterization of Lick Soils

Soil sampling

Soil samples from 7 licks were collected both during the high water season (March - April), and the months of low rainfall or low water season (September-October). At each lick, 1 to 2 composite samples were collected from the sites where animals ate soil, plus a composite control sample from areas within 10 to 20 m outside of each lick. Each composite sample was made up from 3 to 4 sub-samples. Additionally 6 licks were

sampled (lick and nearby non-lick soils) in September through November 2001, for a total of 13 natural licks sampled in those months. For the whole year, a total of 55 samples was collected (35 lick soil samples and 20 control samples, Table 3-1). Each sample (about 1 kg) was air dried and stored for further analysis. All natural licks sampled also were monitored for animal activity with one or several methods (Chapter 2).

Laboratory analyses

Samples were sent for analysis to the Terrapreta Soil Laboratory, a private laboratory in Colombia. Chemical characterization of soils was conducted using the methods described by IGAC (1990), and included the following: soil texture, pH, organic C, available P, exchangeable Al, carbonates (CO_3), cation exchange capacity (CEC), and extractable Ca^{2+} , Mg^{2+} , K^+ and Na^+ . Samples collected during the high water season also were analyzed for concentration of B, Cu, Fe, Mn, Zn and S. Percentages of sand, silt and clay in soil samples were determined by the Bouyoucos hydrometer method. Soil pH was measured with a potentiometer in a volumetric 1:1 soil: water suspension. Organic carbon was determined by the Walkley-Black method, which uses chromic acid to measure oxidisable organic carbon in soil (Walkley & Black 1934; IGAC 1990). Available P was measured with the Bray II method, in which P is extracted using Bray II solution and measured colorimetricly, based on the reaction with ammonium molybdate (Bray & Kurtz 1945; IGAC 1990). Exchangeable Al was determined by the Yuan's method in KCl extractions (Yuan 1959; IGAC 1990). Carbonate concentration was qualitatively measured by reaction with 10% HCl. Cation exchange capacity and exchangeable Ca^{2+} , Mg^{2+} , K^+ and Na^+ were extracted with 1N ammonium acetate at pH = 7. B, Cu, Fe, Mn, Zn and S were extracted with acid solutions of HCL and H_2SO_4 . Concentrations of these elements in extracts were determined by atomic absorption spectrophotometry.

Data analysis

Since samples from each lick were matched with non-lick samples from nearby areas, differences in element concentrations between lick and non-lick samples were tested within seasons using paired t tests (Zar 1974). Likewise, differences in element concentrations between high water and low water seasons were tested with paired t tests, using data from only those licks that were sampled in both seasons. For the latter tests, comparisons were made among licks and non-lick samples separately. Since the paired t test requires that differences among related samples have a normal distribution, a test for normality was conducted for each data set using the Kolmogorov-Smirnov test for normality. All tests for normality were non-significant, and no data transformations were needed to reach normality. For all tests, a p -value <0.05 was considered significant. All statistical analyses were performed with the software SPSS version 11.5 for Windows.

Results

Lick Location and Description

Most natural licks found at the Yavari-Miri River, between San Cristobal Creek to Maquisapy Creek, where located in the area on the northwest side of the river. Only 1 natural lick (lick number 14) was located on the right side of the Yavari-Miri River, on its flood plain. Distance to the licks from the river varied from 0 m (at the river bank) to 5,400 m in the upland forest (Table 3-2). Licks were located at elevations varying from 92 - 116 m. The majority of licks (18 or 75%) were located on the sedimentary plain, and the remaining 6 (25%) were located on the Yavari-Miri River flood plain (Table 3-2, Figure 3-1). No lick was found on terraces.

Natural licks were classified according to their location as the following 4 types: (1) upland licks, (2) low *bajjal* licks, (3) high *bajjal* licks, and (4) river bank licks.

Upland licks (n = 18) were located on the sedimentary plain, in an upland forest environment that does not flood at any time of the year. These licks occur in forest openings, usually in depressions 3 - 10 m deep, often with large stones, and caves made by constant mining of the animals. Numerous animal teeth marks on the carved holes are present, and are accessed by clear animal paths. Most of these licks are close to small creek headwaters. Vegetation cover inside these licks is scarce, represented by some palm trees, shrubs and some ferns scattered on muddy surfaces. Low *bajial* licks (n = 2) were located on low flooded plains that are inundated for several months during the high water season. They were located in low areas with poor drainage, from a few up to 400 meters away from the riverbank. This type of lick is functional only during the drier months of the year (June to September), and even in those months, may become flooded for several days after a heavy rain. Vegetation inside those licks is mainly herbaceous with scattered bushes on a muddy, soft surface. High *bajial* licks (n = 3) were also located on the flooded plain of the Yavari-Miri River, but unlike low *bajial* ones, they are flooded for shorter periods of time (approximately 30-40 days a year). They were located from 161 to 436 m from the riverbank (Table 3-2). Finally, 1 riverbank lick was found on the Yavari-Miri River. Although a few more licks of this type exist along the Yavari-Miri River, they were difficult to identify because they are underwater for several months of the year, and animal paths usually disappear with the flooding.

Lick size varied from 10 m² to 1,196 m². Total area of licks added up to 7,282 m². Total area of these licks represents 0.0033% of the 220 km² crossed by the trails. Although it is possible that some licks were missed in the search, their proportional area is very small. Number of geophagical sites inside the licks varied from 1 to 3 depending

on the size and form of the lick, with the largest licks having more than one geophysical site.

Physical and Chemical Characterization of Lick-Soils

Particle size

In lick soils, mean percentages of sand, silt and clay were $39.5 \pm 8.5\%$, $41.5 \pm 6.9\%$, and $18.9 \pm 11.18\%$, respectively. In non-licks soils, proportion of sand, silt and clay were $35 \pm 6.6\%$, $37.7 \pm 7.3\%$ and 27.22 ± 7.6 , respectively (Figure 3-2). Differences between lick and non-lick soils regarding particle size proportions were not significant ($p > 0.05$). Texture of individual samples varied from loam to sandy loam, silt loam and clay loam. All textures were found in both lick and non-lick soils. However, loam soils were the most frequent across all samples.

Chemical properties of lick and non- lick soils

Soil pH was higher in lick samples as compared to non-lick samples (Table 3-3), both in the high water season ($t = 11.84$, $df = 6$, $p < 0.001$), and the low water season ($t = 7.74$, $df = 12$, $p < 0.001$). In general, licks soils were either neutral or alkaline with a pH of 7 to 8, whereas non-lick soils were always acid, with pH of 3.5 to 5.

Mean percentage of organic carbon varied from $0.6 \pm 0.27\%$ in non-lick soils to $1.26 \pm 1.03\%$ in lick samples (Table 3-3). Although organic carbon seems to be higher in lick soils, there was a large variation within samples (range 0.3% to 3.7%), and differences were not significant in either the high water ($t = 1.18$, $df = 6$, $p = 0.28$) or the low water season ($t = 1.82$, $df = 9$, $p = 0.10$). However, most samples, from both lick and non-lick soils had relatively low organic carbon, usually less than 1%.

Exchangeable Al was very low in lick samples compared to non-lick samples in both seasons. In fact, only in the low water season, some free Al^{+3} was found in lick soils,

but in a much lower concentration than in non-lick soils ($t = 4.16$, $df = 6$, $p = 0.009$), and none was found in the high water season (Table 3-3). In contrast, in non-licks soils, exchangeable Al varied from 11.65 to 12.88 meq/100 kg of soil.

Cation exchange capacity varied on average from 21.88 ± 4.32 to 25.22 ± 5.76 meq/100 g of soil (Table 3-3), with no significant difference between lick and non-lick soils either in the high water season ($t = 0.78$, $df = 6$, $p = 0.46$) or the low water season ($t = 1.59$, $df = 12$, $p = 0.13$). Lick soils had higher base saturation (many times over saturation) than non-lick soils (Table 3-3).

Lick soils had higher content of P, Ca, Mg, and Na than non-lick soils, and those differences were consistent in both seasons (Table 3-3). Likewise, B, Cu, and S were present in higher concentrations in lick samples as compared to non-lick samples (Table 3-4). No significant differences between lick and non-lick soils were found for K, Fe, Mn and Zn concentrations ($p > 0.05$, Tables 3-3 and 3-4). Comparing lick and non-lick soils between seasons, concentration of Ca in lick soils increased during the low water season ($t = 6.4$, $df = 6$, $p = 0.001$). Na concentration increased also during the low water season in lick soils ($t = 2.49$, $df = 6$, $p = 0.047$), and marginally in non-lick soils ($t = 2.40$, $df = 7$, $p = 0.053$), being always much higher in lick than non-lick samples (Table 3-3). No seasonal differences were found for P, Mg and K concentrations ($p > 0.05$) within each soil type. No seasonal comparisons were done for concentration of microminerals (B, Cu, Fe, Mn, Zn and S) because they were analyzed only in samples from the high water season.

Discussion

Lick Location and Description

Location and other features of the natural licks at the Yavari-Miri River are related to the geological formations, landforms, and past and present tectonic processes in the area. Researchers often associate natural licks in this part of the Amazon with the Pebas formation (Lips & Duivenvoorden 1991; Hoorn 1993). This formation is made of sediments deposited during the Middle Miocene (11 to 17 million years) in a long lasting, large shallow lake system with fluvial influence from the Andes, and occasional marine incursions from the Caribbean (Hoorn 1993; Räsänen *et al.* 1998). The Pebas formation is characterized by blue clay alternating with sand and lignite layers with an abundant presence of fossil mollusks (Hoorn 1993).

From a satellite image of the area, it is noted that main rivers in this part of the Amazon basin are controlled by a general linear pattern with a SW-NE orientation, dissected by smaller rivers running in a NW-SE linear pattern. These alignments form a tectonic micro-block pattern that indicates neotectonic activity. A similar pattern exists in the southern Colombian Amazon (IGAC 1999). Because of this neotectonic activity, the Yavari-Miri and Yavari Rivers are being “pushed up” in a NW direction. As a consequence, terraces are formed to the SE of rivers, whereas on the NW side, the action is mainly erosive. This dynamic could be related to the fact that most licks were found on the NW side of the Yavari-Miri River, where erosive activity is stronger. This fluvial erosion is probably associated with some of the riverbank licks of the Yavari-Miri River valley because it sporadically exposes the Pebas formation sediments.

Riverbank licks, as named in this study, coincide with the *barranco* (cliff) licks described in the middle Caqueta region of southern Colombia, about 400 km north of the

Yavari-Miri River (Lips & Duivevoorden 1991). Also, some of the licks termed in this study as upland licks could coincide with the *abandoned meanders* (Lips & Duivevoorden 1991), which are formed when old streams dissecting the sedimentary plain become dry during low water season. This latter type of lick is probably formed by a subterraneous flux of water enriched with elements leached from either sediments of the Pebas formation or sediments of different origin. In fact, although most of the sedimentary plain is characterized by low mineral content, superficial sediments can be very variable, with some having higher nutrient contents, depending on many factors (Linna 1993). Therefore, some licks may not be directly related to the Pebas formation, but could be associated with the flux of enriched water leaching superficial sediments.

The names given to licks in this study (upland, high *bajjal*, low *bajjal* and riverbank licks) reflect their location on the main landforms in the area, rather than their origin. This classification is arbitrary, with the intention to reflect their functionality through the year. Riverbank licks (especially if their location is within maximum-minimum water level), as well as low *bajjal* licks are functional only when they are exposed, during low water season (from June to September-early October).

Upland licks are more permanently functional since they do not become flooded at any time of the year. However, those licks are not static, but may occasionally lose their function, when new sediments cover the exposed materials that attract the animals. This dynamic, however, occurs on a larger time scale, and thus is difficult to monitor in the short term. In the study area some old licks were found where the caves carved by the animals are still evident, but with no sign of recent use, and even with growth of pioneer

plants. These considerations indicate that contrary to what it may seem, natural licks are a dynamic resource.

Licks in the study area were relatively small, compared to licks in other sites of the world, such those used by large mammals in Africa (Klaus *et al.* 1998) and Asia (Moe 1992). Licks in those parts of the world may actually be very large, which is associated with the size and density of their users. The users of African licks, for example, are elephants and large ungulates, some of which occur in high densities (Klaus *et al.* 1998). The Amazonian licks are not as impressive in size, because their users are not as large as the African ones. However, in all these regions (Africa, Asian and the Amazon) the licks occupy a small proportion of the habitat, but yet, are frequently used by many species. In this study, all ungulates, and several species of large rodents, large primates and large birds frequently use licks (Chapter 2), and even if they represent a small proportion of their habitat, they appear to be a very important resource for these species in the Yavari-Miri River valley. In other words, natural licks in the study site may play an important role in the ecology of their users, disproportionately to the area they occupy.

Physical and Chemical Characterization of Licks

Particle size

Natural licks did not show significantly higher mean clay content as compared to non-licks samples. This contrasts with findings in other licks of southern Amazonia in which clay content was 50% vs 35% in non-lick samples (Galetti *et al.* 1999). In the licks in the Yavari-Miri region, mean clay content was about 19% vs 27% in non-lick samples, and the difference was not significant due to variation in both sets of samples. This percentage of clay content is considered medium according to the scale (15 to 40%) used by Kauffman *et al.* (1998) for the upland soils around Iquitos. Only 2 lick samples (out of

32) were classified as clay (about 40% of clay), and 5 were classified as clay loam (>28% of clay). The same textures were present in non-lick samples. Also, in the licks studied in the Colombian Amazon, 2 licks of the type called “abandoned meander” had high sand content (68-86% respectively) (Lips & Duivenvoorden 1991). In addition, 2 of the 3 soil samples consumed by mustached tamarins (*Saguinus mystax*) at the Rio Blanco, in northeastern Peruvian Amazon, were sandy and only 1 was fine-grained (Heymann & Hartmann 1991). Results of our study do not support the hypothesis that it is the clay content that attracts animals to the licks, as may be the case for large parrots and macaws at licks in southern Peru (Gilardi *et al* 1999). These results agree with the view that there is not a single reason for geophagy across species. Most licks studied in the Yavari-Miri River valley were located inside the forest, and large parrots or macaws were never observed in those licks, although they were observed flying above the tree canopy and along the Yavari-Miri River.

Chemical properties of lick and non- lick soils

Lick samples had the following differences with non-lick samples: higher pH, minimum free aluminum, and higher content of P, Ca, Mg, Na, B, Cu and S. These results coincide with other lick characterizations in the Amazon region, in which more than one element is in a higher amount at the licks. For example, Ca, Mg, Na and sometimes K have been frequently more abundant in natural licks of Manu, in southern Peru (Emmons & Stark 1979; Montenegro 1998), middle Caqueta region of Colombia (Lips & Duivenvoorden 1991), and Amacayacu, in southern Colombia (Narvaez & Olmos 1990). In other tropical areas, like Africa, licks also show a high content of Na (Weir 1972; Abrahams 1999; Holdo *et al.* 2002) and other elements, including Ca, Mg, P, and some times K (Klaus *et al.* 1998; Ruggiero & Fay 1994; Henshaw & Ayeni 1971;

Tracy & McNaughton 1995). In a few cases, however, researchers have found it difficult to determine differences between lick and non-lick soils because of the large variation among samples (Seidensticker & McNeely 1975). An important factor in some studies has been the nature and origin of control samples, which may obscure actual differences of lick *vs* non-lick materials. Some times samples used as controls come from very distant sites from the licks and the regional variation of soil properties is seldom taken into account when doing comparisons.

In temperate areas, licks used by large ungulates are often rich in Na (Hebert & Cowan 1971; Fraser & Hristienko 1981; Klein & Thing 1989, Tankersley & Gasaway 1983; Miller & Livitaitis 1992). However, at a large scale some differences occur across the whole region. For example, in eastern North America the main elements in licks are Na and Mg, whereas in western North America they are Ca and Mg (Jones & Hanson 1985).

Since often more than one element is in higher concentrations at the licks, researchers find it difficult to attribute the use of licks to one single element as the one sought by the animals. However, it is important to consider that availability of one element in the soil is not independent to the other elements, as well as other properties of the soil. For this reason, in order to better interpret the differences between lick and non-lick samples found in this study, it would be useful to consider not only the high concentration of some elements, but also other soil properties.

Differences among lick and non-lick soils in this study fit in several aspects the characterization of 1 of 5 group soils described by Kauffman *et al.* (1998) for the upland areas (*terra firme*) around Iquitos, 170 km west of the study site on the Yavari-Miri

River. This group of soils (group I in Kauffman *et al.* 1998) are young soils, not or slightly lixiviated, occurring on sites where erosion had exposed parental materials unaltered with meteorizable minerals such those of the Pebas formation or the named Buena Union unit (a unit described by the Amazon River, close to the Iquitos area). Such soils are located in low areas (less than 200 m) or in transitional zones between upland forest and alluvial plain of the Amazon River or its tributaries. This group of soils has contrasting characteristics, with the upper part being very acid, with low base saturation and high exchangeable aluminum. The same soil, at a depth between 2 to 3 m has a very high base saturation, no exchangeable aluminum, and neutral or slightly alkaline pH. The upper layer of these soils and the immediate subsoil are porous and water permeable, whereas the deeper layer is water saturated due to a low permeability. Clay and other textures are found in those soils.

