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Clay Licks as a Keystone Resource and Their Potential in Conservation in the Las Piedras Watershed

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Clay Licks as a Keystone Resource and Their Potential in Conservation in the Las Piedras Watershed

Senior Project submitted to

The Division of Science, Mathematics and Computing

of Bard College

by

Gowri Varanashi

Annandale-on-Hudson, New York

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Abstract

Clay licks, or salt licks or mineral licks are sites of exposed clay in the rainforest where mammals ingest soil (geophagy) in order to obtain salt and other essential minerals such as calcium, potassium, and magnesium and so on, which are lacking in the vegetation. The minerals supplement the diets of the animals and help fight parasites and gastrointestinal problems. These sites promote biodiversity and the health of animal populations. My paper is a camera trap study, done from May 7th to June 17th of 2013, at a research station in an eco-tourism concession on the Las Piedras River, Peru, where there had been hunting and selective logging prior to 2002. The camera traps recorded visitation rates of species at a clay lick and were compared to a dataset from a study conducted in 2003 at the same lick to ascertain changes in abundance and diversity. The increase in the average number of visits per week for species was not large enough to confirm that abundance has increased and populations are recovering from hunting or logging activities, although there seems to be a general trend towards slowly increasing visitation rates for most species. Species diversity revealed by the camera traps is higher in 2013 as compared to 2003 with 8 new species caught feeding on clay.

Keywords: Amazon rainforest, clay licks, mineral licks, salt licks, biodiversity, abundance, hunting, logging, camera trap, geophagy, conservation.

Chapter 1

The Las Piedras River

On a January morning I was relaxing at the main deck of the research station in the Las Piedras River where I work, when suddenly I heard a cacophony of high pitched screeching, hooting and wailing calls. The screams had an uncanny resemblance to people's voices, which was a cause for concern since the vast forests that surrounds the station are uninhabited by humans. The three others at the research station came running with eyes wide, they too were worried. After all, the tributary that we were on is known to have isolated un-contacted tribal groups.

The Las Piedras is one of the longest drainage in the Madre de Dios of Peru, snaking through three-hundred miles of rainforest in the southwest Amazon; bordering Brazil and Bolivia. The river made international news in July of 2013 when over 100 un-contacted tribals, known as Mascho-Piro, appeared on the banks of the river. They stayed on the beach for two days and assumed an aggressive attitude, which is only natural, as they had been victimized by the Spanish conquerors in the 1500s, then the rubber tappers in the 1900s, and loggers in the mid-1980s. Due to illegal activity, they had receded deeper into the forest to stay hidden but recently they have begun to show anger towards the increasing encroachment on their territory by illegal loggers, miners and poachers (Bajak, 2013, para. 3-19).

As our station is only two days boat ride downstream from Monte Salvado, one can imagine what our initial reaction to the calls was. All of us knew that it was possible that the tribes could come down river. We all looked at each other with suppressed fear, squinted eyes and a grin, wondering at the same time if there was a tiny chance that it could be people. But after some minutes of listening, we came to the conclusion that it was not humans, but a group of spider

monkeys. Relieved that we were not in danger, we decided to go track the monkeys. The four of us began quietly walking towards the calls coming from a beautiful trail that has a thick deep green canopy on either side. Often while tracking in the rainforest, you come to the realization that animals are very adept at staying hidden and so at one point even though, we were right under the loud, reverberating calls, we could not find a single monkey in the canopy.

Finally, after squinting up into the back lit canopy for a couple of minutes we caught sight of a group of ten or more spider monkeys, all swinging around in a state of distress. It turned out that there were two groups, both causing chaos in an attempt to keep their authority over that territory. Spider monkeys look graceful, gliding along the canopy due to their long, lanky appearance. Their smooth, shiny, black coat camouflages with the rest of the forest, allowing them to traverse stealthily through the canopy. These primates are primarily canopy dwellers and so they climb down to the ground on very rare occasions, only to eat soil, or rotting wood from which they get minerals and nutrients (Campbell et al., 2005, p. 1039). The ingestion of soil, known as geophagy, is practiced by other primates and mammals too in order to supplement their diets with sodium, calcium, magnesium and other elements (Link, Galvis, Fleming & Fiore, 2011, p. 386).

These individuals were moving with grace but bellowing as if under attack. When they finally saw us down below, their collective effort shifted from squabbling amongst each other to try and be rid of us and so they began throwing sticks, seed pods and anything else they could get their hands on. As for us, it was a great moment of interaction and excitement and this was only one small event out of many unexpected surprises that we experienced when living at the station on the Las Piedras River.

The Madre De Dios region , or Mother of God, in which lies Las Piedras, is the headwaters of the Amazon and one of the most ecologically diverse places on this planet; it is internationally known as “the biodiversity capital of the world” (Hume, Lee, Moore, & Hammer, 2006, p. 4). It is the Andes/Amazon region or the convergence of two separate mega-diverse biomes, the Andean cloud forest and lowland rainforest, which creates the perfect ecosystem for the most amount of biodiversity to thrive. The name of the region itself bestows upon us the magnitude of its wildness. Some say that the region earned its name for being wild and unexplored; while others say that it was due to deep respect and awe for the jungle since the conquering Spanish themselves were overcome by the abundance of rainforest, wilderness and biodiversity. Even today, this region has remained to be one of the most bio-diverse places and it receives run-offs from glaciers of the Andes mountains, rich in minerals, through several streams that eventually converge to create the Madre De Dios river (Rosolie, 2014, p. 11).

Figure 1. Map of Peru and the Madre de Dios region (around red spot). Reprinted from “Icons of the Amazon: Jaguars, Pumas, Parrots and Peccaries in Peru” by A. Lee, M. Mazzolli, E. Hume, C. Kirby, & M. Hammer, 2010. Copyright 2006 by Biosphere Expeditions.

Unlike the short, thick, gnarled trees draped with wet, green, moss covered wines in cloud forests; the trees in floodplain are constituted of large hardwoods, bamboos and tall palms sometimes with ten-inch spikes. Some trees contain poisonous compounds flowing through their cambiums, others possess compounds that cause hallucination and still others have armies of ferocious red ants that live within the hollow stems and charge out at whatever tries to harm the tree.

The discoveries of medical plants and edible plants in the Amazon are many. Tomatoes, peppers and coca plants were all first discovered in this rainforest (Pearce, 2005, pp. 39-41). It is also where the cure for malaria was first discovered by using a plant called Cinchona or fever bark tree (Pearce, 2005, p. 66). Rubber was tapped in large scale and aspirin was extracted from a plant called *Caña Caña*, which is used to treat a variety of illnesses such as bronchitis, laryngitis and other inflammations (Pearce, 2005, p. 75). These are only a handful of all the amazing plants used from the rainforest by people.

Similar to flora, there is a high diversity in fauna with 414 mammals (including 12 species of primates), 1,666 birds, 479 reptiles, 834 amphibians and too many species of insects to even be able to count (Rosolie, 2014, p. 12). Amongst all this diversity are the numerous apex predators, each with their own specialized niche. For instance, harpy eagles, kings of the raptor world, govern the canopies, while jaguars and pumas roam the ground. Canopy dwelling bicolored-spined porcupine and collared anteater live solely in the trees sharing it with the primates. Sloths cling upside down from branches of trees and have growing on their fur, a type of moss that only grows on sloths, which help it camouflage extremely well with all the different shades of green. Giant anteaters remain below the trees and are known to defend themselves by standing on their two hind legs and using their large, sharp claws to attack its predator. Anacondas and the four

species of caiman, including the largest, which is the black caiman, compete in rivers and lakes. Within this larger politics are the numerous smaller predators and animals that develop their own niche.

In terms of birds, the Madre de Dios is renowned for its healthy population of macaws, which are considered a threatened species and these fly over the canopies and along river banks exhibiting bright reds, greens, and yellows against the deep, dark green of the rainforest. The world's second smallest humming bird buzzes by the flowering plants. Insects and amphibians are so abundant that we find new species every week but we also see the legendary bird eating spiders, tarantulas of various sizes, giant two inch dung beetles that are bright blue and that have mites living on their shells and many more interesting little creatures of the forest.