The above description coincides in many aspects with the features of the lick and their associated non-lick samples described in this study. It is possible, then, that the licks in the Yavari-Miri valley are associated to a similar type of soils under comparable erosion processes.

In the topsoil, when leaching removes Ca and other bases, pH reduces in approximately the same proportion (Brady 1974). At lower pH, more Al is free in the soil, reducing availability of other cations. Soil materials less exposed to leaching have higher pH, and consequently less free aluminum. Kauffman *et al.* (1998) found that critical pH after which there is no interchangeable Al in the soils of upland forest around Iquitos is 5.5. This coincides with the absence of free Al in the lick samples, since all of

them had pH >5.5. As seen here, when pH is high, as in the lick samples, not only 1 but several cations (such as Na⁺, Ca²⁺, Mg²⁺ and K⁺) become more available.

The presence of carbonates in the licks also indicates that less altered parent materials are the constituents of the licks of the middle course of the Yavari-Miri River. For these reasons more than one element (bases) are available at the licks.

In general, nutrient availability in soils has been studied mainly in relation to plant nutrition, but not in direct association with animal nutrition. However, consumption of mineral-rich soil has been interpreted as a strategy to alleviate mineral deficiencies or imbalances in the diet of some animals. Evidence supporting the hypothesis that soil intake may help in reducing mineral deficiencies was summarized by Kreulen and Jager (1984) and includes: (1) the ability of grazing livestock to choose supplemented salts containing elements that are deficient in their diets, (2) in vivo and in vitro experiments showing increase of macro and micronutrient levels in digestive liquors by elements released from ingested soil, and (3) increase in absorption and retention of several minerals by adding soil or clay to the diet of some domestic animals.

In southern Amazon, however, Gilardi *et al.* (1999) did not find significant difference in the release of Na in an in vitro experiment by adding soil to an acid environment, simulating the parrots gut conditions, and concluded that lick soils were not a significant source of Na for the parrots, although Na content was higher in lick samples. These researchers did not provide, however, information on the mineral content of the parrots diet, making it difficult to see whether other minerals could be of importance for the birds. Instead, they found support for the detoxification hypothesis, in part because of higher clay content in lick samples. In contrast, the natural licks we studied in the Yavari-

Miri River valley did not show consistent differences in clay content, but they did consistently show higher concentrations of several elements as compared to non-lick soils.

It is possible that more than one type of lick exists in the Amazon, and that they have different origins, and properties. The role of natural licks may vary across species as suggested by other researchers in several parts of the world (Kreulen 1985; Diamond *et al.* 1999; Klaus & Schmid 1998; Krishnamani & Mahaney 2000).

Since the licks studied in the Yavari-Miri River valley showed a higher concentration of several elements, it is possible for animals to exploit them according to their needs. Elements sought by animals will depend on the properties of their food, and especially their elemental concentrations. In Chapter 4, element concentration in the food of the lowland tapir, the most frequent lick user in the Yavari-Miri River, is examined.

Summary and Conclusions

The purpose of this chapter was to describe the natural licks occurring along the middle course of the Yavari-Miri River, and to establish whether they were a source of mineral nutrients and/or clay for herbivores. Another objective was to examine whether licks maintain their mineral concentration through the year. Most licks were located on sedimentary plains, and most seem to be related to the deposits of the Pebas formation. Mineral content of licks was higher than non-lick samples, and did not drop through the year. Some elements such as Na and Ca even increased in concentration during the drier months, probably because leaching is reduced during those months.

Several elements were available and potentially used by the animals in the Yavari-Miri River valley. Among macrominerals, Na, Ca, Mg and P had consistently higher concentrations in licks than non-lick samples. This is related to the low alteration of the

sediments that form the licks. Also, among microminerals, Cu, S and B were more concentrated in the licks. Overall, our results indicate that natural licks represent a source of minerals for wildlife in the Yavari-Miri River valley. Whether animals use licks for one or more minerals would depend on the mineral concentration of their food and their potential needs for specific elements, which probably varies across species. Further research is needed in order to examine the mineral concentration foods eaten by lick users in the Amazon forest. A study in this direction was conducted for one of the most frequent lick visitors, the lowland tapir (Chapter 4).

Table 3-1. Number of soil samples from lick and non-lick sites gathered in year 2001 in the Yavari-Miri River valley in the Peruvian Amazon.

Lick number	High water season		Low water season	
	Lick soils ¹	Non-lick soils ²	Lick soils ¹	Non-lick soils ²
1	2	1	2	1
2	2	1	2	1
11	2	1	2	1
12	1	1	1	1
13	2	1	2	1
15			2	1
16	2	1	3	1
18			2	1
19	2	1	1	1
20			1	1
21			2	1
22			1	1
24			1	1
Total samples	13	7	22	13

¹ Number of licking sites inside each lick; a sample was taken from each site

² Matched control samples taken within 10-20 m outside the licks

All samples (lick and non-lick soils) were composed of 3-4 sub-samples

Table 3-2. Descriptive features of 24 natural licks in the upper Yavari-Miri River valley, Peruvian Amazon.

Lick Number	Location		Distance from river (m)	Elevation (m)	PhU ¹	Lick type ²	Size (m ²)	GS ³
	Coordinates							
	Latitude	Longitude						
1*	-04°22.16	-72°11.57	1,300	109	SP	Upland	1,196	2
2*	-04°22.10	-72°10.28	1,350	104	SP	Upland	201	2
3	-04°22.70	-72°11.91	564	109	SP	Upland	25	1
4	-04°21.90	-72°12.47	1,326	109	SP	Upland	80	1
5	-04°22.54	-72°11.91	533	116	SP	Upland	30	1
6	-04°27.43	-72°19.50	733	94	SP	Upland	25	1
7	-04°27.30	-72°19.62	1,050	94	SP	Upland	30	1
8	-04°27.69	-72°19.21	100	94	FP	Low <i>bajial</i>	400	1
9	-04°26.58	-72°19.54	1,685	94	SP	Upland	15	1
10	-04°26.80	-72°20.95	3,500	94	SP	Upland	35	1
11*	-04°26.17	-72°18.60	770	92	SP	Upland	928	2
12*	-04°30.47	-72°25.26	625	109	SP	Upland	81	1
13*	-04°30.73	-72°25.26	310	112	FP	High <i>bajial</i>	293	2
14*	-04°20.08	-72°10.93	586	110	FP	Low <i>bajial</i>	100	2
15*	-04°23.70	-72°15.19	500	103	FP	High <i>bajial</i>	436	2
16*	-04°23.11	-72°15.24	1,500	103	SP	Upland	1,010	3
17	-04°30.80	-72°25.74	0	111	FP	Riverbank	25	1
18*	-04°29.79	-72°25.72	1,800	112	SP	Upland	180	2
19*	-04°29.78	-72°25.78	2,000	112	SP	Upland	527	2
20*	-04°25.51	-72°18.39	880	97	SP	Upland	357	2
21*	-04°24.50	-72°19.01	3,030	97	SP	Upland	323	2
22*	-04°23.56	-72°19.52	5,400	97	SP	Upland	814	1
23	-04°30.62	-72°25.23	590	111	SP	Upland	10	1
24*	-04°30.67	-72°25.25	380	100	FP	High <i>bajial</i>	161	1
Mean natural-lick size (sq meters ± standard deviation)						300 ± 351		
Total area of natural licks (square meters)							7,282	

* Licks sampled for soil analyses

¹ PhU = Physiographic Unit; SP = Sedimentary Plain; FP = Flood Plain.

² Lick type: Upland = licks appear as depressions in upland forests, usually with large stones and caves or mined holes; Low *Bajial* = licks are on areas flooded for several months; High *bajial* = licks are on areas intermittently flooded for days to several weeks; Riverbank = licks are on the cliffs of the Yavari-Miri riverbank, and are under water several months a year.

³ GS = Number of geophagical spots (where animals actively consume soil) inside each natural lick

Table 3-3. Chemical characterization of soils from lick and non-lick sites in two seasons of year 2001 in the Yavari-Miri River valley in the Peruvian Amazon.

Feature	High water season			Low water season		
	Lick Soils (n = 13)	Non-lick Soils (n = 7)	Paired t-test <i>p</i> -value	Lick Soils (n = 22)	Non-lick Soils (n = 13)	Paired t-test <i>p</i> -value
	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	
pH (1:1 soil:water)	7.41 ± 0.54	4.61 ± 0.63		6.95 ± 0.82	5.15 ± 0.61	
Organic Carbon (%)	1.26 ± 1.03	0.84 ± 0.26		1.22 ± 0.88	0.60 ± 0.27	
Samples with CO ₃ (%) ¹	84.61	0		59.09	15.38	
P available (ppm)	82.55 ± 38.90	2.57 ± 2.27	0.001	85.90 ± 50.39	22.05 ± 35.52	0.001
Al ³⁺ (meq/100 gr)	0.00	11.65 ± 6.85	*	0.027 ± 0.128	12.88 ± 7.48	0.009
CEC (meq/100 gr)	21.88 ± 4.32	23.32 ± 5.87		22.46 ± 4.33	25.22 ± 5.76	
Base Saturation (%)	97.6 to >100	57.9 ± 13		79.3 to > 100	47.00 ± 21.1	
Extractable bases						
Ca ²⁺ (ppm)	4114.00 ± 941.00	1969 ± 541.00	0.001	4385 ± 1324	2031 ± 1395	<0.001
Mg ²⁺ (ppm)	720.00 ± 326.00	375.00 ± 202.00	0.001	764 ± 355	338 ± 168	<0.001
K ⁺ (ppm)	75.49 ± 32.57	65.91 ± 29.47	0.520	99.88 ± 30.80	86.92 ± 31.53	0.333
Na ⁺ (ppm)	67.82 ± 44.90	6.87 ± 4.39	0.014	102.74 ± 57.92	17.79 ± 9.94	<0.001

¹ The value refers to the percentage of samples that had positive reaction to 10% HCl, indicating the presence of carbonates in the sample.

* No test

SD = Standard deviation

Table 3-4. Microminerals in lick and non-lick soils during the high water season of 2001, in the Yavari-Miri River valley in the Peruvian Amazon.

Element	Lick Soils (n = 13)	Non-lick Soils (n = 7)	Paired t-test <i>p</i> -value
	Mean ± SD	Mean ± SD	
B (ppm)	0.32 ± 0.20	0.13 ± 0.04	0.006
Cu (ppm)	3.08 ± 1.12	1.12 ± 0.83	0.012
Fe (ppm)	95.51 ± 69.73	55.81 ± 29.06	0.156
Mn (ppm)	19.33 ± 15.31	51.53 ± 49.82	0.164
Zn (ppm)	2.17 ± 0.99	1.39 ± .090	0.282
S (ppm)	141.74 ± 153.93	6.79 ± 3.91	0.020

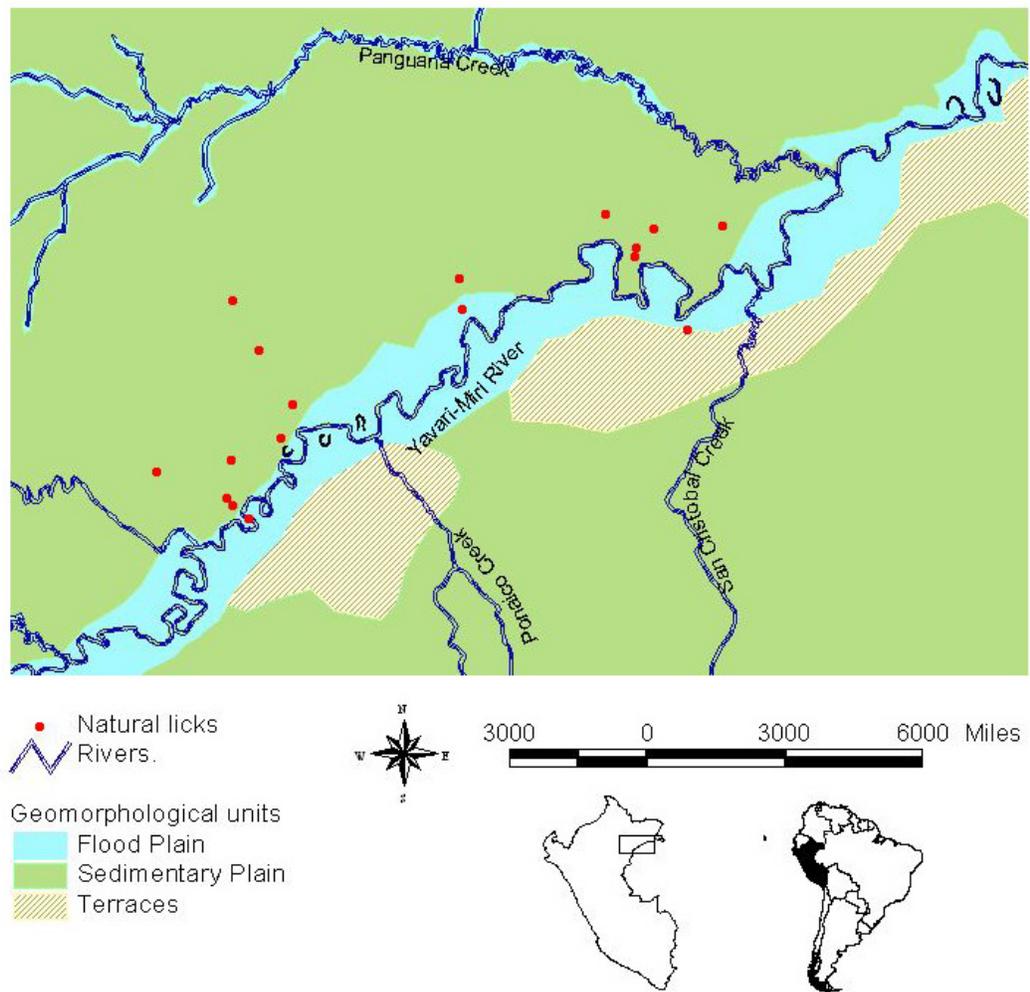


Figure 3-1. Location of the study site in the Yavari-Miri River valley, in northern Peruvian Amazon.

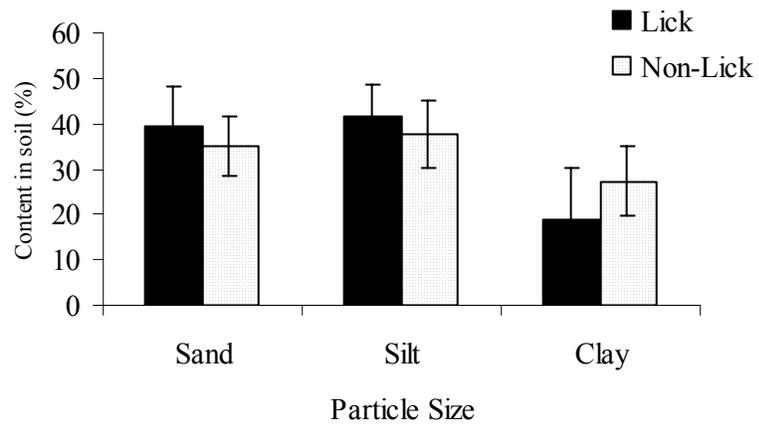


Figure 3-2. Mean content of sand, silt and clay in samples from lick and non-lick soils. Size of vertical lines indicates ± 1 standard deviation.

CHAPTER 4
BROWSE AND FRUIT AS A SOURCE OF MINERALS FOR LOWLAND TAPIR IN
THE YAVARI-MIRI REGION

Introduction

Lowland tapir (*Tapirus terrestris*) is the largest wild terrestrial mammal of the South American tropics (Eisenberg 1989). Average adult weight varies from 150 to 300 kg, with females being slightly heavier than males (Padilla & Dowler 1994, Emmons & Feer 1997, Shoemaker *et al.* 2004). Tapirs are odd-hoofed ungulates, and are related in their phylogeny to horses and rhinoceroses, sharing with them several morphological and physiological characteristics. For example, like horses and rhinos, tapirs are non-ruminants, and have a relatively simple stomach contrasting with a large cecum and a voluminous and enlarged sacculated colon (Stevens 1988), and have hindgut fermentation (Janis 1976). However, unlike horses and some species of rhinos, tapirs are browsers/frugivores (Bodmer 1990), and live primarily in humid tropical forests.

In several sites of the Amazon forest, especially in western Amazonia, lowland tapirs frequently visit natural licks (Peña *et al.* 1996; Montenegro 1998), and may spend on average half an hour in geophagy (ingestion of soil materials) (Montenegro 1998). Lowland tapirs are the most frequent nocturnal species visiting natural licks in the Yavari-Miri River region of the northern Peruvian Amazon (Chapter 2). This habit seems to be related to the tapir's nutritional ecology. Analysis of consumed soils in the Yavari-Miri region revealed a higher concentration of several elements (P, Ca, Mg, Na, B, Cu and S) as compared to control samples outside the licks (Chapter 3).

One common hypothesis is that animals engaging in geophagy are under some kind of stress, often of nutritional nature. Several studies have investigated the chemical characteristics of the eaten soils to identify which elements are in higher concentration at licks, in order to explain geophagy in some species (Emmons & Stark 1979; Jones & Hanson 1985; Tracy & McNaughton 1995). However, often more than one element is in higher concentration in consumed soils, making it difficult to associate soil consumption to a particular mineral nutrient. Often, low levels of dietary sodium in tropical areas explain geophagy in both wild and domestic animals such as elephants (Holdo *et al.* 2002) and cattle (McDowell 2003). In addition, several studies have found that in temperate areas many ungulates also obtain Ca or Mg from licks (Jones and Hanson 1985). Also, some trace minerals such as Se and Co could be obtained from ingested soils (Grace *et al.* 1996; Underwood and Suttle 1999).

The nutritional importance of soils as a dietary source of minerals depends on the amount of soil ingested, the ratio of mineral concentration in soil to that of consumed plants, and in the ability of the animal to extract and absorb elements directly from the soil (McDowell 2003). For many wildlife species, however, information on the mineral concentration of their foods is unknown, making it difficult to identify potential mineral deficiencies or unbalances that could be driving animals to consume soil.

Although the lowland tapir's diet has been studied in several tropical locations such as Peru (Bodmer 1990), Brazil (Fragoso 1997; Olmos 1997; Fragoso *et al.* 2000; Galetti *et al.* 2001), Venezuela (Salas and Fuller 1996), French Guiana (Henry *et al.* 2000), and Colombia (Peña *et al.* 1996), very little is known about the nutritional contents of foods eaten by tapirs in the wild, except for some reports of fat, carbohydrate and protein

content of several Amazonian fruits (Lopes *et al.* 1980). Also, mineral requirements and status of tapirs in the wild are unknown, making it difficult to identify any deficiency or unbalance that may be driving them to visit natural licks.

In captivity, tapirs are usually fed following guidelines for horses, due to their similarity in digestive system anatomy (Barongi 1992; Janssen *et al.* 1999; Shoemaker *et al.* 2004). Those diets comprise legume hay, herbivore pellets and commercial produce and/or harvested browse plants, and mineral supplementation when needed (Shoemaker *et al.* 2004). In the wild, however, lowland tapirs feed on a large amount of fruits, relatively high for a herbivore of that size (Bodmer 1990). They also consume leaves and fiber (other plant parts such as stems, bark or wood) (Bodmer 1990; Henry *et al.* 2000). Although estimation of percentages of each of these 3 items may vary according to food availability, studies in the Amazon and French Guiana have shown that at least 30% of the lowland tapir's diet is comprised of fruit, and the remainder made up of varying amounts of leaves and fiber (Bodmer 1990; Henry *et al.* 2000). In French Guiana, lowland tapirs may consume up to 70% of fiber (Henry *et al.* 2000).

It is unknown, however, whether lowland tapirs can obtain all their necessary nutrients exclusively from food. Since lowland tapirs frequently visit natural licks that are rich in several minerals in the Yavari-Miri River valley, lowland tapir food in this area might be limited in some elements. Since no seasonality was found in lick use in the Yavari-Miri region (Chapter 1), any potential nutritional limitation in tapir food related to lick use is expected to be present all year around.

An indirect way to examine potential deficiency of one or more minerals is by examining fecal excretion of such minerals. Fecal mineral content has been used in other

herbivores as a method to examine mineral status, particularly for sodium (Khalili *et al.* 1992; Studier *et al.* 1994), or absorption, particularly for calcium (Schryver *et al.* 1983). In cases of depletion, fecal excretion of some minerals (i.e. sodium and phosphorus among others) reduces considerably, in some cases virtually to zero (i.e. phosphorus) (McDowell 2003).

If tapir food is limited in one or more mineral nutrients throughout the year, very little excretion of such minerals (at least for sodium and phosphorus) is expected in feces, unless such limitation is alleviated by other sources. If tapirs consume mineral rich soils, natural licks, may represent a critical resource for lowland tapir nutrition, and overall, their persistence in western Amazonia.

The purpose of this chapter is to evaluate lowland tapir's food as a source of minerals in the Yavari-Miri River valley. The main hypotheses examined in this chapter are the following:

- **Hypothesis 1.** Lowland tapir food is limited in one or more mineral nutrients in the Yavari-Miri River valley, and such limitation is constant through the year.
- **Hypothesis 2.** Excretion of limited minerals (at least for some minerals) is low in tapir feces.

To test these hypotheses, the diet of lowland tapir in the Yavari-Miri River was studied, and the mineral content of the most frequently eaten foods was analyzed. Also, analyses of minerals in lowland tapir feces were conducted to examine fecal mineral excretion. If lowland tapirs eat mineral rich soils at natural licks because of a mineral nutritional deficiency or unbalance, it is expected that: (1) one or more elements in tapir food are low in comparison to mineral requirements of lowland tapirs, (2) no significant changes occur in the mineral content of tapir food through the year, and (3) mineral

concentration of one or more minerals in tapir feces would be higher than expected if the animals are facing a deficiency of such minerals.

Study Area

This study was conducted in the middle course of the Yavari-Miri River, in the Peruvian Amazon, in the area between 4°30.23'S, 72°26.69W and 4°24.77'S, 72°09.76'W. Weather in the area is characterized by a mean annual temperature of 26°C, with mean maximum temperatures ranging from 28-30°C, and mean minimum from 17-20°C (Marengo 1984). Mean annual precipitation varies from 2400 to 3100 mm, with the highest monthly rainfall occurring from February to April, and the lowest from June to September. The water levels are the lowest during the months of less rainfall (June to September), and the highest during the months of maximum precipitation (February to May).

Plant diversity in the area is very high. Recent estimates indicate that number of plant species in the Yavari region may reach up to 3,500 species (Pitman *et al.* 2003). Habitat types in the area include upland and flooded forests. Upland forests are very diverse and vary greatly with soil characteristics (Roukolainen & Tuomisto 1993). Flooded forests tend to be heterogeneous and continually changing due to the river fluctuations (Puhakka & Kalliola 1993). Among flooded forests, swamp forest, is common along these rivers, covering 25-50% of the flood plains (Pitman *et al.* 2003).

Methods

Lowland Tapir Diet in the Yavari-Miri Region

Diet of lowland tapir in the Yavari-Miri region was studied through both examination of feeding signs and inspection of tapir feces. A search for tapir feeding signs was conducted along 26 trails opened on both sides of the Yavari-Miri River, from

January to December 2001. Trail length varied from 2 to 5 km, for a total of 65.8 km of trails. Once a feeding sign was found, browse clearly eaten by tapirs was collected. When feeding on leaves, tapirs usually pull down branches and stems, leaving teeth marks on the bark (Salas & Fuller 1996), and very often may cut the stem at about 1 m from the ground (usually when it is up to 2 cm in diameter), leaving a characteristic feeding sign of a broken stem with its upper part hanging down. When feeding on lower vegetation, especially from plants growing in gaps, tapirs eat leaves from young plants up to 1.5 m above ground (personal observation), and the feeding sign is unmistakable. In addition, since tapirs also feed on fruits (Bodmer 1990; Olmos 1997; Henry *et al.* 2000), several fruits were collected from tapir feeding sites. In all cases, tapir feeding was confirmed by the presence of tapir tracks at the feeding site, and only browse or fruits undoubtedly eaten by lowland tapirs were collected.

Composite samples from every browsed plant were collected with stainless steel scissors and rubber gloves, and placed in cotton bags. Samples were air-dried for several days and stored in dry plastic bags until they were analyzed for mineral content. Also, a part of the fresh sample was prepared as botanical vouchers for species identification. Voucher samples were sun dried for several days and stored. Fruit samples were preserved in 95% ethanol in tight plastic containers until they were dried for mineral analyses later. Fruit samples were dried in an oven at 60°C for 24 hours prior to mineral analysis. Botanical vouchers were identified at the Herbarium Amazonense (AMZ) in Iquitos, Perú. Voucher specimens were deposited at the same herbarium. Plant identification follows nomenclature from Gentry (1996).

Also, lowland tapir feces were collected along trails, from streams, and to a lesser extent, from tapir latrines. Fecal samples were sun dried for several days and stored for further analyses. All samples were handled with rubber gloves and placed in individual clean plastic bags. About 50 % the feces samples was examined for proportion and frequency of occurrence of food types (fruits, leaves and fiber), following Bodmer (1990), with the difference that no stomach samples were used in this study. The remaining 50% of the samples, mainly the most fresh, were left for examination of mineral content.

Determination of Minerals in Tapir Food and Fecal Samples

Browse, fruit and fecal samples were analyzed for concentration of nitrogen and 11 minerals: 6 macrominerals (P, K, Ca, Mg, S and Na) and 5 trace minerals (Mn, Zn, Cu, Fe, and B). Laboratory analyses were conducted in the laboratory of soils, water and plant tissues of the Institute for Agriculture (CORPOICA) in Colombia. Samples were pretreated (or mineralized) with a wet oxidation-digestion procedure to remove organic matter. Reagents for this procedure were Nitric and Perchloric acids in proportion 3:2. Digestion was conducted by gradually increase of temperature at 100°C intervals up to 300-330°C approximately, in a Tercator digester. Part of the resulting aqueous solution was completed with water and concentration of Fe, Cu, Mn, and Zn was determined in an atomic absorption spectrophotometer Perkin Elmer 2380. For determination of K, Ca, Mg and Na, lanthanum was added to another part of the aqueous solution and their concentration was determined also by atomic absorption spectrophotometry. Phosphorus concentration was determined by adding a colorimetric reagent of ammonium and potassium tartrate, sulfuric acid, ammonium molybdate, and ascorbic acid to the aqueous solution containing the minerals, reading the absorbance of the solution in a Milton-Roy

light spectrophotometer, and comparing with a calibration curve. Sulfur concentration was determined also by spectrophotometry, after adding a solution of nitric and acetic acids and a turbidimetric reagent of bacto-gel and barium chloride to the aqueous solution containing the minerals.

To determine Boron and Nitrogen content, non-digested samples were used. For B, 1 g of plant tissue was mixed with 0.1 g of calcium oxide and dry ashed in a muffle furnace at 500°C. Ashes were mixed with sulfuric acid, filtered and mixed with Azometin H for color development, and concentration of B was determined by spectrophotometry. Nitrogen was determined with the Kjeldahl method (Ma & Zuazaga 1942).

Data Analyses

Assumptions of normal distribution and homogeneity of variances were tested for all variables with the Kolmogorov-Smirnov test and Lavene's test respectively. When assumption of normality was not met, alternative non-parametric tests were used. For testing differences between 2 groups, t-tests or the Wilcoxon test were used. When comparing more than 2 groups, a one-way Analysis of Variance (ANOVA) or alternatively the Kruskal-Wallis test were used. If differences were found when comparing more than 2 groups, further multiple comparisons were done with the Tukey test to find which groups were different. For all tests, a $p < 0.05$ was considered significant. Mean concentration of each mineral in leaves was compared between high water and low water seasons. Also, mineral content of leaves was compared among the most common plant families in tapir's diet. Mean concentration of each mineral was compared between leaves and fruits. Finally, mean concentration of each mineral in feces was compared to mean concentrations in both leaves and fruits separately. All statistical analyses were performed with the software SPSS version 11.5 for Windows.

Results

Lowland Tapir Diet at the Yavari-Miri Region

A total of 134 browse samples was collected from the forest on both sides of the Yavari-Miri River. Samples represent 31 plant families, 63 genera and 89 species (Table 4-1). The most common lowland tapir's browse was from the Melastomataceae (22%) and Rubiaceae (17%) families (Figure 4-1). The next most common families in tapir browse were Areaceae (6%), Myristicaceae (5%), Fabaceae (4.47%), and Sapotaceae (3.73%). The remaining species represented from <1% to 2.2 % of tapir's browse (Figure 4-1).

A total of 72 tapir fecal samples was collected from January to December 2001. 80% of those samples were found in shallow water, along banks of small streams, while only 20% were found on the ground, in tapir latrines. Tapir latrines were found only twice in this study. A total of 37 fecal samples were sent to the laboratory for mineral analyses. The remaining 35 samples were examined for determination of the components of tapir's diet. Fruit parts, leaves, fibers (stems, wood, and other fibrous plant materials), and soil were found in tapir feces. Percentage of occurrence of these items in feces was 96.6% for fruit parts, 100% for leaves and fibrous materials, and 76.6% for soil. Proportions of these items on a dry matter basis were the following: fruit parts $8.89 \pm 9.33\%$ (range 0 – 43.75%), leaves $75.42 \pm 16.91\%$ (range 18.09 – 90.22%), fibers $12.54 \pm 13.27\%$ (range 2.17 – 68.09%) and soil $3.20 \pm 3.14\%$ (range 0 – 8.42%). The proportion (on a dry weight basis) of fruit in tapir diet is underrepresented. All but one fecal sample analyzed for diet components had fruit remains (exocarps and seeds), but their weight was comparatively low because the largest seeds are spit out and are not in the feces,

although the pulp was consumed in large amounts. This was observed in other studies where stomach contents were analyzed (Bodmer 1990; Henry *et al.* 2000). In consequence, real proportion of fruit in tapir diet in the Yavari-Miri River is higher than the average shown above.

Tapirs ate at least 14 fruit species (Table 4-3). The most common fruits found in tapir feces and their percentages of occurrence were the following: *Mauritia flexuosa* (70%), *Annona* spp (40%) *Spondias mombin* (40%), *Oenocarpus bataua* (35%), *Couma macrocarpa* (25%), and *Attalea* sp. (15%) (Figure 4-2). Also, from feeding signs along tapir trails, we found that fruits of a species of Moraceae (*Ficus insipida*) are also part of the tapir's diet (Table 4-3).

Minerals in Lowland Tapir Food

Concentration of minerals in lowland tapir's browse was analyzed in 37 leaf samples, representing 32 species (Table 4-1). Analyzed samples included the most common species browsed by lowland tapirs. Mean concentrations of macrominerals (P, K, Na, Mg, S and Na) and trace elements (Mn, Zn, Cu, Fe and B) in tapir browse are illustrated in Figures 4-3 and 4-4, respectively. No seasonal differences were found in macromineral concentration in tapir browse ($p > 0.05$ in all tests), except for a barely significant difference in P during the low water season ($t = 2.05$, $df = 35$, $p = 0.047$) and a higher concentration of Mg during the high water season ($t = 2.2$, $df = 35$, $p = 0.034$). Although K seems to be at higher concentrations in the low water season, there was large variation among samples, and the statistical test was not significant (Wilcoxon's test $z = 0.68$, $p = 0.50$). Among trace elements, only Fe ($t = 2.3$, $df = 35$, $p = 0.008$) was different, occurring at higher concentration in browse collected during the low water season (Figure 4-4). Although mean concentration of Mn looks higher also during the low water season,

large variation within samples yielded a non-significant test (Wilcoxon's test $z = 1.4$, $p = 0.14$).

Since tapirs eat leaves mainly from the Melastomaceae and Rubiaceae families, mean concentrations of minerals were compared among those families, pooling the other families as a third group. Differences were found only for Ca ($F_{2,34} = 5.3$, $p = 0.010$) and Mg ($F_{2,34} = 4.1$, $p = 0.024$). Higher concentration of Ca was found in leaves of the Melastomaceae and Rubiaceae family, whereas Mg was more concentrated in leaves of the Rubiaceae and the other group of families.

Although 14 samples of fruits were collected, the amount of dry pulp was enough for analyzing only 4 fruit species (*Mauritia flexouosa*, *Spondias mombin*, *Couma macrocarpa* and *Jacarantia* sp.). These species, however, were among the most frequent in tapir diet (Figure 4-2), and may give a good idea of the quality of fruits as a source of minerals in tapir's food. When compared with browse, differences were found for 2 macrominerals (K and Na) and 2 trace elements (Mn and Fe). All these 4 elements were at higher concentrations in browse than in fruits (Wilcoxon's test: $z = 3.07$, $p = 0.002$ for K, $z = 3.26$, $p = 0.001$ for Na; $z = 2.98$, $p = 0.003$ for Mn, and $t = 4.8$, $df = 22.9$, $p < 0.001$ for Fe). Mean concentration of Na was particularly low in fruits ($0.03\% \pm 0.01$).

Since tapir mineral requirements are unknown, concentration of minerals in tapir food was examined in relation to minimal requirements for horses (NRC 1989) because of their similarity in digestive system (Janssen *et al.* 1999). Levels of P were below minimal required concentrations in horse diets (Table 4-4) in both browse and fruit samples. P levels were much below the minimal requirement for growing horses or pregnant females (Table 4-4). Although mean P level in browse was slightly higher in the

low water season, its concentration was lower than required in both seasons. Mean Na concentration in browse samples was within the minimal required for horses, but below requirements in all fruit samples (Table 4-4). Potassium levels were below requirements only in fruit samples. The remaining macrominerals were within the minimal required levels for horses, in both browse and fruit samples.

Among trace elements, Zn concentration was below minimum requirements for horses in both browse and fruits, and Cu was below requirements in browse and barely at a minimum requirement in fruits (Table 4-5). However, Cu requirements for tapirs may be much higher than the requirement for horses (Janssen *et al.* 1999), suggesting that both browse and fruits would be deficient in Cu in tapir diet. In contrast, levels of Mg and Fe were much higher than required in horse diets (Table 4-5). Concentration of B was similar between browse and fruit samples, but requirements have not been established in horse diets. Besides minerals, both browse and fruit samples showed high levels of crude protein (measured as N concentrations) (Table 4-5). In summary, minerals in tapir diet in the Yavari-Miri River seem adequate except for P, Na, Zn and Cu, based on requirements established for horses.