We get a peek into this diverse life while staying at the Las Piedras station. Early morning walks consist of macaws crowing, monkeys swinging about in a hyper state as though they have been awake all night, squirrels scurrying in every direction and now and then a surprise sighting of an armadillo, peccary, tamandua (anteater) or a tapir. On the other hand, night walks display completely different wildlife such as night monkeys that are nocturnal, many types of frogs, snakes, and caimans along the river banks and sometimes the large eye shines of one of the big cats that always create a rush of excitement amongst everyone. On one of the night walks, as Paul and JJ, who is our Peruvian partner, were guiding seven people along a trail we all heard loud rustling and smashing sounds and when we looked to our right we saw a huge mother tapir stomping around in distress as her baby had crossed over to the left side of the trail. Tapirs are large mammals that look like grey, muscular cows with a stubby tail, four hooved toes on the front legs and three on the hind legs and a short prehensile snout, which can move around like an elephant's trunk. Through the beams from our headlights, we could barely make out the white

stripes and spots that young baby tapirs have. We moved a little further along the trail, allowing the mother to reunite with her baby and watched them for a few minutes as they recovered from their confusion.

On yet another night walk, we were interrupted by the roaring of a male and female jaguar in heat in close proximity to the trail, which sent chills down my back and an adrenaline rush to my head. One rarely has the opportunity to see a big cat in the jungle, let alone hear two cats in heat. As the roars echoed through the canopy, it was magical but at the same time haunting to the point where we all decided to turn around and head straight back to the station. As we walked rapidly back, we all had to be aware of strange hollow mud tubes, twenty to thirty centimeters, growing out of the ground. These tubes are hollow mud tubes built by cicada nymphs that live underground for two or more years feeding on sap of tree roots and when they are ready to emerge, it occurs through a hole from the tip of the mud tube, only to survive a short lived period to mate and reproduce. While walking often people do not realize that these have cicadas in them and crushing the tube means that it would have to rebuild the entire tube before emerging.

History of Madre de Dios Region and Las Piedras

The Las Piedras is located between the Tambopata River and the Madre de Dios River and is surrounded by three national park systems at its headwaters. Creation of the first two national parks, Manu national park and Bahuaja-sonene are one of the most important events in the history of national parks and conservation in the Amazon. The exploration of Buhaja-sonene on the upper Tambopata River was first undertaken by the English explorer Colonel Percy Fawcett in 1910. His experience of the river was overridden by fear of the unknown, un-contacted tribes and their long arrows flying at Fawcett and his team, it had been a challenging feat, which had been accomplished (MacQuarrie, 2001, pp. 28-29).

The story of creating the park began with Max Gunther, who in the 1980's, purchased 260-acres of land far up the Tambopata to be used for hunting safaris but soon converted it into an eco-tourist lodge called Explorer's Inn. The lodge was just a small area compared to the dense untouched jungle that blanketed miles and miles behind it but attracted plenty of tourists even though few animals were left as it had been a hunting ground. The fact the lodge was so successful even with so few animals fascinated a young Ph.D. candidate from Princeton, named Charles Munn, when he visited the first time (MacQuarrie, 2001, pp. 40-41).

Munn was already well known in the field of conservation having discovered new, important information on macaw reproduction, while working in Manu national park. His new goal became to protect an entire watershed, the Tambopata River and its offshoot, the Candamo river region. He explored the rivers, cataloging the biological richness of the region and how it could benefit the local economy through eco-tourism and other forms of business such as research. After years of data collection and talking to Peruvian government officials, in 1994, the region officially became the Bahuaja-sonene national park (MacQuarrie, 2001, pp. 42-43).

Manu national park, on the other hand, was established before Bahuaja-sonene in 1977 and in 1987 was recognized as a world heritage site (About Manu, n.d., para.12). The last one, Alto Purus national park was the most recent addition in Madre de Dios; created in 2004 and enclosing the largest area of rainforest protected in Peru (Alto Purús, n.d., para 1). Headwaters of Las Piedras and Purus, which is a major tributary of the Amazon River, wind through this national park, which is wilder and more remote than the other two parks.

With the highest number of reptile and amphibian species recorded, Manu is one the most biologically diverse places in trees, birds and other animals. It shelters at least four un-contacted communities, the Machiguenga, the Mascho-Piro, the Yaminahua and the Amahuaca. These

tribes, who are nomadic, depend on subsistence farming of some sort of root crop, hunting, fishing and gathering (Manu national, 1987, para. 5). Since part of the park is in the foothills of the Andes, which is a unique ecosystem on its own, it contains endemic species such as the Andean cat, spectacled bear and a species of cedar, called the cigar-box wood, which are not found lower down the Las Piedras or Madre de Dios rivers (Manu national, 1987, para. 8).

Bahuaja-sonene, also rich in biodiversity, has been recognized as the largest uninhabited area in Peru. Apart from the landmark species such as giant armadillo, giant anteater, harpy eagle, crested eagle, and others that live there, it has been identified as the 'center of plant diversity' by WWF (World Wildlife Fund) and the IUCN (International Union for Conservation of Nature) with over 150 species of trees found within just one 100 meter square area in the forest (Hume, Muller, Schmidt, & Hammer, 2003, p. 4). Meanwhile, Alto Purus is on an entirely different spectrum of wildness and the unknown compared to the other two, with very little research or exploration taking place.

Threats to Las Piedras

Nestled in the middle of these three biodiversity hotspots is the Las Piedras region, which as of now is unprotected. Due to its location, the protection of this region is crucial, as it acts as a buffer zone and a connector between the national parks for wildlife and the tribes that move around in these areas. Even though Las Piedras is still remote, it is subject to increasing illegal activities such as selective logging and hunting. Selective logging for mahogany began during the 1920s and it swept across Peru, wherever loggers had access to rivers (Rosolie, 2014, p. 184). Hunting occurs along with logging since people rely on bushmeat while working in the forest. Brazil nut collection has been another source of income for the local people along the Las Piedras. This is the only occupation that safeguards the rainforest since in order to harvest brazil

nuts, a mostly intact standing forest is essential due to the complex symbiotic relationship that is taking place between the brazil nut tree and two other species.

Brazil nuts, first discovered by Bonpland and Humboldt, two naturalists in the 1790s, are one of the largest exports of Peru (Pearce, 2005, p. 46). The Brazil-nut tree grows very erect and tall similar to a Tulip tree and one can usually spot the wide spread branches of the tree, protruding from the rest of the canopy line. Its life cycle begins with a hard shelled pod, which contains five to seven seed pods inside arranged like the liths of a lemon. This pod is so strong and hardy that it takes five or six times of whacking with a machete to open only to find the smaller seeds enclosed in another extremely hard casing (Pearce, 2005, p. 117-119). A common warning passed on by Peruvians to tourists or foreigners in the forest is to watch out for the Brazil nuts hurdling towards the ground and supposedly, animals are victims of this occurring quite often as well.

The only animal in the forest that is capable of cracking open the canon-ball like pod is the agouti, a type of rodent. The agoutis with their sharp teeth carve and chisel into the pod and like a squirrel they bury and hide the seeds in different places. Just as squirrels forget, they forget most of the locations of the seeds, which then have the opportunity to regenerate into a new young Brazil-nut sapling. Although, the agouti can survive without Brazil nuts, the opposite is impossible. On the other hand, for the creation of the Brazil-nut pod there is only one pollinator. The female orchid bee is the only one that pollinates the Brazil nut flower, while the male bees fly about with waxy scented secretions that they wipe off of an orchid to attract the females (Pearce, 2005, p. 119-121). Thus, without the orchids there would be no orchid bee, which means no pollination and so no Brazil nuts. The empty Brazil nut pod bears another function, the

egg laying site for a species of poison dart frog which takes advantage of the water collected in the pods to lay eggs.