Mean fecal concentration of minerals is shown in Table 4-5. Among macrominerals, levels of P in feces were similar to those in browse and fruit. Concentration of Na in fecal samples was higher than the one in browse and especially fruits. Fecal concentrations of other macrominerals were always lower than concentrations in tapir foods. Most trace elements were at higher concentrations in fecal samples than in tapir foods especially for Fe, Zn and Cu. Fecal Fe was particularly high

in fecal samples. The only exception was Mn, which was lower in feces than in browse, but was higher than in fruit samples. No fecal B was analyzed.

Discussion

Lowland Tapir Diet at the Yavari-Miri Region

Lowland tapir diet at the Yavari-Miri River is composed of a large number of plant species. This result agrees with previous research in other tropical forests. For example, in the Tabaro River valley of Venezuela lowland tapirs also feed on 88 plant species (Salas 1996), and on 81 species in the Duda River of Colombia (Peña *et al.* 1996).

Most browse samples were found in tree fall gaps or early successional stages of riverbank vegetation where plants from the Melastomataceae and Rubiaceae were growing. Those two families are typical of second growth states and are usually represented by pioneer species. Salas and Fuller (1996) also found such foraging behavior of lowland tapir in the Tabaro River valley (Venezuela), and established that tapirs are more selective when foraging in sites other than tree fall gaps. In the Yavari-Miri River valley tapirs foraged also on growing trees with trunks > 2 cm in diameter or semi-epiphyte plants (family Araceae) growing on tree trunks. Tapirs ate those plants mainly during their young states. Frequency of browsing on fast growing plants seems to be a characteristic of tapirs in general, according to the list of browsed species reported in the diets of the other 3 tapir species (Janzen 1982a; Terwilliger 1978; Naranjo 1995; Foerster 1998; and Tobler 2002 for *Tapirus bairdii*; Downer 2001 for *Tapirus pinchaque*; and Williams 1980 for *Tapirus indicus*).

Besides browse, fruits are very important in the tapir's diet. This feature was also described in the Blanco River of Peru (Bodmer 1990), French Guiana (Henry *et al.* 2000), Colombia (Peña *et al.* 1996) and Brazil (Fragoso 1997; Fragoso & Huffman

2000). The most common fruits eaten by lowland tapirs in the Yavari-Miri River were from *Mauritia* palm (*Mauritia flexuosa*) and trees of *Spondias mombin*, *Couma macrocarpa* and *Oenocarpus bataua*, among others. Tapirs consume the same fruit species in other tropical forests and disperse many of their seeds (Olmos 1997; Fragoso 1997; Fragoso *et al.* 2003). Overall, fruits consumed by lowland tapir in the Yavari-Miri River are very similar to those described for the Blanco River (Bodmer 1990), located about 100 km northwest of the Yavari-Miri river, in the same continuous forest. The highest percentage of occurrence of the palm *Mauritia flexuosa* and the occurrences of other fruit species is common in both areas. This resemblance is expected, since it is the same forest, and overall plant composition in both areas is probably very similar.

Proportion (on a dry basis) of fruit in tapir diet in the Yavari-Miri River estimated from fecal examination seems lower than in the Blanco River, but this result does not really reflect the real proportion of fruits in the diet, since the largest seeds are not in feces. As noted by Bodmer (1990) and Henry *et al.* (2000) tapirs spat out the seeds of *Mauritia flexuosa*, but large amounts of its pulp were in stomach samples. These fruits are large (about 50-60 cm long and 30-40 cm in diameter) and are covered by very small scales. Seventy percent of fecal samples from the Yavari-Miri valley had large amounts of *Mauritia flexuosa* scales. Bodmer (1990) found a similar percentage of occurrences for *Mauritia flexuosa* (76.3%), examining both fecal and stomach samples. For this reason, a proportion of 33% of fruit in tapir diet (obtained from both stomach and fecal examination) in the Blanco River (Bodmer 1990) is probably a better estimation on the true proportion of fruit in the diet of tapirs at the Yavari-Miri River. Other plant parts, such as stems, bark or wood (termed fiber in several studies) was found in tapir feces in

variable amounts from about 2-68% on a dry matter basis. This result indicates that tapirs feed not only on leaves and fruits. Fibrous materials may represent a significant portion of tapir feeding habits in some circumstances. For example, fiber content in tapir diet was very high during the low fruit production season in French Guiana (Henry *et al.* 2000). Soil also was found in 76.6% of the tapir feces analyzed, indicating that tapirs often consume soil. Since tapirs purposely visit natural licks (Chapter 2), soil consumption is not accidental. The amount of soil in feces was however relatively low (3.2% of fecal sample on a dry matter basis), indicating that tapirs eat soil frequently, but in relatively small amounts. Soils are never discussed as part of tapir diet since this behavior has been either disregarded or considered abnormal. In fact, soil consumption is often seen as a type of pica, a behavior that refers to consumption of abnormal materials with no nutritional value (Maynard *et al.* 1979). Overall, tapir diet in the Yavari-Miri River is composed of a large diversity of browse, mainly from growing plants, a significant amount of fruits, mainly palm fruits, and variable amounts of fiber.

Minerals in Lowland Tapir Food

Animals derive the majority of their mineral needs from their food. For herbivores, however, sources of some minerals may be limited, depending on the characteristics of the soil and vegetation. Poor mineral content in vegetation may result in nutritional deficiencies if animals do not find alternative mineral sources.

Most minerals in lowland tapir diets seem adequate in browse and fruits based on suggested requirements for horses, except for Na, P, Cu and Zn. Although mean Na in browse did not appear too low, about 50% of individual samples had Na concentration below the average. Also, Na intake from tapir food is probably low, considering that browse accounts for only a portion of tapir food. Fruits had very low Na concentrations,

and they comprise a significant part of tapir diet. Unfortunately tapir mineral requirements have not been assessed, and the assumption that their requirements are the same as horses may be inadequate for some minerals. Horses are primarily grazers feeding on high fiber diets. The digestive system of tapirs is less specialized than that of horses for fiber digestion (Janis 1976). Data from captive animals suggest that comparative digestibility of cellulose and hemicellulose is slightly lower in tapirs than in horses (Janssen *et al.* 1999). Tapir fecal samples often contain entire leaf fragments and large fibrous materials. Coarsely chewed forages also were observed in fecal samples from the Malayan tapir in the wild (Williams 1980). These observations are in agreement with a rapid rate of food passage in tapir digestive system. Efficiency of cellulose digestion reduces with an increase in rate of passage. Rate of passage in horses is lower than that of ruminants of similar weight (48 h vs 80 h) and efficiency of cellulose digestion is 70% of that of a ruminant (Janis 1976). Na requirement in horses is higher than the requirement for ruminants (0.10% vs 0.08% respectively). Although rate of passage should not be a factor for Na, since this element is rapidly and almost completely absorbed (McDowell 2003), the ability of tapirs to absorb Na in the lower part of the gastrointestinal track is unknown. If digesta remains longer in the digestive tract, it is possible that more cellulose will be broken down by microflora and thus release minerals from lignin complexes. However, this is not expected in tapirs, since their rate of passage seems to be very rapid.

Optimal Na concentration in equine diets has been suggested to be 0.16 to 0.18% of dry matter for growth, maintenance and late gestation (Jarrige & Martin-Rooset 1981; NRC 1989). Na concentration in 51% of browse samples and 100% of fruit samples was

below the above requirements, and tapirs could develop a Na deficiency, especially when feeding mainly on fruits, if no other source of Na is available. Bioavailability of Na in feeds is seldom addressed because normally sodium is added to the diet as salt supplements (Ammerman *et al.* 1995) and it is almost completely absorbed. Bioavailability of Na in tapir food is unknown and should be studied. In general, most plant products have relatively small amounts of Na in comparison to animal products (McDowell 2003).

Sodium (in addition to chlorine and potassium) is very important for maintaining osmotic pressure and regulating acid-base equilibrium in organisms, functioning as an electrolyte in body fluids (McDowell 2003). These elements are involved in cellular water metabolism, nutrient intake and transmission of nerve impulses (McDowell 2003). Sodium deficiency has been found in many tropical locations and is one of the factors limiting animal production in some tropical countries (McDowell 1985). Tropical areas with high rainfall are usually Na-depleted since this mineral is easily leached from the soil and plants usually do not accumulate it –except for halophytes- (Robbins 1993).

Sodium is excreted mainly in urine and with smaller amounts in feces. When Na intake is low the organism conserve this element by reducing its excretion (McDowell 2003). Based on the low Na concentration in tapir food (especially in fruits) below its requirement, a potential deficiency could occur. In a deficiency status, tapirs should reduce fecal excretion of endogenous Na, and very little amounts of this element would be expected in tapir feces. However, fecal excretion of Na was not as low as expected if tapirs were facing a deficiency of this mineral. Tapirs consume soils at natural licks and those soils had higher concentration of Na as compared to non-lick soils. These results

agree with the hypothesis that tapirs obtain Na from natural licks. The same could be suggested for other lick users. For example periodic Na deficiencies were suggested for frugivorous bats in a location close to the Amazon and Napo Rivers (Studier *et al.* 1994), a forest relatively close to the Yavari-Miri River forest. Such a deficiency results from low Na concentrations of fruits. Frugivorous bats were very common lick users (Chapter 2).

The other macromineral that was low in tapir diet was phosphorus. Phosphorus and calcium are major mineral constituents of the animal body (Robbins 1993). In bones the ratio of Ca:P is usually constant and somewhat greater than 2:1 (McDowell 2003). Phosphorus is fundamental in almost all aspects of animal metabolism, including energy metabolism, muscle contraction, nerve tissue metabolism, transport of metabolites, nucleic acid structure, and nutrient metabolism (Robbins 1993). Phosphorus absorption efficiency in horses is 35%, but it may vary according to the form (organic or inorganic) in diet, being reduced in diets with high concentrations of oxalates (NRC 1989). Requirements in horses during gestation and lactation increase because of milk production. Calcium was at adequate levels in tapir foods, but P was significantly low. Ratios of calcium to phosphorus should be 2:1, but very low phosphorus intake is detrimental (NRC 1989). Deficiency of P produces rachitic changes in growing horses and osteomalacic changes in adult horses. In herbivores, P is excreted primarily in feces, although animals fed high concentrated diets excrete P also in urine (McDowell 2003). Levels of P in tapir feces were expected to be low since P in food was below requirements for maintenance and very low for growth and lactation. As with Na, tapirs

may be adding P to their diets by consuming soils. Phosphorus was very high in lick soils as compared to non-lick samples.

Among microminerals, Cu appears to be limiting in tapir diet. A potential deficiency of Cu could be expected from tapir diet because tapirs may have a unique metabolic requirement for this element (Janssen *et al.* 1999). This suggestion comes from the observation that levels of Cu in 22 captive tapirs of 3 species had a mean serum copper level of 0.21 µg/ml when a normal level in horses is 0.7 ppm. Dietary copper concentrations in those tapirs were adequate in comparison to horse requirements (Janssen *et al.* 1999). Concentration of Cu in plants depends on several factors such as form of soil copper, pH, concentration of other elements and organic residues and plant species. Usually, severely leached, sandy soils, alkaline soils or peat or muck soils produce plants with a low copper content. Absorption of copper tends to be low, and is affected by chemical form, copper status of the animal and levels of other ions such as calcium, cadmium, zinc, iron, lead, silver, molybdenum, and sulfur (Robbins 1993). A high proportion of ingested Cu is excreted in feces, and most fecal Cu is unabsorbed (McDowell 2003). Copper was also higher in lick soils as compared to non-lick soils (Chapter 3). By consuming those soils, tapirs could be adding Cu to their diets.

Summary and Conclusions

Lowland tapir's diet in the Yavari-Miri River valley is very diverse, including more than 80 species of browsed plants and at least 13 species of fruits. Most browsed species are of the families Melastomataceae and Rubiaceae, and are pioneer plants growing in tree fall gaps. Fruits eaten by tapirs represent several palms and other tree species. Diet of

lowland tapir in the Yavari-Miri River valley is similar to what is described for other tropical locations.

Mineral contents in browse and fruits eaten by lowland tapirs seem adequate, based on horse diets, except for Na, P, Cu and Zn, whose levels are below suggested requirements, especially for growing and lactating female horses. Levels of Na, P and Cu excreted in tapir feces are higher than expected if tapirs were facing a deficiency of these minerals. These elements were found in higher concentrations in soils eaten by tapirs, suggesting that geophagy at natural licks functions as natural supplementation of those minerals in the forest.

These results suggest that tapirs, and possibly other lick users, obtain minerals that are in short supply in their diets by consuming soils from natural licks. As a consequence, natural licks may be a very important resource for lowland tapirs and possibly other herbivore/frugivore species in the Yavari-Miri River.

Table 4-1. Plant species in tapir browse along the Yavari-Miri River, Peruvian Amazon.

Family	Species	F	Family	Species	F
Anacardiaceae	<i>Spondias mombin</i> *	1	Melastomataceae	<i>Miconia nervosa</i> *	2
Annonaceae	<i>Oxandra euneura</i>	1	Melastomataceae	<i>Miconia splendens</i>	4
Apocynaceae	<i>Tabernaemontana</i>		Melastomataceae		
	<i>flavicans</i>	1		<i>Miconia ternatifolia</i> *	1
Apocynaceae	<i>Tabernaemontana</i>		Melastomataceae		
	<i>siphilitica</i>	1		<i>Tococa capitata</i>	1
Araceae	<i>Anthurium</i>		Melastomataceae		
	<i>brevipedunculatum</i> *	2		<i>Tococa caudata</i> *	6
Araceae	<i>Heteropsis</i> sp.	1	Melastomataceae	<i>Tococa coronata</i>	1
Araceae	<i>Philodendron</i>		Melastomataceae		
	<i>elaphoglossoides</i>	3		<i>Tococa guianensis</i>	1
Araceae	<i>Philodendron</i>		Melastomataceae		
	<i>rudgeanum</i>	2		<i>Tococa setifera</i> *	1
Araliaceae	<i>Dendropanax</i>		Meliaceae		
	<i>arboreus</i> *	1		<i>Trichilia pallida</i>	1
Bignoniaceae	<i>Arrabidaea</i>		Moraceae		
	<i>bilabiata</i> *	1		<i>Cecropia</i> sp.	1
Blechnaceae	<i>Salpichlaena</i>		Moraceae		
	<i>hookeriana</i>	1		<i>Naucleopsis</i> sp. *	1
Bombacaceae	<i>Matisia bracteolosa</i>	2	Moraceae	<i>Sorocea hirtella</i>	1
Capparidaceae	<i>Capparis</i>		Myristicaceae		
	<i>macrophylla</i>	2		<i>Otoba glycyarpa</i>	1
Clusiaceae	<i>Chrysochlamys</i> sp. *	1	Myristicaceae	<i>Otoba parvifolia</i>	1
Clusiaceae	<i>Garcinia acuminata</i> *	2	Myristicaceae	<i>Virola elongata</i> *	5
Clusiaceae			Myrtaceae	<i>Eugenia</i>	
	<i>Moronobea coccinea</i>	1		<i>myrobalana</i> *	1
Combretaceae	<i>Combretum</i>		Myrtaceae		
	<i>fruticosum</i> *	1		<i>Myrcia paivae</i> *	1
Combretaceae	<i>Combretum</i>		Myrtaceae		
	<i>laurifolium</i>	1		<i>Myrciaria</i> sp. *	1
Combretaceae	<i>Combretum laxum</i>	1	Nyctaginaceae	<i>Neea floribunda</i> *	2
Convolvulaceae	<i>Maripa</i> sp.	1	Nyctaginaceae	<i>Neea spruceana</i> *	1
Cyclanthaceae	<i>Evodianthus funifer</i>	3	Ochnaceae	<i>Ouratea aromatica</i>	1
Ebenaceae	<i>Diospyros</i>		Ochnaceae		
	<i>poepigiana</i>	4		<i>Ouratea</i> sp.	1
Ebenaceae	<i>Diospyros subrotata</i>	1	Olacaceae	<i>Heisteria cauliflora</i>	1
Euphorbiaceae			Rhamnaceae	<i>Ampilozzygium</i>	
	<i>Acalipha</i> sp.	1		<i>amazonicus</i>	1
Euphorbiaceae	<i>Conceveiba</i>		Rubiaceae		
	<i>rhytidocarpa</i>	1		<i>Coussarea brevicaulis</i>	3
Euphorbiaceae	<i>Didymocistus</i>		Rubiaceae		
	<i>chrysadenius</i> *	1		<i>Faramea multiflora</i>	3
Euphorbiaceae	<i>Mabea elata</i>	1	Rubiaceae	<i>Psychotria capitata</i>	1
Fabaceae			Rubiaceae	<i>Psychotria</i>	
	<i>Inga alba</i>	1		<i>cartagenensis</i>	2
Fabaceae	<i>Inga capitata</i>	1	Rubiaceae	<i>Psychotria cincta</i> *	1

Table 4-1 (continued)

Family	Species	F	Family	Species	F
Fabaceae	<i>Inga dumosa</i> *	1	Rubiaceae	<i>Psychotria deflexa</i>	1
Fabaceae	<i>Inga semialata</i>	1	Rubiaceae	<i>Psychotria iodotricha</i> *	3
Fabaceae	<i>Machaerium floribundum</i> *	1	Rubiaceae	<i>Psychotria loretensis</i>	1
Fabaceae	<i>Macrolobium angustifolium</i>	1	Rubiaceae	<i>Psychotria lupulina</i>	1
Flacourtiaceae	<i>Hasseltia floribunda</i>	1	Rubiaceae	<i>Psychotria poeppigiana</i> *	2
Flacourtiaceae	<i>Ryania speciosa</i> *	1	Rubiaceae	<i>Psychotria tenicaulis</i> *	5
Flacourtiaceae	<i>Tetrathylacium macrophyllum</i>	1	Rubiaceae	<i>Warszewiczia coccinea</i>	1
Hippocrataceae	<i>Salacia</i> sp. *	1	Sapotaceae	<i>Micropholis egensis</i>	1
Icacinaceae	<i>Humirianthera ampla</i>	1	Sapotaceae	<i>Pouteria guianensis</i> *	4
Lecythidaceae	<i>Eschweilera tessmannii</i>	1	Solanaceae	<i>Cestrum microcalyx</i>	1
Melastomataceae	<i>Coussarea brevicaulis</i>	1	Solanaceae	<i>Cestrum</i> sp.	1
Melastomataceae	<i>Henriettea lasiostylis</i> *	3	Solanaceae	<i>Solanum</i> sp.	1
Melastomataceae	<i>Loreya mespiloides</i>	1	Violaceae	<i>Leonia glycycarpa</i>	1
Melastomataceae	<i>Miconia amazonica</i>	1	Vochysiaceae	<i>Vochysia lanceolata</i>	1
Melastomataceae	<i>Miconia eriocalyx</i>	1	Vochysiaceae	<i>Vochysia lomatophylla</i> *	3
Melastomataceae	<i>Miconia mazanana</i> *	1		Non-identified *	1

F = Frequency of each plant species in tapir browse samples.

* = Samples analyzed for N and mineral (P, K, Ca, Mg, S, Na, Mn, Zn, Cu, Fe, B) content.

Table 4-2. Number of composite samples of each family analyzed for mineral concentrations in 2 seasons in the Yavari-Miri River valley, Peruvian Amazon.

Family	Season	
	High water	Low water
Araceae	0	1
Araliaceae	0	1
Bignoniaceae	0	1
Clusiaceae	0	2
Combretaceae	0	1
Euphorbiaceae	0	1
Fabaceae	0	2
Flacourticeae	1	0
Hippocrataceae	1	0
Melastomataceae	1	8
Moraceae	1	0
Myristicaceae	1	1
Myrtacea	3	0
Nyctaginaceae	0	2
Myrtaceae	0	0
Rubiaceae	2	3
Sapotaceae	0	2
Vochysiaceae	0	1
Non-identified	1	0
Total samples	11	26

Table 4-3. Fruits in lowland tapir diet in the Yavari-Miri River valley, northeastern Peruvian Amazon.

Family	Species	Local name	Evidence	
			Feces	Feeding sign
Anacardiaceae	<i>Spondias mombin</i> *	<i>Uvos</i>	X	X
Annonaceae	<i>Annona</i> sp.	<i>Sacha anona</i>	X	X
	<i>Couma macrocarpa</i>			
Apocynaceae	*	<i>Leche caspi</i>	X	X
Arecaceae	<i>Mauritia flexuosa</i> *	<i>Aguaje</i>	X	X
Arecaceae	<i>Oenocarpus bataua</i>	<i>Hungurahui</i>	X	
Arecaceae	<i>Attalea</i> sp.	<i>Shebon</i>	X	
Caricaceae	<i>Jacarantia</i> sp.*	<i>Papaiya</i>	X	X
Cecropiaceae	<i>Pourouma</i> sp.	<i>Sacha uvilla</i>	X	
Celastraceae	<i>Maytenus</i> sp.	<i>Sacha shushuhuashi</i>	X	
Chrysobalanaceae	<i>Licania</i> sp.	<i>Parinari de altura</i>	X	
Fabaceae	<i>Hymenaea</i> sp.	<i>Azucar huayo</i>	X	
Moraceae	<i>Ficus insipida</i>	<i>Oje</i>		X
Sapotaceae	<i>Pouteria</i> sp.	<i>Sacha caimito</i>	X	

* Fruits analyzed for N and mineral (P, K, Ca, Mg, S, Na, Mn, Zn, Cu, Fe, B) content.

Table 4.4. Mean content of nitrogen and macrominerals in tapir foods (browse and fruits), suggested requirements (based on guidelines for horses) and mean concentrations of excreted N and macrominerals in tapir feces.

		N	P	K	Ca	Mg	S	Na
		% dry matter						
Tapir food								
Browse	Mean	3.44	0.12	0.73	0.53	0.27	0.15	0.22
	SD	1.13	0.05	1.26	0.32	0.14	0.03	0.13
Fruits	Mean	1.20	0.11	0.14	0.70	0.14	0.36	0.03
	SD	0.80	0.08	0.03	0.94	0.13	0.34	0.01
Required ¹								
Maintenance			0.17	0.30	0.24	0.09	0.15	0.10
Growth			0.17 - 0.38	0.30	0.31 - 0.68	0.10	0.15	0.10
Females ²			0.34	0.38	0.45	0.10	0.15	0.10
Tapir feces								
	Mean	2.38	0.14	0.18	0.26	0.12	0.09	0.29
	SD	0.65	0.09	0.18	0.21	0.7	0.05	0.25

SD = 1 Standard deviation.

¹ Suggested requirements based on guidelines for horses (NRC 1989).

² Suggested requirements for pregnant and lactating females based on guidelines for horses (NRC 1989).

Table 4-5. Mean content of microminerals in tapir foods (browse and fruits), suggested requirement (based on guidelines for horses) and mean concentrations of excreted microminerals in tapir feces.

		Mn	Zn	Cu*	Fe	B
		mg-kg ⁻¹				
Tapir food						
Browse	Mean	454.49	32.30	7.15	348.94	14.91
	SD	471.61	39.36	6.46	290.34	9.87
Fruits	Mean	42.98	22.45	10.55	70.48	14.33
	SD	52.89	7.39	5.56	62.44	0.65
Required ¹						
Maintenance		40.00	40.00	10.00	40.00	
Growth		40.00	40.00	10.00	50.00	Unknown
Females ²		40.00	40.00	10.00	50.00	
Tapir feces						
Mean		202.04	85.54	42.86	2952.15	
SD		151.34	91.12	68.25	11767.28	

¹ Suggested requirements for horses (NRC 1989).

² Suggested requirements for pregnant and lactating females (NRC 1989).

* Copper requirements for tapirs may be much higher than requirement for horses (Janssen *et al.* 1999).

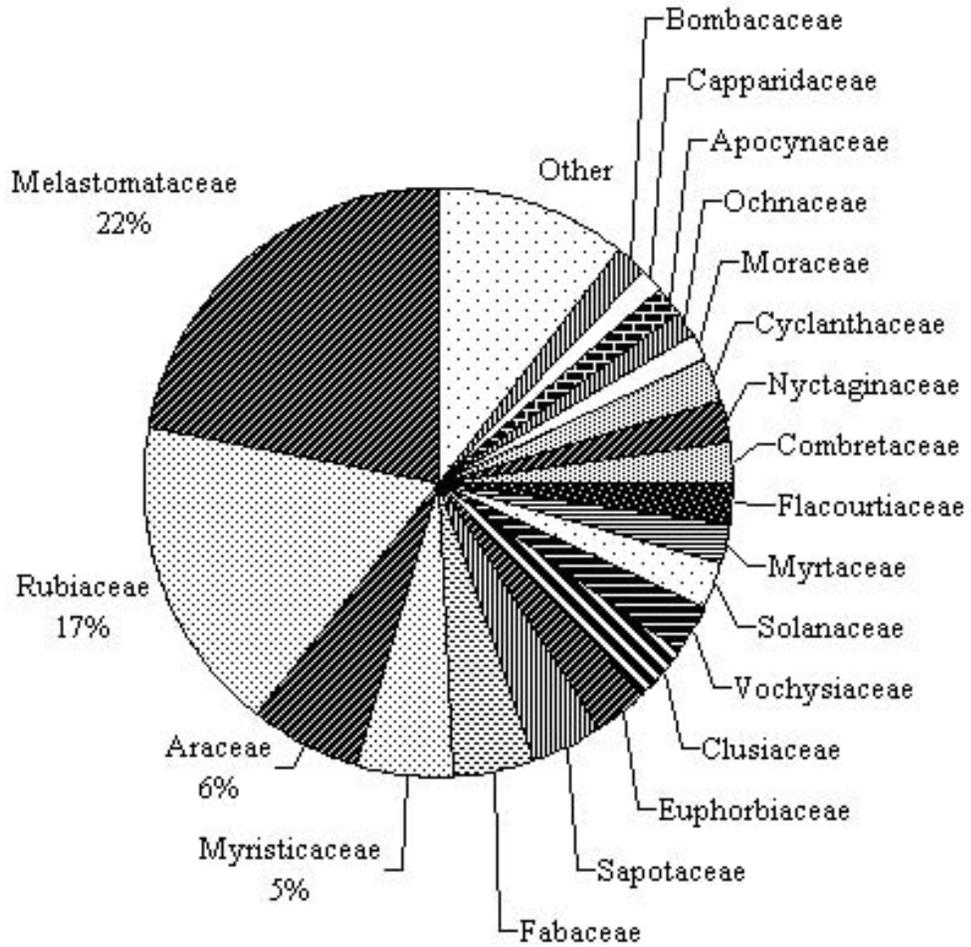


Figure 4-1. Percent distribution of plant families browsed by lowland tapir (*Tapirus terrestris*) in the Yavari-Miri River valley, of the northeastern Peruvian Amazon

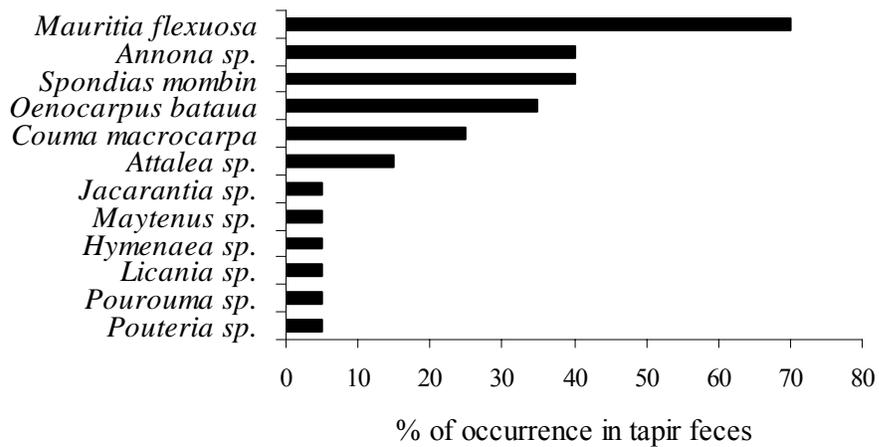


Figure 4-2. Percentage of occurrence of several fruit species in lowland tapir feces along the Yavari-Miri River valley, Peruvian Amazon.

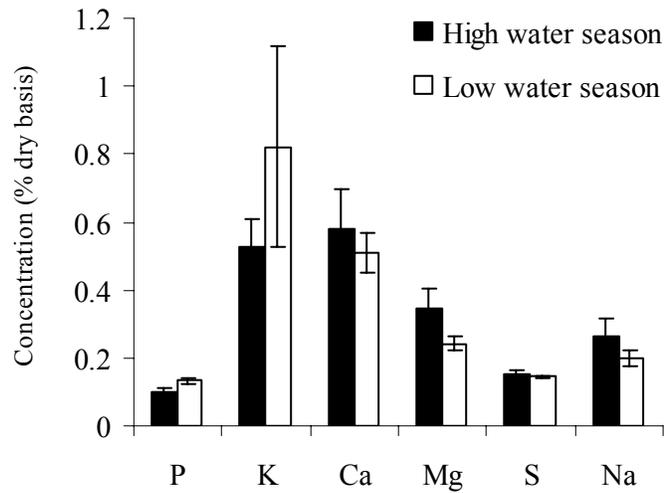


Figure 4-3. Concentration of macrominerals in tapir browse, during high water and low water seasons in the Yavari-Miri Rivier valley, Peruvian Amazon. Vertical lines indicate ± 1 standard deviation.

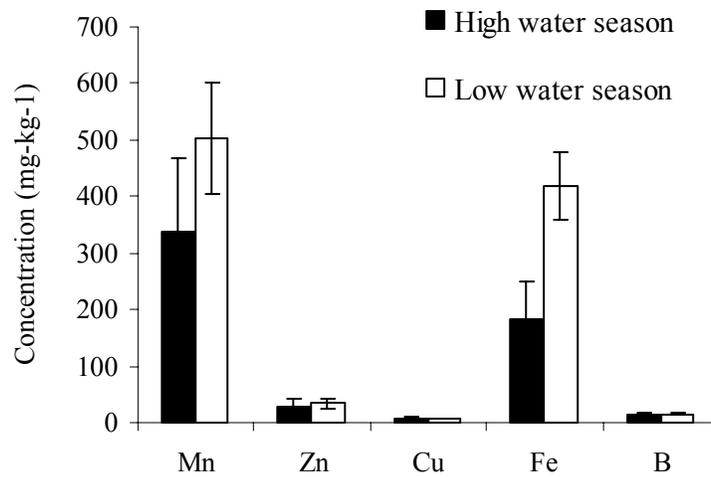


Figure 4-4. Concentration of trace minerals in tapir browse during high water and low water seasons in the Yavari-Miri River valley, Peruvian Amazon. Vertical lines indicate ± 1 standard deviation.

CHAPTER 5 NATURAL LICKS AND RURAL PEOPLE OF THE AMAZON

Introduction

For most rural communities of the Amazon, wildlife hunting continues to be one of the most important sources of subsistence (Alvard *et al.* 1996; Robinson & Bodmer 1999). Although most hunting is primarily for subsistence, over-harvesting is associated with current declines of many wildlife populations. A large body of research exists on the effects of subsistence hunting on wildlife populations and its sustainability (examples in Robinson & Redford 1991; Bissonette & Krausman 1995; Robinson & Bennett 2000). Non-sustainable harvest rates have been found in many studies for a number of species. Besides the effects on wildlife, over-harvesting threatens food security of communities that rely on game for their subsistence. Clearly, wise wildlife management is needed in order to secure both human well-being and wildlife persistence in tropical regions.

Appropriate wildlife management in the Amazon requires an understanding of the hunting systems in the region and the elements that may represent important components of the system. Hunting systems vary depending on the attributes of the environment and ethnic composition of communities (Redford & Robinson 1987; Bennett and Robinson 2000). An often overlooked characteristic feature of western Amazon is the existence of natural licks that provide nutritional benefits to wildlife (Chapters 3 and 4). Natural licks attract a number of species and become sites of either high congregation of animals, or a natural trap for a solitary animal. Such a feature has been observed in other tropical regions where hunters take good advantage of the animals' need for the licks

(Seidensticker & McNeely 1975). In many areas of Amazonia, the existence of licks represents an important criterion for a person to establish a hunting site (Puertas 1999). This corresponds to the common practice of many hunters of waiting for game animals at natural licks, especially during the dry season (Ayres & Ayres, 1979). Accounts of the use of natural licks as hunting sites seldom appear in the literature, and therefore little is known of the relative importance of these places in terms of their contribution to overall hunting in an area. A study in an indigenous community in Colombian Amazonia revealed that 25% of the meat consumed was obtained from natural licks (Walshburger & Hildebrand 1988). Indigenous cultures of western Amazonia apparently prevented over-harvesting of wildlife at natural licks by a set of cultural practices and beliefs. For example, the Uitoto Indians regard natural licks as dangerous and mysterious places, where hunting is allowed only under a set of cultural prescriptions (Pineda 1992). Because such prescriptions are uncommon within many human communities in the Amazon, hunting at licks is usually uncontrolled.

The purpose of this chapter is to examine the importance of natural licks in subsistence hunting in an Amazonian rural community and its implications for management and conservation. This is done by (1) examining the relative contribution of natural licks to the overall hunting, (2) inventorying, locating and describing the licks used as hunting sites, and (3) examining hunters' perceptions and beliefs concerning natural licks. The main hypotheses examined in this chapter are the following:

- **Hypothesis 1.** Hunting at natural licks provides a higher contribution to the overall harvest, at least for some species, as compared to other hunting sites
- **Hypothesis 2.** Most hunters use natural licks as hunting sites.

As a framework to understand the management and conservation implications of this study, background information about the community and the current wildlife co-management process going on in the area is presented first.