In order to export Brazil nuts as a product, it requires Brazil nut collectors to go on week long camping trips into the rainforest to collect every Brazil nut they can find in the area designated as the Brazil nut concession. The collectors bring along their entire families and so rely on hunting bushmeat while they are in the forest. Therefore, Brazil nut harvesting leads to subsistence hunting in Las Piedras, which inevitably scares away populations of the most hunted species such as peccaries, howler monkeys, spider monkeys, spix's guan and other species of birds and mammals.

Today the threats to the Las Piedras are extensive. Timber extraction has always been intertwined with the history of the region; however, timber extraction has reached an all new level lately with completion of the Trans-Amazon highway, known to be one of the most environmentally destructive projects.

Traveling to Las Piedras the first time had been an adventure in itself. It was a one hour precarious bike ride along a slushy, muddy jungle road and past a small shanty town called Alegria. The forest was dense, deep green, closing in on the road. It seemed to be a small tunnel that would end in the grand opening or meeting of the Las Piedras River. I remember the ride; the bike skidding often in the mud, the giant towering trees with branches hanging above us on either side of the road. Red-and-Green Macaws would fly above us cawing loudly, smaller birds such as tanagers, ant birds and more all fluttering about looking like swirls as I got glimpses of them from the corner of my eye as we sped past on the bike. I spotted at least a few species of frogs, plenty of different, brightly colored butterflies and even a snake on this first bike ride. At the end of the road was a small port, which was literally two thatched huts and a small clearing at

the edge of the water. From here, we would travel by boat for another hour up to the research station. This was my experience back in 2009, when the road was no more than a mud path that had originally been part of the larger Trans-amazon highway project that was at a standstill.

Figure 2. A section of the Trans-Amazon highway before it was paved. Reprinted from art.com, by J. Dominis, retrieved April 26, 2014, from http://is.gd/nG5uum. Copyright by J. Dominis.

The Trans-Amazon project, driven largely by Brazil and funded by the World Bank, was part of Brazil's National Integration Program by creating a network of highways connecting places to rest the of the country that would allow development and settlements of the more remote forest areas. It also aimed to connect Brazil, Peru and Ecuador as a trade route. As soon as a road exists there is a "fish bone effect," which is when hundreds of smaller roads and offshoots appear along the main road, this is exactly what is taking place in this region now (Rosolie, 2014, pp.

185-186). With the paving of the highway, smaller roads, tiny logging roads, more houses and settlement have increased on the route to the port at Las Piedras.

Thus, when I returned two years later, the route and the area seemed as though it had been disguised in a new look of an agricultural society. All I saw for miles on either side of the road was fields, cows grazing, and silhouettes of thin, dead, naked branched trees holding onto the bare, dry soil underneath and huge charred buttress root stumps or trunks lying on the ground after being burned down. One cannot help but feel hopeless at seeing such as landscape. Miles behind this dismal scene was the curtain of the still standing, dense rainforest that once existed all along the highway. Alegria is no longer a small shanty town; it is a cleaner, more organized town with at least a hundred households. The only section of the road that remains muddy and the same is the last stretch from Alegria to the port, which has also grown in size to support close to ten households plus two shops with refrigerated soft drinks and other packaged goods. Along the road, I witnessed increased number of trucks driving by carrying large tree trunks, some the girth of a trucks wheel or even larger. One of the immediate outcomes of the road of course is increased timber extraction, which is a big concern for the Las Piedras watershed, along with more settlements and hunting.

Figure 3. Logs being transported out of the Las Piedras port. Copyright Paul Rosolie.

Figure 4. Burned down trees and field along Trans-Amazon highway. Copyright by Paul Rosolie.

Even while this is happening, Las Piedras seems wild and high in biodiversity as of now and it seems to retain a wildness that is reminiscent to the times of the great explorers. It is one of the few rivers, apart from one other in all of Peru, that has an active macaw clay lick along the banks of the river, close to the research station, where 50 - 100 macaws converge every morning from nine to eleven to socialize and chatter amongst each other while feeding on the clay. Most of the forest has not been explored yet and a beautiful black and white banded lizard, called a Galliwasp, which was recently discovered, is evolving right now and is in the process of losing its legs. The lizard, therefore, glides like a snake rather than walking on its tiny legs, which are dysfunctional.

Las Piedras has the potential to be the final piece to the puzzle of the national park system in Peru. Now, it is a crucial time period to study and learn everything one can, to try and protect the area as this can be a resource globally, for the country and the local people for decades to come.

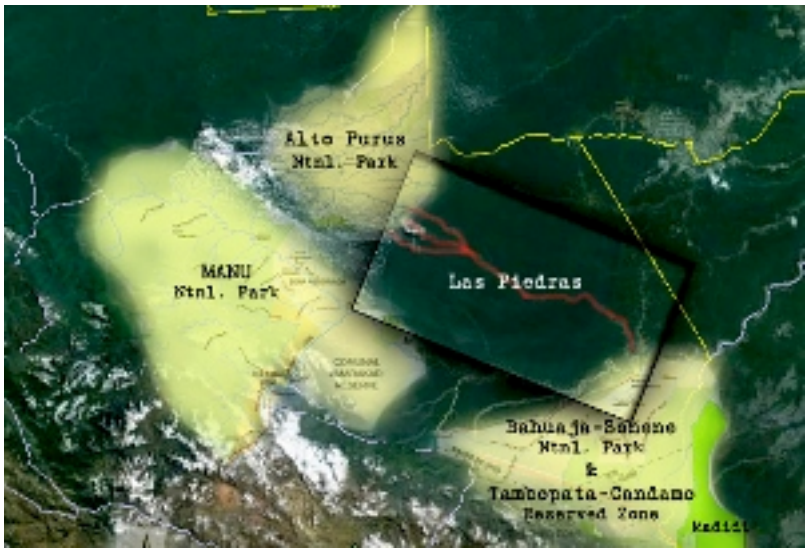

Figure 5. The three major national parks and the Las Piedras region in the center. Copyright by Paul Rosolie.

Chapter 2

Clay Licks

We had already been walking for an hour when we heard the grunting, tooth clacking calls of peccaries nearby. Peccaries are wild boar with thick coats made up of bristly hairs that are grizzled black, brown and gray colors and their heads are much larger than their bodies. Paul, our local partner JJ and his brother Federico, and I were scouting a location on the Tambopata River for a new research station. Federico's eyes wide with excitement beckoned us to follow him. Paul whispered to me that the peccaries are most likely at the colpa, the Spanish word for clay lick. This was my first experience at a clay lick so I did not know what exactly he meant. As we began tracking the calls, our steps became lighter as our pace picked up and our gaze was fixed straight ahead of us. The trail was narrow and it had recently been cleared. Freshly cut vegetation lay under our feet and slender stumps with clean machete slices lined the trail. We hurried along the trail in single file for about twenty minutes but as we got closer, the calls abruptly came to an end. Had they heard or sensed us? Were they still there but being quiet?

When we arrived at the clay lick, there were no animals. The lick was right next to the stream. It looked like a piece of earth had eroded from the bank of the stream and left a large steep clearing of exposed clay that continued as the stream bed into the water, as animals had trampled it down. The color of the clay and the color of the water were the same, an orange brown. Paul had begun to walk and explore the stream. As I was watching him, I saw his face change into a puzzled expression. In the next instant he was waving his arms, beaming with excitement and calling us all. There, in the water, lay a fourteen foot anaconda wrapped around a peccary, completely submerged except for its head and the peccary's back. Its gaze fixed in our direction. Its coils were tight around the peccary's bent and mutilated body.

Figure 6. Anaconda constricting a peccary at the edge of a clay lick. Copyright by Gowri Varanashi.