Study Area

Location and Biophysical Setting

This study was conducted at Nueva Esperanza Village, a small rural community located at 4°19'53" S, 71° 57'33" in the low Yavari-Miri River region in northeastern Peruvian Amazon (see description below). The landscape is dominated by continuous tropical rainforest dissected by the Yavari-Miri River and its tributaries such as Arabela, Esperanza and Panguana Creeks. Types of forest in the area include upland forest on terraces and sedimentary planes and flooded forest in relatively narrow flood planes of the Yavari-Miri River and its tributaries. Mean annual temperature is 26°C, with monthly mean maximum temperatures ranging from 28-30°C, and monthly mean minimum from 17-20°C. Mean annual precipitation ranges from 2400 to 3100 mm (Marengo 1998), with the highest monthly rainfall occurring from February to April, and the lowest from June to September. Plant and animal diversity is high in the area. Estimated regional species richness includes up to 3,500 plants (Pitman *et al.* 2003), 393 fishes (Ortega *et al.* 2003), 123 amphibians and reptiles (Rodriguez & Knell 2003), 550 birds (Lane *et al.* 2003) and over 80 mammalian species (Valqui 1999; Salovaara *et al.* 2003).

History and Description of Nueva Esperanza Village

Like most of the Amazon region, the Yavari and Yavari-Miri Rivers have an interesting history of consecutive raises and falls of economic booms including rubber, timber, rosewood oil, and animal pelt extraction, with resulting fluctuations in human population demographics (a more detailed account in Bodmer & Puertas 2003). Prior to

the beginning of the rubber boom (in the late 1800s) the human inhabitants of the Yavari-Miri region were mainly native communities of Matses Indians (known also as Mayurunas), whose territory included the whole Yavari valley. But with the intermittent economic activities, the Yavari region became more populated, and many non-indigenous settlements were established along the rivers. By the 1960s more than 1000 people were living along the Yavari-Miri River (Bodmer & Puertas 2003). However, a progressive decline in economic activities in the area since the 1970s and a high incidence of malaria (with a deadly epidemic outbreak in 1995) resulted in the reduction of human population. Almost half of the population died and most of the survivors migrated to other areas. Currently, the Yavari-Miri River is probably at its lowest human population density since the beginning of the rubber boom (Bodmer & Puertas 2003).

Currently, the only 4 small communities along the Yavari-Miri River are: Carolina, in the lower course of river, Nueva Esperanza and San Felipe close to Esperanza Creek (Figure 5-1), and San Francisco de las Mercedes comprised of only one family in Pavaico Creek, in the upper part of the Yavari-Miri River. Nueva Esperanza village is the largest of the 4 communities. It was founded in 1971 (Bodmer & Puertas 2003) and according to the oldest settlers, it was first established close to the mouth of the Esperanza Creek. However, repeated flooding motivated settlers to move the community to its current location, on a high terrace around 18 km downstream. As in other rivers of the Peruvian Amazon, inhabitants of the Yavari-Miri River are *ribereños* –detribalized communities of several origins (Bodmer 1994). According to a census conducted in year 2002 (Montenegro unpublished data), the oldest members of Nueva Esperanza came from

several areas of the Amazon River and its tributaries (Iquitos, Pebas, Tamshiyacu, Cochiquina, Rio Tigre, and Nauta).

In 2002, Nueva Esperanza village had 162 inhabitants, grouped in 28 households. Average size per of household was 6, with a high proportion of infants (Figure 5-2). The village has a primary school (with intermittent absence of a teacher), and an infirmary for first aid services. The closest hospital is on the Yavari River, in a Brazilian military base at the international border between Peru and Brazil. It takes 1 day to travel from the community to the hospital paddling in a canoe. The main subsistence activities in Nueva Esperanza village are wildlife hunting, fishing, agriculture and low scale extraction of trees for fruits or wood (Antunez 2001; Del Campo *et al.* 2003). There is an average of 1 hunter per family. Hunting in the Yavari-Miri River is slight compared to other areas in northeastern Peru, and this area still maintains abundant wildlife populations. Currently the Yavari-Miri basin is the most important area for wildlife recovery from hunted areas of the Orosa, Maniti, Tamshiyacu, Tahuayo, Yarapa, Galves and Yaquirana (Bodmer *et al.* 2003).

To the northwest of Nueva Esperanza, in the headwaters of the Yavari-Miri River, lies the Reserva Comunal Tamshiyacu-Tahuayo (RCTT). This reserve covers 322,500 ha, that also includes the upper Tamshiyacu and Tahuayo river watersheds. The RCTT was created in 1991 by the Department of Loreto's government, in response to a joint effort of local communities and researchers (Meyer & Penn 2003). The RCTT is run by the local communities of the Tamshiyacu and Tahuayo Rivers, and comprises areas of use for managed hunting and extraction of other natural resources, and areas of strict protection. Local hunters work together with extension workers and researchers monitoring hunting

levels (Puertas 1999, Bodmer & Puertas 1999, Meyer & Penn 2003). Although the 4 communities of the Yavari-Miri River are located outside the reserve, they have participated in the wildlife co-management initiative since 1994, primarily in self-monitoring of hunting levels.

Currently, several threats to local lifestyle practices exist in the region (Del Campo *et al.* 2003): medium-and large scale logging prospects, immigration of outsiders with agricultural practices incompatible with local natural resources, and irregular provision of basic services. Settlers of Nueva Esperanza are currently concerned about the re-emergence of large-scale extractive activities and high-impact agricultural practices of colonists. Immigrant members of a religious sect (colloquially referred as to the “Israelitas”) are already settled in the lower Yavari River, and plan to extend their territories towards less inhabited areas. An immediate goal of settlers of Nueva Esperanza is to acquire legal title to their lands and government recognition of a protection area for the region (Del Campo *et al.* 2003). In summary, Nueva Esperanza village is a small *ribereño* community living in the area for more than 40 years, currently practicing low impact resource use, and actively involved in the management of their natural resources.

Methods

Subsistence Hunting Records

This study was linked to the community based co-management process going on in northern Peru (Puertas 1999; Bodmer & Puertas 1999; Bodmer *et al.* 2003), which includes a permanent hunting register by rural hunters in the Yavari-Miri area. Hunting records have been kept in Nueva Esperanza village since 1994 (Puertas 1999). Since 2001, hunting records included not only the species and hunting area, but also the specific hunting site (natural lick, forest, and riverbank). Hunting records from January to

December 2001 were used in this research. Species hunted, number of animals and biomass were compared among hunting sites (natural licks, forest trails and riverbanks).

Natural Lick Mapping and Description

Most licks used by hunters of Nueva Esperanza were visited in 2002, guided by the most experienced hunters of the village. Lick locations were obtained from a global positioning system (GPS), and access trails and other features were drawn with the hunters' help. Also, size of licks was obtained by measuring both its length and width. Lick boundaries were determined as the limits where animal activity was evident. Animal tracks at the licks were recorded, and additional information of lick users was obtained from the hunters. Skull and other bones, as well as platforms or other evidence of hunting at the licks were recorded. Licks were located on a map (1:100,000 scale) to estimate the distance traveled from the community to the licks, and the overall spatial layout of the licks. When possible, location of other hunting sites was also included on the map. Location of hunting trails was obtained combining both hunting registers and geographical information on streams, lakes and other features collected during the mapping process. From information provided by hunters, buffer areas of 5 km around hunting trails were calculated using the ArcView software (version 3.2) to visualize the area of harvesting. Natural licks used by hunters were overlaid on top of the calculated buffer areas to visualize their location in relation to the hunting area. Both hunting areas and licks were displayed on top of a satellite image of the area.

Hunters' Perceptions Concerning Natural Licks

Structured interviews were conducted with the 27 hunters at Nueva Esperanza. Interviews addressed the following subjects: (1) preferred hunted sites, (2) perceptions about natural licks, including types of licks, descriptions and drawings, (3) species hunted

at licks, (4) hunting techniques at licks, (5) beliefs concerning licks, and (6) lick management including conservation perceptions and attitudes.

Results

Subsistence Hunting in Nueva Esperanza Village

Hunting records indicate that 683 animals from 19 species were harvested from January to December 2001 (Table 5-1). Game species included 1 species of Amazonian tortoise (*Geochelone denticulata*), at least 5 species of large birds from the families Cracidae (2 species) and Tinamidae (1 species), and 13 species of mammals, including 1 carnivore species (*Nasua nasua*), 5 species of medium and large primates (*Alouatta seniculus*, *Ateles paniscus*, *Cebus albifrons*, and *Lagothrix lagothricha*, and *Pithecia monachus*), all ungulates native to the area (*Tapirus terrestris*, *Tayassu pecari*, *Pecari tajacu*, *Mazama americana* and *M. gouazoubira*) and 2 large rodents (*Agouti paca* and *Dasyprocta fuliginosa*).

Harvest was not evenly distributed among species (Figure 5-3). White-lipped peccaries (*Tayassu pecari*) and collared peccaries (*Pecari tajacu*) were the most frequent prey animals, accounting for 55% and 22% of the total number of harvested animals respectively. Lowland tapirs (*Tapirus terrestris*) were the next most frequent prey species, accounting for 8% of the total number of hunted animals. Red brocket deer and large primates represented about 4% each of the total harvested individuals. The remaining species accounted for 0.1% to 3% of the total number of harvested animals.

Total biomass hunted during year 2001 was 26, 211 kg. Contribution of each game species to the total harvested biomass differed among species (Figure 5-4). White-lipped peccaries contributed to the 47.5% of the total harvested biomass. Lowland tapirs made up 33% of total biomass, followed by collared peccaries, representing 14.2%, and red

brocket deer representing 3.7%. The remaining species' contribution to total biomass ranged from 0.1% to 0.9%.

There were differences in total biomass obtained from each hunting site. Hunting along trails provided 65% of the harvested biomass, whereas natural licks and riverbanks provided 18% and 17%, respectively (Figure 5-5). Most white-lipped peccaries were obtained along hunting trails (Figure 5-6), and in less proportion at natural licks and riverbanks. In contrast, lowland tapirs were hunted mainly at natural licks and riverbanks, and to a lesser extent along trails. Collared peccary and red brocket deer were hunted along trails, and occasionally in natural licks.

Natural Lick Mapping and Description

Hunters of Nueva Esperanza village use more than 42 natural licks as hunting sites. These licks are located along the Esperanza Creek (20 licks) and the middle and low Yavari-Miri River (22 licks). Most licks used as hunting sites are located at or near the riverbanks in both the Yavari-Miri River and the Esperanza Creek (Figure 5-7). Only 6 licks (14%) were located more than 500 m from the riverbank, up to 1 km inside the forest. Size of natural licks varied from 110 m² to 1,200 m². All hunted licks were found within the 5 km buffer areas from hunting trails. Distance from Nueva Esperanza village to the licks varied from 10 to 35 km (straight line), but travel times vary throughout the year according to river levels. Remains of rustic temporary platforms built by hunters were found in 5 licks. These platforms allow hunters to wait for game animals at the licks. For many of the riverbank licks, waiting for animals is done from a canoe, instead of a platform. Another alternative is using a hammock instead of a platform, in order to hunt inside a lick. Bones of lowland tapirs (mainly skulls) were found near 2 natural

licks. Hunters report that they usually do not process their kill inside the licks, and that bone and other materials are not left close to the licks.

Several hunter camps were found close to a number of natural licks. Hunters indicated that occasionally they conduct hunting trips of 5 to 10 days when they desire to hunt in those areas far away from the community. Usually they maintain a campsite close to licks and surrounded by hunting trails.

Hunters' Perceptions Concerning Natural Licks

All hunters of Nueva Esperanza were interviewed in order to gather their perceptions about natural licks. Most hunters listed all ungulates, large primates, large rodents and large birds as potential prey at natural licks. However, there were only ungulates reported as prey in natural licks in 2002. Most hunters recognized more than one type of natural lick, depending on either the species using them or their location. Hunters' classification of natural licks included the following: tapir licks, deer licks, peccary licks and small animal licks. Differences among those licks are mainly in size, with the tapir licks being the largest. Most hunters (75%) indicated that large natural licks are more frequent in a type of upland forest named *shapajillal*. This type of forest is characterized by the dominance of *shapaja*, a palm of the genus *Attalea*. However, most hunters also recognized that many licks they use are those close to the river, in seasonally flooded forest or along riverbanks.

About 70% of hunters of Nueva Esperanza village expressed their preference for using licks as hunting sites, whereas 30% of them stated that they dislike hunting at licks. The former group indicated that natural licks are a very reliable site for hunting lowland tapirs, and occasionally other species. The latter group stated that even though they could hunt tapirs, nocturnal waiting at the licks is very unpleasant, and even dangerous.

Almost all hunters (90%) have beliefs regarding mythical owners of natural licks. However, only a few (2%) claim having actual experiences that reinforce those beliefs. For 96% of interviewed hunters, some natural licks have a “mother” that may interfere or even prevent hunting at licks. The practical result of those beliefs is that hunters use only those licks where they believe the “mother” does not exist or is not dangerous.

About 74% of hunters of Nueva Esperanza village proposed that the best management strategy to avoid over-exploitation of natural licks is rotation of their use through time. About 21% of hunters indicated that prey should not be processed at the licks to avoid degradation of animal remains that may “damage” the licks, as a management strategy. Finally, 5% of hunters stated that management of licks should involve exclusion of alien hunters coming from outside areas, in order to avoid over-exploitation of natural licks.

Discussion

Subsistence Hunting Records

From the hunting records in Nueva Esperanza village, it is clear that subsistence hunting in the Yavari-Miri River is concentrated in large mammals, especially ungulates. The most frequently harvested mammals are white-lipped peccary and collared peccary, and to a lesser extent the lowland tapir. However, when comparing the contribution of each species to the total harvested biomass, lowland tapirs are second after white-lipped peccaries, accounting for about 33% of total biomass. Peccaries are harvested with more frequency along hunting trails, whereas the lowland tapir is harvested with more frequency at natural licks and riverbanks. A close examination of tapir hunting records by month indicated that tapirs were harvested inside natural licks on average 68.66% of the occasions, except in November, when more tapirs were harvested at the riverbanks.

Examination of riverbank locations where tapirs were hunted in November 2001 indicated that 3 of the 7 hunting sites were very close to natural licks (sites Gamarra, Guedes and Maquisapay). In other words, most of the lowland tapir hunting occurred inside or around natural licks.

Total biomass from lowland tapirs harvested inside and around natural licks adds up to 25% of total biomass hunted in the Yavari-Miri River in 2001. The other species harvested at licks provide an additional 10% of the total biomass, for a total of 35% of biomass obtained from licks.

The effect of hunting at licks varies among species. Peccaries are hunted at licks but less extensively than tapirs. Hunting of peccaries could be sustainable, within certain limits (Bodmer *et al.* 1997a). In contrast, lowland tapirs are more susceptible to over-hunting than other Amazonian species because of their low reproduction rate, long generation time and longevity (Bodmer *et al.* 1997b). Tapirs visit licks in a predictable manner, making them more susceptible to hunting at those sites.

A preliminary analysis of hunting at licks in the same area showed the same tendency, with most tapirs hunted at natural licks (Parish 2001). Proportion of hunted animals at licks was higher for all ungulates in terms of biomass during April-June 2001 (Parish 2001). Although proportions differ a little when using data for the whole year, similar patterns were seen.

Compared to hunting at Quebrada Blanco, another location inside the RCTT, hunting pressure in the Yavari-Miri region is lower. Hunting at Quebrada Blanco is 5 times greater than at the Yavari-Miri River, and most large mammal species are harvested above sustainable levels (Bodmer *et al.* 2003). Recent analysis of capture for unit effort

in both the Yavari-Miri River and Quebrada Blanco (Bodmer *et al.* 2003) indicated that lowland tapir in the Yavari-Miri River is currently hunted within sustainable levels with 16% of its reproductive productivity being harvested. In contrast, lowland tapir is clearly over-harvested at Quebrada Blanco, where 140% of tapir reproductive productivity is taken (Bodmer *et al.* 2003). Natural licks are frequently used in Quebrada Blanco, and are in fact an essential requirement for a hunter to establish a hunting site there (Puertas 1999). The larger human population size of Quebrada Blanco compared to the Yavari-Miri River site accounts for differences in hunting pressure between the 2 sites. In order to maintain lowland tapir hunting within sustainable levels, it is important to consider their high susceptibility at licks, and to regulate harvest from licks as a part of the wildlife management in the Yavari-Miri River. Such a management strategy is very important, since the Yavari-Miri River valley is currently considered as a source area (on a source-sink model) for other heavily hunted areas of the northern Peruvian Amazon (Bodmer *et al.* 2003). For the Yavari-Miri region to effectively work as a source, its populations should be near carrying capacity (Pulliman 1988) so animal dispersal can replenish the hunted (or sink) areas. Such a system is very important for sustainability of wildlife hunting in Amazon (Sirén *et al.* 2003), and particularly for lowland tapirs (Novaro *et al.* 1999, Salas & Kim 2002).