Since mammals visit the licks often, predators such as jaguars, ocelots and pumas prowl around the clay licks to acquire easy prey. In this case it was an anaconda, an ambush hunter, which probably lay waiting, hidden under the water and seized a peccary driving the rest of the herd to scatter away. We had disturbed the snake before we even saw it, so it slowly unwound itself and swam away. Snakes often abandon their prey if disturbed while eating, since they feel most vulnerable while they are in the process of constricting and swallowing, which takes over an hour at times. If they have just eaten they hibernate in one spot, sometimes for days, to digest the food. Due to the inability to defend themselves during these times, snakes choose to leave their kill rather than feel helpless when disturbed. This was my first thrilling experience at a clay lick and more were to follow.

Peccaries are not the only creatures attracted by licks; several other animals such as deer, monkeys, tapirs, rodents and many more make their appearance in these locations in order to

obtain salt and minerals by eating clay. Thus, licks are constantly busy with different species of animals stopping by but timing it so that most of them never intersect each other.

This behavior known as geophagy, is a worldwide phenomenon and has been noted in South America, North America, Africa and Asia (Klaus & Schmidg, 2009, p. 2). It is the act by which animals eat clay to obtain various minerals that are lacking in their regular diet. The licks vary in elemental composition, for example, in eastern North America the main elements are Magnesium and Sodium, while in western North America they are Calcium and Magnesium (Montenegro, 2004, p. 49). Licks vary in the animals that visit in the different parts of the world as well; White-tailed deer in North America, African elephants and other ungulates in Savannas and Asian elephants in Thailand and Indonesia (Montenegro, 2004, p. 7). The northern most licks visited by muskoxen were found in the northeast of Greenland and a lick on the equator was found in East Africa, visited by Mountain Gorillas (Klaus & Schimdg, 2009, p. 2).

Often the term clay lick is interchangeable with salt licks because they are popular for their high sodium content. However, sodium is not the only mineral the animals are consuming in the clay. Larger amounts of magnesium, calcium, copper, phosphorous, sulfur and boron have been found in soil samples from clay licks compared to control samples (Montenegro, 2004, p. 48). Specifically, sodium, potassium, magnesium and calcium were consistently higher in lick soil samples compared to non-lick samples in Peru (Montenegro, 1998, p. 52). These are key nutrients that supplement an animal's diet, particularly in the Amazon jungle where the vegetation is low in mineral content.

Geophagy is common in places with poor quality soils. In the paper, "Geophagy at Natural Licks Mammal Ecology," it says that in the Kalahari Desert animals browsing on infertile soil partake in more geophagy than animals that browse on fertile soil (Klaus & Schmidg, 2009, p.

8). Due to the abundant rainfall and leaching, rainforest soils are poor in minerals and that in turn effects the concentration of nutrients in the leafage, which remains at a low throughout the year (Emmons & Stark, 1979, p. 311). Hence, animals are highly dependent on clay to obtain these elements lacking in their diet and it has been observed that frugivores and folivores are the main visitors of licks in the Amazon (Link et al., 2011, p. 2).

Since these plants grow in poor soils, they defend themselves by containing high secondary compounds and so animals eat clay to help decrease the negative effects of secondary compounds, which often can be poisonousness in large quantities (Krishnamani & Mahaney, 2000, p. 8). Clay also seems to help fight intestinal infections, parasites and acts as an anti-diarrheal agent too or as medicine to gastric disorders (Krishnamani & Mahaney, 2000, p. 9). One of the main benefits of course, is mineral supplementation for all the species that don't obtain enough nutrients from their regular diets, so as to deter mineral deficiencies (Kreulen, 1985, p. 8). It also helps breakdown tannins, which are high in woody plants (Kreulen, 1985, p. 9). All these functions might be taking place at the same time and clay ingestion could have all these various benefits. Animal's intake of minerals probably varies across species depending on the mineral content in their food and the specific nutrient they would need (Montenegro, 2004, p. 53).

Clay licks are the one location in the rainforest where one can view multiple animals that visit it in large densities or frequencies. At the Las Piedras clay lick, deer visit cautiously and tend to stay for longer periods of time consuming quite a bit of clay. Two species of peccaries, the collared and the white-lipped, stomp around compressing the earth underneath them, as they eat clay. Tapirs visit often, sometimes with babies. Two species of monkeys, the Spider monkey and the Red Howler monkey come down from the canopy to obtain the minerals that they don't

receive from fruits, seeds and canopy vegetation. These primates live entirely in their giant green perches and visit the ground only on the occasion of eating clay. The rodent species that visit licks consists of agoutis, pacas, porcupines, and squirrels. Out of the many bird species, there are two large birds that take advantage of clay licks, the spix's guan and razor billed curassow. All these numerous animals are dependent on the licks to gain the minerals that are at a premium in the jungle. When all these animals move through this one spot in the jungle, it naturally attracts the predators, such as jaguars, ocelots and pumas that pass by hoping to gain an easy catch.

Figure 7. Agouti feeding on clay at the Las Piedras Lick. Copyright by Gowri Varanashi.

In the paper, "Geophagy at Natural Licks and Mammal Ecology," the authors describe the unusual densities of species visiting various licks such as 300 elk at a lick in Montana, 706 elk in Idaho, and 108 forest elephant in Central African Republic (Klaus & schimdg, 2009, p. 2). Although, we do not see animals in such large numbers since they are not in herds, certain species were recorded in comparatively larger numbers a few times at the clay lick at Las Piedras by our camera traps. For instance, there were 9 spix's guans at one point and 8 or more red howler monkeys another time all trying to squeeze into the one spot where the clay was richest. Every species visit frequently per week and they all seem to depend on eating quite a bit of clay during their visits.

The field of conservation biology has referred to clay licks as keystone resources. Similar to how keystone species, typically predators, are crucial to ensure a healthy balance of smaller prey populations and dynamics, clay licks are a crucial resource that supports various species and communities. Ingesting soil seems to be related to the nutrition and health of populations and reducing the costs of obtaining adequate minerals. It clearly is beneficial for survival of populations as it influences groups of animals to move around in the forest based on the locations of licks. Apart from effecting population structure, licks seem to influence the carrying capacity in the areas with licks (Montenegro, 2004, p. 8). Many studies have suggested a strong correlation between clay licks and the range of spider monkeys (Link et al, 2011, p. 387) and this is most likely true for a few other species as well. The clay has another role in this interaction; the animals release excess minerals into the soil through their mineral rich urine making the soil healthier and a lure for clusters of butterflies and moths (MacQuarrie, 2001, p. 228). These locations also might act as a magnet; species concentrating frequently in one spot could attract other individuals of the same species, so clay licks could function as place of congregation and play a role in the social life of animals (Klaus & Schimdg, 2009, p. 11).

I have seen plenty of times, razor-billed curassows feeding each other in the camera trap videos. Red howler monkey groups come to eat but also seem to relax in a way and sit around, since often they take turns eating clay while two or three others just hang about. On one occasion, there were nine spix's guans all strutting about, few eating here and there but mainly walking around. They seem to have some form of interaction and communication amongst themselves during these times.

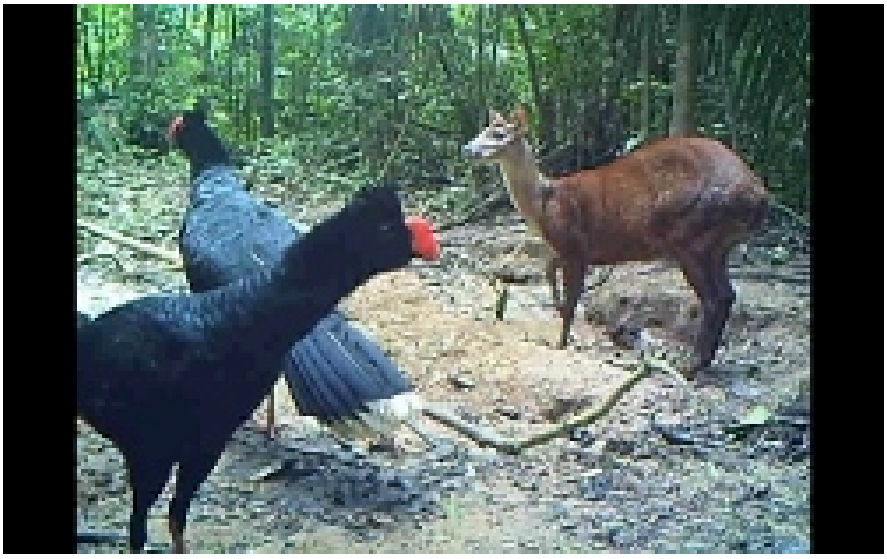

Figure 8. Camera trap clip of two razor-billed curassows and a red brocket deer. Copyright by Gowri Varanashi.

Figure 9. Camera trap clip of red howler monkey and spider monkey feeding at Las Piedras. Copyright by Gowri Varanashi.

The temporal patterns of visitation differ among species and so the clay lick is never inactive. While primates, agoutis and the birds are all diurnal, tapirs, paca and porcupines are

only nocturnal. Deer seem to be crepuscular and squirrels are around at varying times during the day.

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Observing the clay lick at the Las Piedras research station, from a platform is always an exciting event. Sitting awfully still, while hundreds of mosquitoes buzz right outside the mosquito net desperate to get in, I have seen howler monkeys, spix's guans, razor billed curassows and agouti appear at different times to feed on clay. On one instance, Paul, a friend and I rescued a baby squirrel monkey from a native community, further down the Las Piedras. Its mother had obviously been killed. With a rope around its waist, it was tied to a bunch of bananas and I could hear its unhappy cries. We decided to take care of it and release it back into the jungle when it was time; we named him Cracker. However, just two days later we realized he was sick and on the second night he died.

Instead of burying him, we decided to go with what would be the natural course in the forest if an animal dies, where it gets eaten by other animals. So we walked to the clay lick, placed him in the center and set ourselves up in the platform, to sit and watch. For hours all we saw were spix's guans and red squirrels coming and going while we heard the droning sounds of insects around us. After about four to five hours, what we had been eagerly waiting for took place. A young, slender and very good looking ocelot cautiously walked out of the wall of jungle, to sniff the dead monkey. Its coat was reddish brown with black blotches but it looked more like shining gold in the evening sunlight beaming directly to the center where it was standing. It must have known our presence as it swiftly picked up the monkey by the neck in one graceful move and disappeared right behind some shrubs at the edge of the lick. We were a little disappointed at how quickly everything had transpired; it had been a matter of seconds. As we sat there trying to

absorb the experience, the ocelot walked out again with the monkey and slowly crossed the clay lick to the other side into the jungle, as if to grant us a final look.

Figure 10. The ocelot with the squirrel monkey (Cracker) in his mouth. Copyright by Mohsin Kazmi.

One gets a sense of how important and favorable clay licks are to view wildlife. It is the perfect tool for eco-tourism, an important business for the economy of Peru. Clay licks along with beautiful pictures of animals spotted at licks are used to advertise and attract people to visit. It also enables companies to guarantee certain wildlife spotting since you will almost certainly see something at licks. For instance, Rainforest Expeditions, one of several tour companies has a page on mammal clay licks under its "tour activities" section that states that a peccary clay lick guarantees 15% chance of sighting peccary or other animals like deer, guans and parakeets (Mammal clay licks, n.d., para. 1). Manu Adventures presents many pictures of a mammal lick with peccaries and tracks of tapirs and jaguars on their page under wildlife (Manu national park,

n.d.). On the “about us” of Amazon Manu Lodge it states, “Perhaps the greatest feature of the Amazon Manu Lodge, however, is its proximity to the Tapir Clay Lick. 20 minutes’ walk from the Lodge” (Welcome to Amazon, n.d., para. 3).

Ecotourism was reported at 10% at mammal licks, 42% of at parrot clay licks, and 15% at deer and monkey licks, out of a total of 130 clay licks (Brightsmith, 2009, p. 13). Although , 10% and15% are not that large, it still conveys the use by ecotourism and it is possible that the study missed a few spots or companies that do use licks but are not well known. When we guide groups, we too rely on the clay lick near the research station for sightings of animals. We organize people into groups of two per group and have them do observation sessions at the lick, which teaches them not only about the site and how animals use it but also how to be aware of the activity around them, what species are seen and so on. Volunteers love their time at the lick as they often return excited with stories of birds, or monkeys, or agoutis and even tapirs that they witnessed eating clay.

Clay licks are an important resource for the local people and communities too as they are used as hunting grounds. People sit at licks for hours, like ambush hunters, and kill for bush meat, which they sell at markets. In some cases, hunters are known to walk trails that pass through clay licks in order to avoid sitting in one spot for hours (Brightsmith, 2009, p. 19). A study in the Yavari-Miri River in Northeastern Peru found that over 30% of meat harvested in 2001 was at licks (Montenegro, 2004, p. xvii). However, hunting is not as prolific on the Las Piedras River as of now.

Although, many studies have looked at why clay licks might be important or how it benefits animals, they are all possible interpretations of animal behavior that is observed during the studies so no one is yet certain about why exactly animals depend on the clay or which particular

minerals they need and how it might affect the forest itself and animal populations; only possible theories or interpretations of animal behavior exists. However, it is clear that clay licks are special locations in the forest that play a vital role in the ecosystem and they are gaining attention from many scientists and organizations. Attempting to understand the relationship between animal populations, clay licks and the rest of the forest can teach us about their spatial movements based on licks, or how animals survive in the forest on a larger scale. Conservation efforts can then incorporate knowledge that we gain from studying these sites to better protect the wildlife and biodiversity.

Chapter 3

Mammal Abundances and Clay Lick Use

Clay licks are sites in the rainforest where exposed clay contains high concentrations of salt, magnesium, potassium, calcium and a few other elements (Montenegro, 1998, p. 52). They are known for their ability to attract many species that visit these sites in order to obtain these minerals lacking in their diets. Geophagy, is a worldwide phenomenon and it has been observed amongst various animals such as deer, birds, primates, rodents and other mammals (Blake et al., 2011, p. 11). Licks play a vital role in the ecology of a place by influencing health, population and range of animals in the surrounding areas (Montenegro, 2004, p. 8).

Several studies attempt to understand all aspects of why animals partake in such behavior and the potential benefits. "Geophagy at natural licks and mammal ecology" (Klaus & Schmidg, 2009, p. 482) and "Geophagy among primates: adaptive significance and ecological consequences (krishnamani & Mahaney, 2000, p. 899)," are but two of these studies. Many of the papers specialize in behavioral patterns of specific species such as tapir (Montenegro, 1998, p. vii; Tobler, 2008, p. iii) and primates (Link et al., 2011, p.386; Campbell et al., 2005, p. 1039; krishnamani & Mahaney, 2000, p.899). The majority of studies base their research on parrot clay licks (Gilardi & Munn, 1998; Burger & Gochfeld, 2003; Brightsmith, 2004). Very few studies have looked into the abundance or change in abundance of multiple species visiting licks over time.

The western Amazon has the highest concentration of clay licks in all of South America and Las Piedras possibly has the most number of mammal clay licks in Peru's department of Madre de Dios (Brightsmith, 2009, p. 16). The research station at Las Piedras, in the Peruvian Amazon, where the clay lick is located had been part of a large logging concession between 1994 and 1999, during which time selective logging was common and wood was extracted using

chainsaws, tractors and circular saws. Brazil nut collection was another activity taking place for three months every year between 1993 and 2000. Hunting goes hand in hand with logging and Brazil nut collection as the workers camp in the forest for a week or so and rely on bushmeat. One of the Brazil nut collectors who worked at the study site reported that he had hunted ten white-lipped peccaries, six collared peccaries and three deer per month. Other species such as tapirs, red howler monkeys and spider monkeys were also hunted at a lower frequency. The entire area has been protected since 2002 (Hume et al., 2006, pp. 11-12).