Natural Lick Mapping and Description

Local hunters at the Yavari-Miri River use a relatively large number of licks. The 42 licks inventoried in this research comprise 82% of the total number of natural licks (52) used in the area (Parish 2001). The additional 10 licks are located in the upper part of the Yavari-Miri River, and are used only occasionally. From hunting records, the most used natural licks are those located along the Esperanza Creek, and some of the licks

located along the Yavari-Miri River within 30 km from Nueva Esperanza village. Parish (2001), using a participatory mapping approach, and interviews of 12 hunters of Nueva Esperanza, found that hunting pressure was greater at those licks more accessible to the community. Similar results were found in this study. Also, licks located within the first 500 m from the river are more frequently used. Hunters avoid using distant licks because carrying the kill would be difficult, especially when a 250-kg tapir is the prey. This fact allows animals to switch to licks that are less visited by hunters. However, during the low water season, many small streams dry up and animals are forced to approach the riverbanks. During those months, hunting at riverbank licks becomes more common. For the above reason, management of hunting at natural licks should take into account changes in natural lick temporal availability and spatial layout.

Hunters' Perceptions Concerning Natural Licks

Although Nueva Esperanza village is a *ribereño* community, where their members do not identify themselves as indigenous people, interviews showed that some of the original indigenous beliefs are still present in the *ribereño* culture. For example, beliefs concerning the “mother” of natural licks are also present in several Indian cultures of the Colombian Amazon (Pineda 1992). In the past those beliefs probably functioned as an intuitive management practice that avoided over-exploitation of wildlife at natural licks. Among the Uitoto Indians of Colombia, for instance, natural licks are considered dangerous and mysterious places where the “mother of the lick” does not facilitate hunting unless the hunter follows a set of cultural prescriptions. Disease or misfortune that happens after treating natural licks barbarously would be interpreted as a punishment (Pineda 1992).

Although beliefs concerning natural licks are not exactly the same in the Nueva Esperanza village, hunting at licks is still associated with mythical owners. The extent to which those beliefs currently function as an intuitive management practice is not very clear. Hunters' preference for or avoidance of natural licks as hunting sites seems related to individual experiences and hunting expertise. Some hunters seem to specialize in peccary hunting, whereas others are less selective of their prey. Those hunters claiming previous negative experiences at natural licks are less willing to spend night hours at licks waiting for tapirs. In contrast, many other hunters decide where to hunt depending on time, logistics and prey demand. Although hunting at the Nueva Esperanza village is mainly for subsistence, part of the kill is often sold or exchanged for other food products with 1 or 2 members of the community. The latter, take the meat, as well as other products, to the closest town, Islandia, close to the Yavari River's mouth in the Amazon River. Occasionally tapir meat is in more demand in Islandia and other towns, encouraging settlers of Nueva Esperanza village to increase their hunting of tapirs. During these times hunting at natural licks may become very common.

Natural licks also are used indirectly to track other species. For example, during the interviews several hunters indicated that they could monitor white-lipped peccaries' movements and herd size by checking tracks at natural licks. Hunters can estimate the time when white-lipped peccaries had passed through the licks, and if visits were recent, hunters could follow peccary tracks to find the herd.

In general, natural licks are an important resource for local hunters because they directly provide a significant portion of the hunted biomass, highly represented by lowland tapirs, and indirectly help to monitor other game species. All hunters interviewed

were receptive to a management strategy that allows protection of the licks. The most frequent strategy mentioned by the hunters was rotation of hunting at natural licks. Such a strategy coincides with one of the recommendations for wildlife management for the RCTT described by Puertas (1999), who also proposed a zoning of the area that allows rotation in natural resource use. The mapping of all licks used by hunters could be used as a starting point to design a rotational system for controlling over-hunting at natural licks. Also, the existence of natural licks in an area should be a criterion in delimiting protected areas.

Summary and Conclusions

The purpose of this chapter was to analyze the importance of natural licks for rural people of the Amazon. For the study, hunting patterns at the community of Nueva Esperanza along the Yavari-Miri River were analyzed through three complementary methods. First, an analysis of one-year-long hunting registers was conducted in order to evaluate the proportion of harvest coming from licks as compared to other hunting sites. Lowland tapirs provided over 30% of total biomass hunted during 2001, and they were mainly hunted at natural licks and surrounding areas. Second, inventory of licks showed that hunters of Nueva Esperanza village use more than 40 natural licks located along the Esperanza Creek and the middle and low Yavari-Miri River. Most licks used as hunting sites are located close to the river, to facilitate carrying of prey. Third, interviews conducted with all hunters at Nueva Esperanza village showed that cultural beliefs are still present in this *ribereño* community, and that most hunters are receptive to management strategies for controlling over-hunting at natural licks, mainly by rotation of use.

Results of this research indicate that natural licks are a very important resource for local hunters because they provide direct and indirect hunting benefits. Natural licks are the main source of the largest mammal of the Amazon, the lowland tapir. Indirectly, natural licks provide, besides a portion of the harvest, a source of information about the most hunted species in the area, the white-lipped peccary. A management strategy that involves protection of licks and rotation of their use was stated as the most recommended practice in the area.

Table 5-1. Species hunted by settlers of Nueva Esperanza Village in the Yavari-Miri River from January to December 2001.

Species	English name	Local name	Number hunted in year 2001	Biomass per individual (Kg)
Reptiles				
Testudines				
Family Testudinae				
<i>Geochelone denticulata</i>	Amazonian tortoise	Motelo	21	5
Birds				
Craciformes				
Family Cracidae				
<i>Crax</i> spp and <i>Mitu</i> spp	Curassows	Paujil	15	3
<i>Penelope jacquacu</i>		Pucacunga		
	Spix's guan		3	3
<i>Pipile cumanensis</i>	Blue-throated Piping-guan	Pava negra	1	3
Tinamiformes				
Family Tinamidae				
<i>Tinamus</i> sp.	Tinamu	Perdiz	1	3
Mammals				
Carnivora				
Family Procyonidae				
<i>Nasua nasua</i>	South American coati	Achuni	1	4
Primates				
Family Cebidae				
<i>Alouatta seniculus</i>	Red-howler monkey	Coto		8
<i>Ateles paniscus</i>	Black spider monkey	Maquisapa	2	11
<i>Cebus albifrons</i>	White capuchin monkey	Mono blanco	1	3
<i>Lagothrix lagothricha</i>	Woolly monkey	Choro	22	8
<i>Pithecia monachus</i>	Black saky monkey	Huapo negro	1	2
Perissodactyla				
<i>Tapirus terrestris</i>	Lowland tapir	Sachavaca	54	160

Table 5-1 (continued)

Species	English name	Local name	Number hunted in year 2001	Biomass (Kg)
Artiodactyla				
Family Tayassuidae				
<i>Tayassu pecari</i>	White-lipped peccary	Huangana	377	33
<i>Pecari tajacu</i>	Collared peccary	Sajino	149	25
Family Cervidae				
<i>Mazama americana</i>	Red-brocket deer	Venado rojo	29	33
<i>Mazama gouazoubira</i>	Grey-brocket deer	Venado gris	1	15
Rodentia				
Family Agoutidae				
<i>Agouti paca</i>	Paca	Majás	3	5
Family Dasyproctidae				
<i>Dasyprocta fuliginosa</i>	Black agouti	Añuje	2	5
Total hunted in year 2001			683	26,211

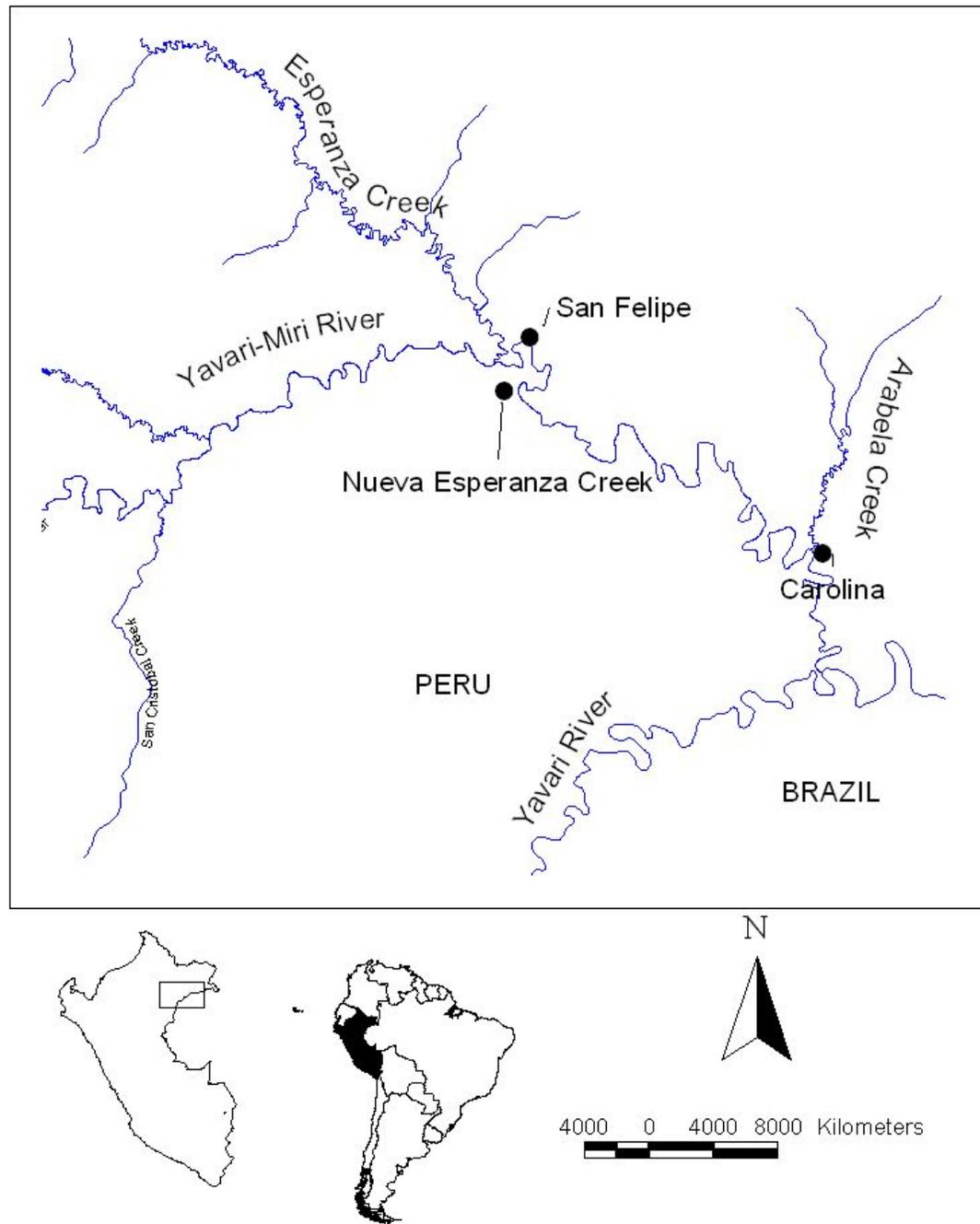


Figure 5-1. Location of the study area in the Yavari-Miri River region, northeastern Peruvian Amazon.

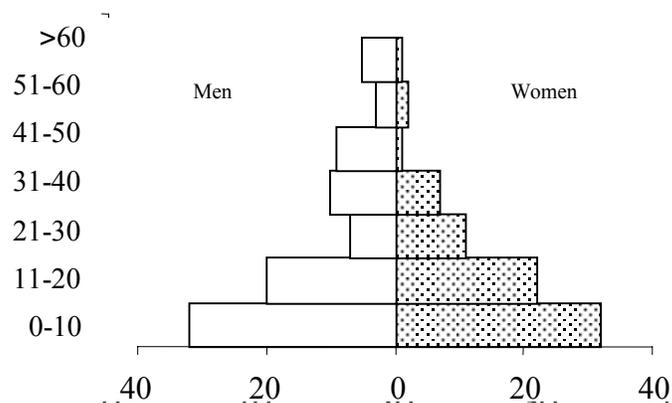


Figure 5-2. Gender and age composition of Nueva Esperanza Village in the Yavari-Miri River region, northeastern Peruvian Amazon (census conducted in 2002). Numbers to the left indicate age class.

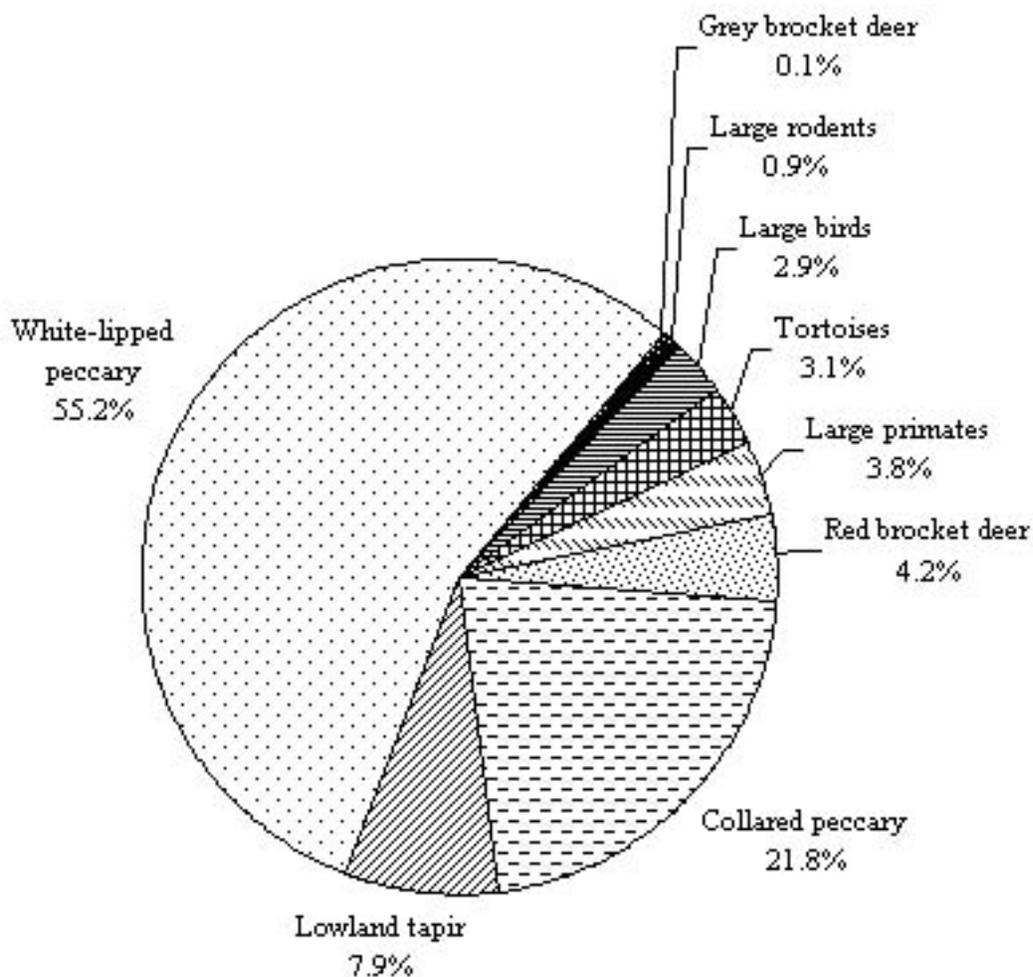


Figure 5-3. Percent contribution of each species to the total number of animals hunted in 2001 in the Yavari-Miri River.

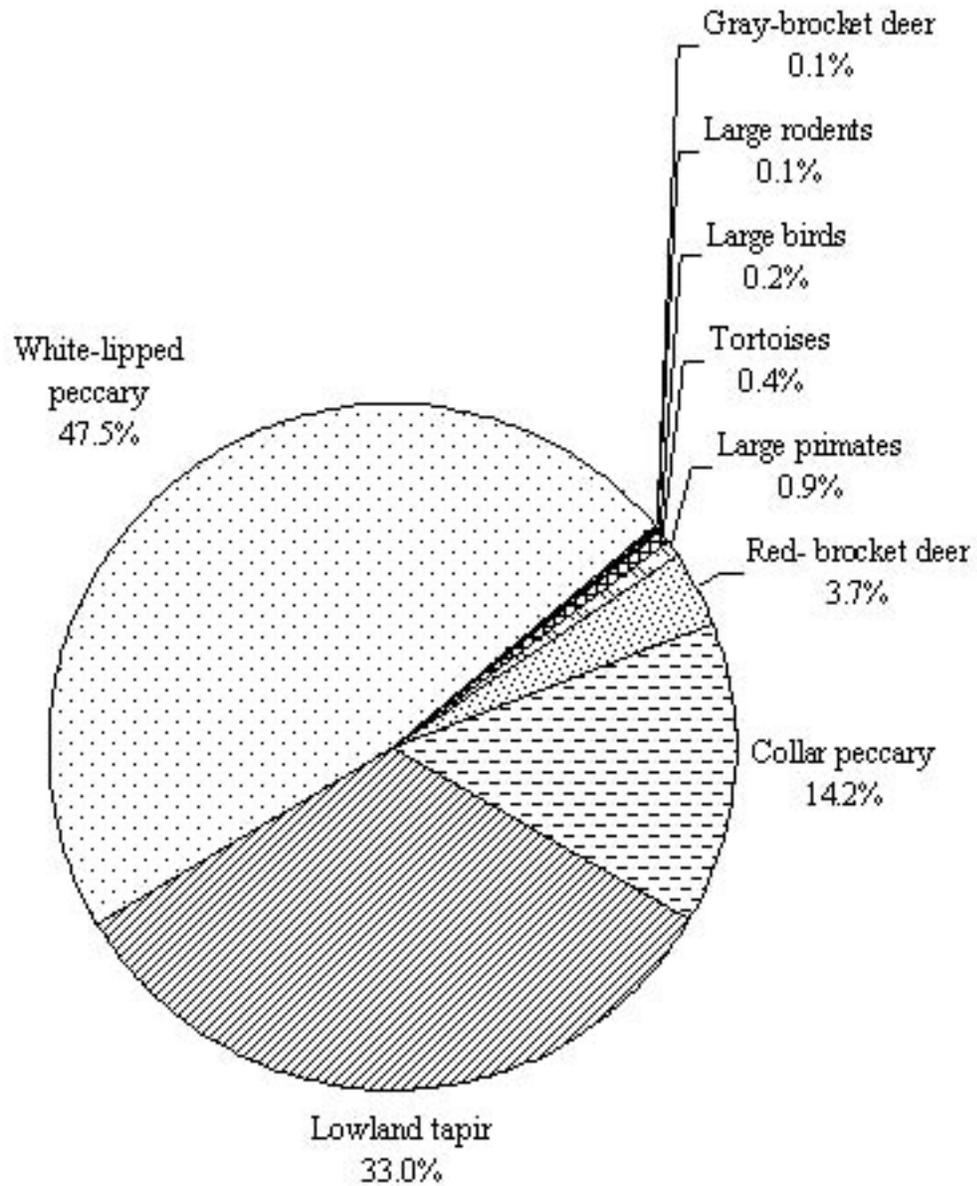


Figure 5-4. Percent contribution of each species to the total biomass hunted in 2001 in the Yavari-Miri River.

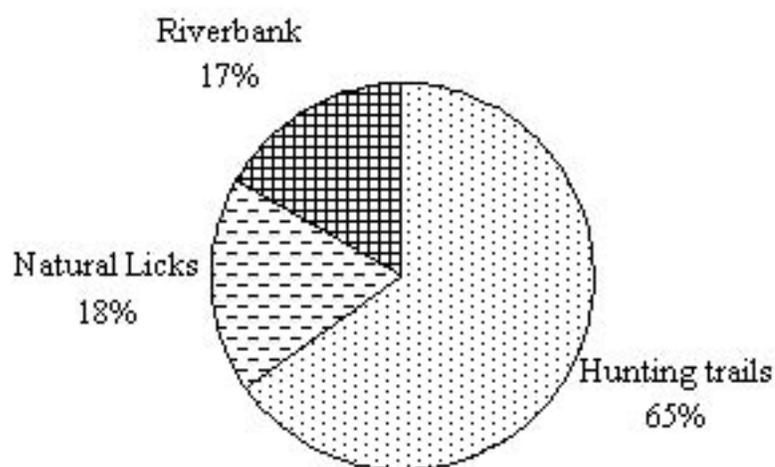


Figure 5-5. Proportion of biomass harvested by hunters of the Nueva Esperanza Village per hunting site from January to December 2001.

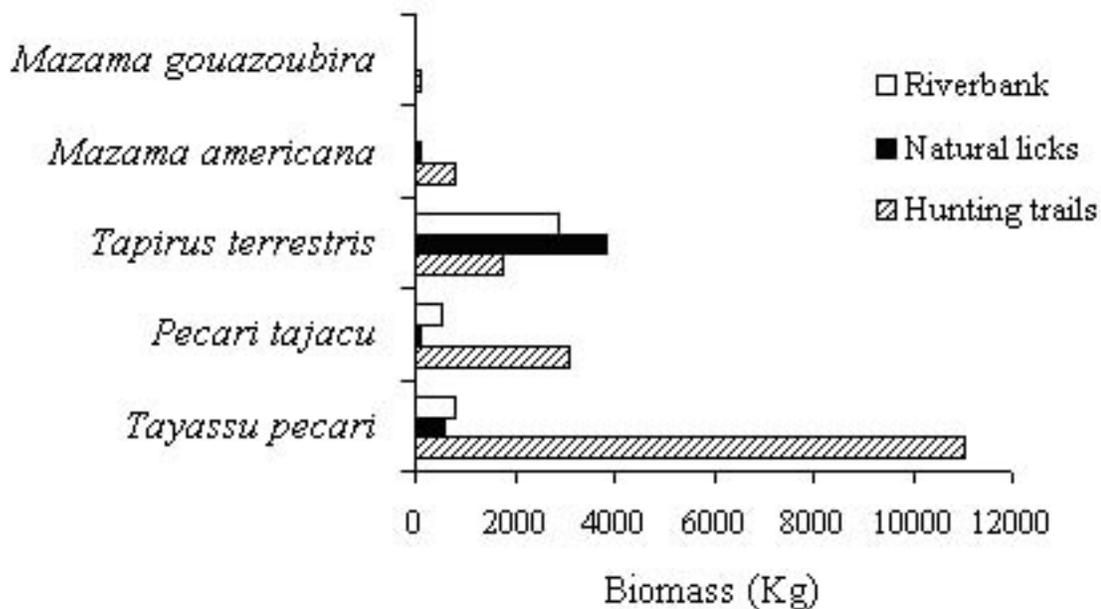


Figure 5-6. Biomass hunted per ungulate species at riverbanks, natural licks and hunting trails in the Yavari-Miri River region during year 2001.

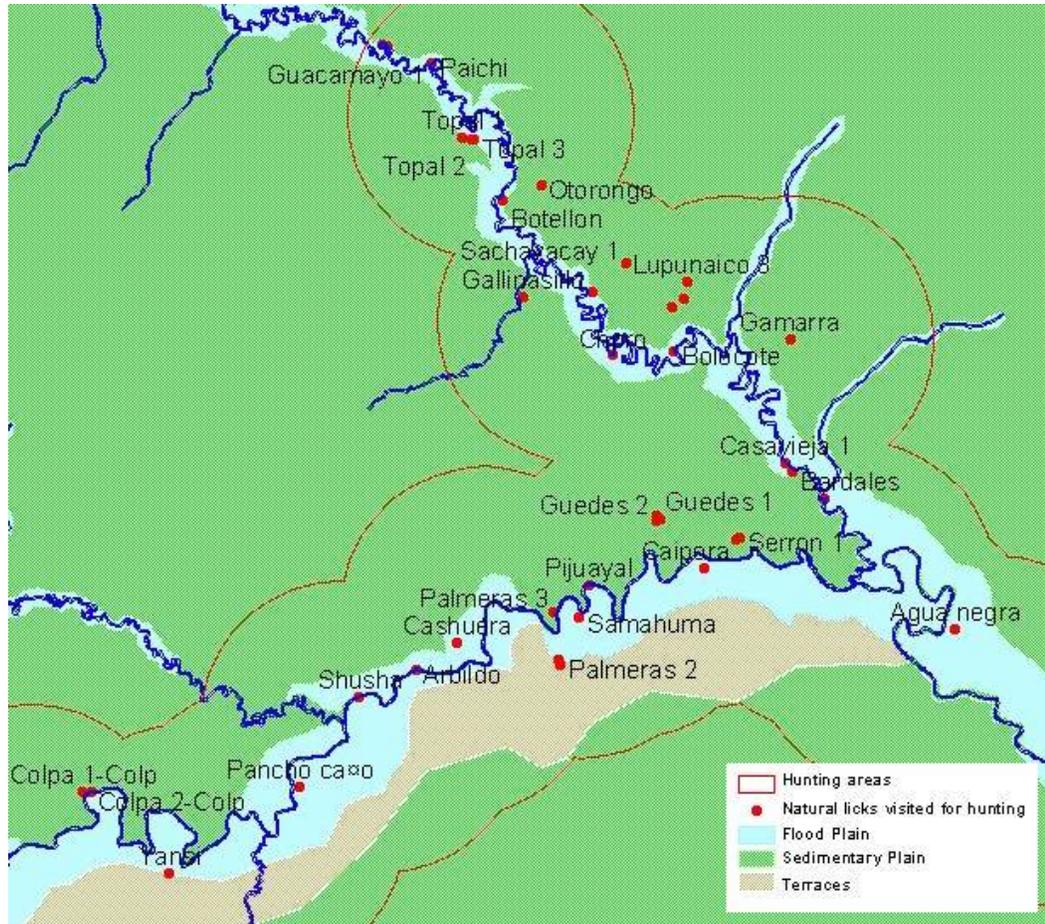


Figure 5-7. Location of hunting areas and natural licks used by settlers of Nueva Esperanza village.

CHAPTER 6 SYNTHESIS AND CONCLUSIONS

This research addressed the importance of natural licks for both wildlife and humans in the Yavari-Miri valley in northeastern Peruvian Amazon. A keystone role is attributed to natural licks to both wildlife and people in this particular region, western Amazonia. This synthesis examines the extent to which a keystone role can be credited to natural licks based on the results of this research.

The following predictions were stated in the introduction of this dissertation: (1) a high proportion of wildlife species use the licks, (2) natural licks provide something to their users that is in short supply and is not easily substitutable (low redundancy), (3) natural licks are a reliable resource (are available when the animals need them), and (4) area occupied by natural licks in the habitat is small relative to its effect on its users.

We found that a relatively large number of species use the licks, mainly large birds and mammals (Chapter 2). Among mammals, all ungulate species, 2 of 3 species of large primates, 2 of 3 large rodents, and many fruit bats were frequent lick users. Even 2 carnivores were found visiting licks, possibly looking for prey. These results agree with the prediction of a high proportion of species using natural licks as a resource.

Examination of the chemical composition of soils consumed by wildlife species at natural licks indicates that several elements of nutritional importance (Na, Ca, Mg, P, Cu, S and B) are in relatively high concentrations throughout the year (Chapter 3). The hypothesis that some of these elements are in short supply in animal diets was tested for the most frequent lick visitor, the lowland tapir (Chapter 2), by examining its diet and the

mineral composition of its foods (Chapter 4). We found that tapir foods are good sources of mineral nutrients, except for Na, P and Cu, as compared to mineral requirements. Since tapir mineral requirements are unknown, the assumption was made that their requirements are similar to those in horses, although the adequacy of such assumption is discussed (Chapter 4). Also, it was found that fecal mineral excretion of those elements was higher than expected considering their low concentration in foods, suggesting that tapirs are supplementing their diets by consuming mineral-rich soils at natural licks. This idea is supported by the fact that over 76% of the tapir fecal samples examined contained visually noticeable amounts of soil. Na was particularly low in fruits consumed by lowland tapirs. Whether that feature is common to most fruits in the area needs to be investigated. However, if that is the case, Na from licks is probably also of benefit for other lick users, since many of them were frugivore species (Chapter 2). Results from Chapters 3 and 4 agree with the prediction that natural licks provide something to its users that is in short supply (at least for tapirs), and is not easily substitutable (low redundancy).

Reliability of natural licks as a source of minerals could be inferred from Chapter 2. No significant drops in mineral content of consumed soils were found throughout the year, indicating that natural licks are a reliable resource for the animals. However, not all natural licks are available year-round, since the ones located along the riverbank and in low plains become flooded during the high water season. For this reason, natural licks located in the upland forest are more reliable through the year. On a larger time scale, natural licks may lose their function when new sediments cover exposed materials that attract the animals. However, animals are not passive in relation to natural lick

availability. If a lick is covered by something that animals can remove, they probably will do it over time. For example, we observed that a few months after the dense crown of a large fallen tree covered a natural lick, animals reopened it by continuous use. In summary, natural licks in upland forest are a reliable source of minerals for the animals.

Although sediments that form natural licks in the Yavari-Miri region have a large geographical extension, more recent sediments cover them, and only the outcrop of those underlying, older sediments forms the actual licks. The area available for animals to exploit is very small compared to the whole extension of the habitat (Chapter 3). However, minerals obtained by animals are likely critical for their nutrition. Poor nutrition reduces reproduction and survival, and overall limits population growth and persistence. This argument agrees with the prediction that area occupied by natural licks in the habitat is small relative to its effect on its users.

In conclusion, natural licks in the Yavari Miri River region are resources used by a relative large proportion of the wildlife community, they provide mineral nutrients that are in short supply (at least to some species) and, even though they occupy a proportionately small area, they may be critical for abundance and persistence of animals in the area.

The keystone role of a resource is not a concept applied to humans. However, humans are an integral part of ecosystems, and their use of natural resources has a tremendous impact on those ecosystems (McDonnell & Pickett 1993). Addressing the importance of natural licks as a resource for human communities using the conceptual framework above provides common criteria for the analysis, and helps to discuss the conservation implications of this research.

Adapting the conceptual framework used above, the following results would be expected if natural licks can be considered as a keystone resource for people in western Amazonia: (1) a high proportion of people use natural licks (as an adaptation of the criterion of degree of consumer specificity, but applied to only one species-humans- and quantification of importance in terms of number of persons using the licks rather than number of species), (2) natural licks provide something to its users that is in short supply and is not easily substitutable (low redundancy), and applied to people, it refers to game species, (3) natural licks are a reliable resource (provide game when used), and (4) area occupied by natural licks is small relative to the benefits they provide to their users.

Examination of such predictions comes from the information gathered at the Nueva Esperanza village, a rural community of the Yavari-Miri River (Chapter 5). We found that 70% of hunters of the village regularly use natural licks as hunting sites. Also, more than 40 natural licks are used within hunting areas, and many are regularly visited, not only for direct hunting, but also for getting information on some species in the area. This result agrees with the prediction that a high proportion of hunters use natural licks.

Also, we found that natural licks were the most important hunting sites for harvesting lowland tapirs. This ungulate species is the largest terrestrial mammal in the Amazon ecosystem, and it is naturally at lower densities than other species. Hunting lowland tapirs on forest trails is more difficult, since direct sightings in the forest are very rare. In fact, the encounter rate of tapirs have been estimated at 1.17 individuals per 100 km (Salaovaara *et al.* 2003) in an area with very low hunting pressure, and is much lower in heavily hunted sites. However, lowland tapir visitation rate to natural licks is higher in proportion to its abundance in the area (Chapter 2), and this feature is used to benefit the

hunters. This result agrees with the prediction that natural licks provide hunters something that is of limited supply in the area, as applied to lowland tapirs as compared to other prey. Also, concentration of other animals in the licks is another direct benefit for hunters.

In addition, many hunters see natural licks as a reliable site for hunting, because of the high probability of finding a prey. However, reliability of hunting at licks depends on several factors, including hunting pressure and location of the most used licks. Licks that are heavily hunted are usually abandoned by animals and become less reliable. Also, most licks used by hunters are those close to the river because of easy access. Many of those licks may become flooded during the high water season (Chapter 3) and, as discussed above, they will not be as reliable all year round. This is probably the reason why many hunters indicated that they use licks more during the low water season. These observations agree with the prediction that natural licks are a reliable resource, although in a seasonal manner because of river level fluctuations.

Also, natural licks are proportionately small compared to the whole hunting area, and yet they provide a significant proportion of the game in terms of biomass. Hunters of Nueva Esperanza village obtained about 30% of the harvested biomass either from licks or nearby riverbanks in 2002 (Chapter 5). These results agree with the prediction that area occupied by natural licks is small relative to the benefits they provide to the hunters.

In conclusion, natural licks in the Yavari-Miri River are a resource used by a large proportion of hunters of Nueva Esperanza village, the largest of the 4 small human communities in the area. Also, natural licks facilitate the hunting of one the largest game species, whose low density makes it difficult to find it on hunting trails. Finally, although

natural licks occupy only a small proportion of hunting areas, they provide significant benefits to hunters in terms of harvested biomass. Also, natural licks have an effect on wildlife nutrition and health, which may result in a high carrying capacity of the area, which in turn benefits the people who use wildlife as a source of subsistence.

Overall, several findings of this study agree with some of the ecological attributes expected from a keystone resource, for both wildlife and people in western Amazonia. However, further research is needed to examine the role of natural licks for all their users, and to better understand lowland tapir mineral nutrition.

Important conservation implications can be derived from the results of this dissertation. The Yavari-Miri River region is currently the most important source area (in a source-sink model) for replenishment of heavily hunted sites of this part of the Peruvian Amazon. For the Yavari-Miri region to effectively work as a source its wildlife populations should be near carrying capacity (Pulliman 1988) so animal dispersal can replenish hunted (or sink) areas. This is particularly important for species that are very vulnerable to over-hunting, such as lowland tapirs.

Currently, settlers of Nueva Esperanza village are involved in a community-based management process. Appropriate management of the licks should be stressed in that process. We recommend regulation of hunting at licks by temporal rotation of use, and to ensure that large areas are maintained with low hunting pressure. Those areas should serve as a source to hunted areas, and should be of the best quality to ensure high animal densities. The existence of natural licks should be taken into account as a key attribute of habitat quality when selecting source areas for wildlife conservation in western Amazonia.

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BIOGRAPHICAL SKETCH

Olga Lucia Montenegro was born in Bogotá, Colombia. She graduated from the Department of Biology at *the Universidad Nacional de Colombia* in 1990. For five years she worked for a non-governmental institution in research and conservation issues in the Colombian Amazon. In the fall of 1996 she began graduate studies in the Department of Wildlife Ecology and Conservation at the University of Florida. On December 1998 she earned a Master of Science. She continued her studies in tropical wildlife at the University pursuing a Ph.D. degree through the same department. After graduation, she plans to dedicate her time to academic and research work in the tropics.