In 2003, a study conducted by scientists, Hume, Muller, Schmidt, and Hammer, who were part of an organization called Biosphere Expeditions, recorded the visitation rates of the different species visiting the Las Piedras lick.

The purpose of my study is to compare the visitation rates of animals captured by our camera traps in 2013 at the clay lick to the visitation rates recorded by Hume et al. (2003) in their study and see if there is a change in abundance and diversity in number of species from 10 years ago. Assuming that the hunting and logging in the area affected the visitation rate of the species or the abundance, the abundance of animals should have increased since 2003 and so should have diversity in the number of species seen.

Methods

The Las Piedras research station is accessible by a car ride and then a boat ride, approximately four hours from the nearest town, called Puerto Maldonado (GPS co-ordinates are S 12º05.663' W 69º52.852') (Hume et al., 2006, p. 11). The clay lick studied is 4km away from the station. The lick itself is a depression and clearing in the forest floor that is about 6 by 10 meters, where the clay is exposed. The wall at the back of it is crescent shaped, with one

exposed tree root under which there is a tunnel that has been dug out by animals scraping for more rich clay. The floor of the clay lick is very slushy with a pool of stagnant water.

Hume et al. (2003) used two methods in their study, a video camera (camera trap) and plates to record tracks, however, my study will only use their camera trap data. The camera was a Sony DCR-TRV19E handycam with a Trailmaster TM 700v passive infrared video trail monitor, which recorded movements for 24 hours a day. The study explains that the camera and sensor position was changed on a few occasions to try and broaden the area of the lick being recorded. The camera was checked roughly every three days to ensure that it was functioning properly and had not run out of tape (p. 19). Hume et al. (2003) refer to each recording of a species as a "hit," so each time a species seen in a 24 hour period was considered one hit. Visitation rate or the average was then calculated for all the "hits" per week over four weeks and were presented as a histogram. Their study was administered over a period of 4 weeks from June 18th to July 24th of 2003 (pp. 19-21).

Our study was conducted by using Bushnell Trophy Cam camera traps taping videos for 6 weeks from May 7th to June 17th, of 2013. Two camera traps were used and they were spaced out so as to cover the entire area of the clay lick, so there was no need to check them until the end of the study date. These were fastened to trees on the edge of the clay lick about two feet off the ground. Individuals of the same species were recorded as separate sightings only if the interval between the two were 90 minutes or more. For instance, if a deer was seen half an hour later again in the video, it was assumed that it was the same individual and not counted twice. The sightings were then organized as the number of sightings per week over 6 weeks and the average or the mean rate for the total number of sightings of all 6 weeks was calculated for each species. The mean rate is the same as the average number of visits per week by each species.

The two deer species grey brocket deer and red brocket deer were listed together as “deer sps” and the brown and green agouti, differentiated in the 2003 study were also grouped together as “Agouti”.

Results

In total 20 species were caught on the camera traps during the study period and outside the study dates, which were videos recorded in 2012 and 2013, prior to the 6 weeks of the study. However, during the study, between May 7th and June 17th, 12 of the 20 species were captured on video (Table 1). Although, the results are not significant, meaning the increase in mean is not large enough to conclude that there is an increase in abundance, there is a general pattern of increase in the mean for most species except for razor-billed curassow, white-lipped peccary and pale-winged trumpeter, for which the visitation rate has decreased (Figure 11). The average rate or number of visits for white-lipped peccary had been 0.5 visits per 7 days in 2003 and it fell to zero. Razor-billed curassow rate decreased from 1.5 visits to 0.5 and pale-winged trumpeter also fell to zero. Highest increase in abundance was the spix’s guan. A mean was also recorded for 8 species that weren’t seen at all by the camera in 2003 (Figure 11).

Diversity is higher in 2013 compared to the species caught on the camera in 2003 (Figure 11), we noted 12 species on camera traps while Hume et al. (2003) recorded 6. Certain species such as the grey and red brocket deer, tapir, red howler monkey, spider monkey, paca, possum and porcupine were not recorded at all on the camera trap by Hume et al. (2003) (Table 1).

Table 1

Number of species observed in total and only during the study period

Total Species Seen (2012-13)	May 7th – June 17th (2013)
Razor-billed Curassow (*Mitu tuberosum*)	✓
Spix's Guan (*Penelope jaquacu*)	✓
Jaguar (*Panthera onca*)	✓
Ocelot (*Leopardus pardalis*)	
Puma (*Puma concolor*)	
South American Red Squirrel (*Sciurus igniventris*)	✓
Paca (*Cunniculus paca*)	✓
Brown Agouti (Dasyprocta *punctate*)	✓
Green Agouti (*Myoprocta pratti*)	✓
Grey Brocket Deer (*Mazama gouzoubira nemorivaga*)	✓
Red Brocket Deer (*Mazama americana*)	✓
Common Possum (*Didelphis albiventris*)	
Bicolored-spined Porcupine (*Coendou bicolor*)	
Side-necked Turtle (*Platemys platycephala*)	
White Capuchin Monkey (*Cebus albifrons*)	
Pale-winged Trumpeter (*Psophia leucoptera*)	
Tapeti (Rabbit) (*Sylvilagus brasiliensis*)	
Giant Armadillo (*Priodontes maximus*)	
Red Howler Monkey (*Alouatta sara*)	✓
Black-faced Spider Monkey (*Ateles chamek*)	✓
South American Tapir (*Tapirus terrestris*)	✓

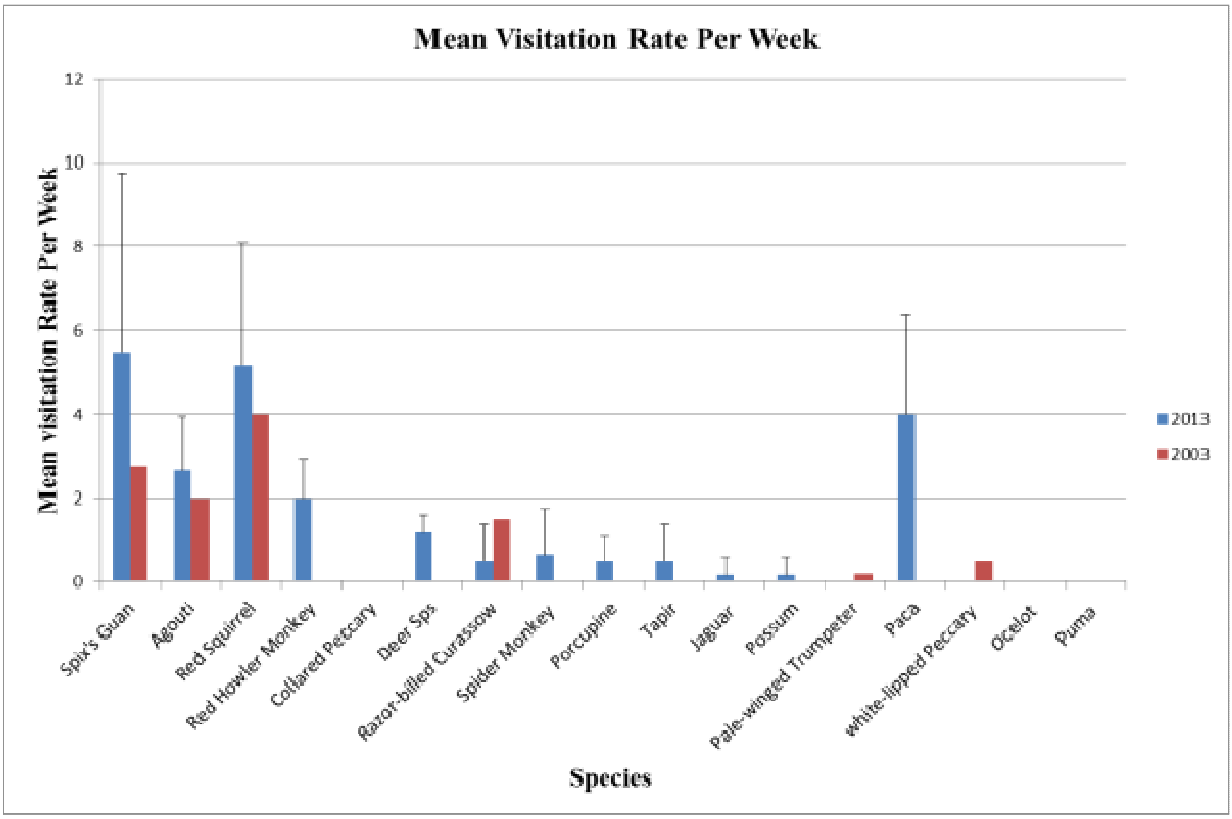

Figure 11. The mean visitation rate per week for each species from 2003 (red) and 2013 (blue). The vertical axis is the mean rate or the average number of visits per week. Horizontal axis is the species. The bars represent a 95% confidence interval around the mean.

Discussion

Even though the results are not significant, they do show interesting patterns in the mean visitation rates. The mean has not increased for every species but an increase could be displaying a trend towards improvement for certain species such as spix's guan, agouti, red howler monkey, spider monkey, deer, and tapir since these are the key species hunted more often than others.

An increase in mean could mainly be a result of differences in the cameras and methods used. The camera, Sony DCR-TRV19E handycam, used by Hume et al. (2003) lacked a wide lens and so did not cover the entire area of the lick. It also had to be checked every three days to ensure it was working properly or if it needed a change of tape (p. 19), which could have caused some

amount of disturbance that stopped animals from visiting for a while. They also mention two other drawbacks, one, the sensor had a delay of a few seconds so they could have missed some species and second, the infrared light at night was not powerful enough to identify the animals so they could not identify which mammals set off the sensor (Hume et al., 2003, p. 22). None of these problems were faced in our study as the Bushnell Trophy Cams are digital and do not need a battery change for months. The likelihood of missing species was rare since we had two cameras covering the entire area and we were able to identify all nocturnal visitors due to a clear image.

The key species that should have increased in abundance are the two important birds spix's guan and razor-billed curassow, the four ungulates (including peccaries and tapir), the two primates, and the three rodents (including paca) as these are the ones that are most common and get effected by human disturbance most easily. These large bodied animals make easy targets for hunters and so they are good indicators of the impacts of human disturbance in an area.

Of the three bird species, the pale-winged trumpeter does not seem very significant as they do not directly reflect the effects of hunting or logging since they seem to be rare visitors in any case and as Hume et al. (2003) said, they "were likely to have just been passing through" (p. 20) and this seemed to be the case in our camera trap videos too. The razor-billed curassow was caught on camera more often outside of the study dates with a rate of 4 visits per week but visited less during the 6 weeks of study period for unknown reasons and presented a mean of 0.5 visits so in fact, it should have been higher.

Mean for deer species increased but was zero for the white-lipped peccary. The white-lipped peccary populations seem to have disappeared from around the area and it was already low to begin with back in the 2003 study (Figure 11). There could be a few possible reasons. One, they

get hunted more easily as they travel in larger herds making them an easy target, so when hunting occurred prior to 2002, they could have been the most effected. Second, they are known to have a much larger range as they travel and move around large distances in the forest, hence their absence could be due to their natural migration patterns.

An interesting observation on white-lipped peccary, made by the pervious groups surveying the station, was that they returned in large numbers to the study site between 2006 and 2009. Two different white-lipped peccary family groups were documented on transects, one consisting of over 70 individuals and the other over 50 and these were consistently seen until 2009. In late 2009, the guard hired to live at the station hunted them for three months and following the hunting period when transects were resumed it was observed that the herds had left the area and today in 2014, we see that the herds have not yet recovered. On the other hand, the collared peccary, which on the histogram also has a rate of zero visits per week (Figure 11), in fact, has a rate of 1.5 outside of the study dates. Similar to the razor-billed curassow, collared peccary visited less during the study period.

The predators are known to be infrequent visitors, as they pass by surveying the lick for mammals to prey on (Montenegro, 2004, p. 23). Thus, the species that are good indicators of health of the animals such as the two birds, the four ungulates, two primates and three rodents, in fact, seem to have a slightly increased mean, including new observations of red howler monkey, spider monkey, possum, porcupine and tapir that were not recorded before. The white-lipped peccary is the only species that seems to have made very little progress with no sign of improvement towards recovery.

Other possibilities for the slight increase in mean could of course be influenced by seasonal changes in visitation rates, migration of species such as the white-lipped peccaries, weather

patterns and other factors that may drive visitation rates to increase or decrease every week. For instance, Link et al. (2011) found that spider monkeys preferred to visit licks on bright, sunny days (p. 393).

Looking at diversity, the number of species recorded in our study is larger than in 2003. There were 6 caught on camera traps in 2003 and it doubled to 12 in our study. Even though Hume et al. (2003) did record 5 more species such as tapir, deer, paca, ocelot and jaguar on their track plate data, these were never seen on their camera trap. Thus, capturing these species on camera, feeding, is a good addition to the list of species seen at licks. On top of this we documented four completely new species not seen feeding at all in 2003, which are possum, porcupine, red howler monkey and spider monkey feeding on the clay.

On a larger context this study shows the possible recovery rates of species after hunting has occurred in an area. Peres (2000) has observed, that even small scale hunting can result in significant population declines among larger mammals (p. 241) such as, tapir, primates, peccary, agouti and so on and larger birds such as the spix's guan and razor-billed curassow. Thus, even though Las Piedras experienced short spurts of hunting, it could still have impacted the large mammal species more, which seem to have a lower rate in our results even after 10 years (Figure 11). It seems to be the case that if hunting is completely restricted, most species are capable of recovering at a slow rate as seen in the results, which shows only but a small increase in mean from 10 years ago. This implies that a long period of time, most likely more than 10 years, with no disturbance is crucial for allowing populations to recover. However, in most places there is no end to selective logging or hunting, which goes hand in hand, so its poses the question of what patterns one would see in terms of declining populations if no recovery time was given to these places. Would species go extinct locally and how many years would that take? Or would they

just move away deeper into the forest and how long would it be before they recovered to earlier numbers? The recovery rate could vary for each species, for instance the white-lipped peccary seem to be more cautious and have not returned to the study site even after 2009, whereas the collared peccary are spotted around the site.

Peres (2000) took a census over 10 years at 25 Amazonian forest sites subject to hunting to see its effects on vertebrate species and found that biomass and abundance declined more at sites with a higher hunting rate (p. 240). Another study found a similar pattern with primate communities, which were less abundant in hunted areas (Peres, 1990, p. 47). A census on white-lipped peccary and collared peccary in hunted and non-hunted sites found that white-lipped peccaries were rare compared to collared peccary that persisted even in the hunted sites (Peres, 1996, p. 115), supporting the pattern found in this study. Studies, such as the ones above and others, have examined the effects of hunting on abundance of species and how it plays out in hunted vs. non-hunted sites but there are no papers on recovery rates of mammals.

Observing clay licks to monitor species abundance and diversity could have potential benefits but a few disadvantages too. Since licks are one location in the forest where animals visit, it allows for studying a larger number species more easily compared to doing line transects which was the main method used in the studies mentioned above where one could miss seeing certain species. Nocturnal species would be missed on line transects while they can be seen at licks through camera traps. If disturbance causes a decrease in populations, it should show in the amount of activity at licks, so clay licks could be a new tool to study species abundance and diversity. Licks are simpler to observe when camera traps are used as it can be done with very little disturbance while results from line transects could be influenced by people walking it and creating noise. The disadvantage of studying licks is that certain species of birds and primates

that do get hunted such as piping guans, saki monkey, squirrel monkey, capuchins and a few others are entirely excluded from the dataset as they do not participate in geophagy. The biggest possible weakness of studying licks is the assumption that if disturbance does effect species, it will definitely show in the use of licks. Since it has been noted in previous studies by Link et al. (2011) on spider monkeys and Montenegro (1998) on tapirs, that clay lick locations influence population dynamics and species range around the forest, licks might be a potential resource for these animals that could help speed up the recovery process after an episode of hunting or logging. As it is very clear from studies that it is a priced resource in the forest where essential minerals are lacking in the vegetation, licks might benefit effected populations to obtain plenty of nutrients at low costs and recover more easily. Therefore, studying clay lick use further could tell us more about populations and how they change over time.

Figure 12. Camera trap clip of a mother tapir, a mostly nocturnal visitor, and baby (behind her on the right). Copyright by Gowri Varanashi.

Conducting a similar study over a longer period of time would provide a larger data set, which should be a more reliable index of a mean or visitation rate. Following the same methods at several clay licks might also reveal more generalizable patterns, which is lacking in this study as datasets from other clay licks were unavailable and so the sample size was only one. Further research on how weather or seasons affect certain species could help clarify the visitation frequencies for species relative to such conditions. Most importantly, studying more carefully how populations might be recovering or not recovering over a longer period after being impacted by hunting or logging would really help in learning about how these populations interact with licks, the forest around it and how human disturbances could effect animal behavior. Learning the patterns in animal behavior around licks due to different external factors will enable the formation of a better conservation strategy.

Chapter 4

Conclusions

On Las Piedras and other parts of the Amazon, clay licks provide vital mineral resources and other health benefits for a range of species. It clearly is a resource that determines survival and health of populations. Given this reality, it would seem prudent to concentrate on protecting these sites. Clay licks could also be used as a tool to better understand the animal populations, how they might be changing, and how they interact with the forest or human disturbance. While line transects are one way to study species abundance and diversity, lick observations might another method.

Several studies (Klaus & Schmidg, 2009; Kreulen, 1985; Emmons & Stark, 1979 & Blake et al., 2011) have looked at why animals use licks or visitation rates at licks, or the chemical composition of licks or how it benefits animals. Yet no one has attempted to understand the role of clay licks in populations and forest dynamics. For instance, could licks be a measure of how healthy populations of certain species are? Could it tell us when there is a decline or increase in populations? Could they help speed recovery rates in an area that has experienced hunting in the past, especially for species that depend on lick soils such as deer, tapirs, peccaries, and primates? Two papers, one by Link et al. (2011), mention the possibility of clay licks influencing the home ranges of primates (p. 386) and Montenegro (1998) said the same for tapirs (p. 25). Tobler (2008) cited another study conducted in Bolivia that found two tapirs that had walked 6 km and 9 km outside their home range to visit a lick (p. 101).

The indirect effects licks might have on forests or biodiversity is unknown. Since licks attract various animals in abundance and influence the home range of species, it could contribute to biodiversity within a certain radius surrounding the clay licks as licks seem to have a high diversity count; more than 20 species have been seen just at Las Piedras. By influencing the

abundance and diversity of animals, licks are playing a role in balancing the health of the forest around it too, since most of the mammals and primates are seed dispersers or grazers (Hume et al., 2006, p. 12) and the distributers of minerals into the soil through urine (MacQuarrie, 2001, p. 228). However, more studies need to be done to see exactly what clay licks can tell us about the larger dynamics taking place.

Clay licks are often formed on paleochannels, or old river beds where water no longer runs, or due to erosions of the earth, where there have been small landslides. It is part of their nature to be in constant flux, changing shape and even location as sediment, vegetation, and rivers move over time. A lick can become inactive over a period of time, for months, years or forever while some erosions or sites can suddenly become active after years of being exposed and not being used. Licks, therefore, can change in availability and positions (Brightsmith, 2009, p. 19). Brightsmith (2009), therefore, argues, "Any plan which seeks to conserve clay licks and the animals that use them must consider not only the species which use them and the characteristics, but also the dynamic nature of clay licks" (p. 19). This dynamic characteristic make licks even more valuable, especially in places where they are uncommon since a clay lick could become inactive leaving fewer licks in an area where there are few to begin with. Lick abundance has been correlated with the type of river systems and increasing abundance from north to south and so a decline in number of licks as one moves further south (Brightsmith, 2009, p. 16). Compared to four other rivers surveyed in the Madre de Dios, Las Piedras, the northern most area studied, was found to have highest lick abundance; 2.63 licks per km, which is high as licks are typically not common (Brightsmith, 2009, p.11).

Large vertebrate communities are the most common visitors at licks and so clay lick conservation is key to ensure a healthy population of these animals (Brightsmith, 2009, p. 4).

Hence, Las Piedras watershed's unique feature of high lick abundance, animal populations, and the diversity of mammal use as seen in our study, should make it a priority in the conservation movement in the Madre de Dios region.

However, several challenges exist when attempting to protect or lobby for clay licks, which are heightened by the lack of information on licks. One challenge is the difficulty in protecting just the clay lick sites, which is futile without the protection of the surrounding forest and animal populations. Hence, it is necessary to look at conserving large areas along the Las Piedras in order to effectively protect clay licks and the large vertebrates that use them. Another challenge is that clay licks are one of those features that lack the attention gained by more iconic conservation topics or animals such as jaguars or macaws. Macaw clay licks in fact, attract a lot of attention from biologists, tourists and others in the conservation world as it is easier to monitor and present to tourists because there is a guaranteed sighting of these beautiful, giant birds feeding on licks. Getting people excited about macaws is easier, which increases awareness about macaw clay licks. For example, on a tour guide website they display a whole page on why it is important to conserve a macaw lick on the Tambopata River (Tambopata macaw, n.d.) and another website is based on the Tambopata macaw project that is attempting to protect the Tambopata clay lick through studies and data collection (Brightsmith & Nixon, 2012). Therefore, one of the greatest challenges is to create excitement and awareness amongst a larger audience, including the local communities, to protect these mammal clay licks and identify its value to the forest and people.

In order to protect clay lick sites and ensure frequent use, the forest surrounding it and the animals need protection, so hunting and logging has to reduce. One of the most important messages we can infer from our study is how, contrary to the common belief that species are

impacted most from commercial hunting or logging or large scale deforestation, even a few hunters or loggers have a profound effect on populations and diversity. At the Las Piedras research station, where there had previously been minimal selective logging and hunting, the impact it had on populations is large. As we have seen in the results, populations need long periods of recovery time, which implies how delicate populations are. The chances of completely losing local populations of species is easier than we imagine while attempting to bring these populations back is extremely hard, so the recovery rate of animals and how long it takes them to reproduce should be considered when conserving areas. The ability to enforce laws or halt hunting or logging is harder and more complicated with the completion of the Trans-Amazon highway, a passage through which more people can enter and go about various activities with no supervision. This creates an urgency to protect the Las Piedras watershed before further developments are underway.

Las Piedras is a great site to study further the effects on populations and to begin conservation efforts all along the river because it contains a high lick ratio and faces the gradually increasing threats. Identifying licks, protecting them and the forest around, either by working with people who own the land it is on or turning them into reserves would be one way to initiate conserving the Las Piedras River and the licks it holds. Designating areas for logging, hunting or Brazil nut collection and creating a system where each area is used in rotation could help decrease concentrated hunting and disturbance in one area. This would have to incorporate a limit to the amount people can hunt or log.

Another method of preservation is by eco-tourism where land is protected and no hunting or logging is permitted. By turning larger and more pieces of land into eco-tourism concessions, it will enable a higher degree of control and monitoring of the land. The scale of tourism, whether

small or large does not matter as much as sticking to the right rules, which are less damaging to the environment. This could be followed by a no electricity policy, which would usually need a generator, fuel etc, or being responsible with waste disposal and not buying too much packaged foods, which encourages more development of shops with all kinds of consumer goods. It does, however, help to keep the group numbers small just because it is less disturbing in the forest when conducting the tours, less consumption and so on. Fewer people means less added noise in general and while walking the trails, which does not scare away animals as much as larger groups. Tourism contributes to revenues towards the local people and communities, which leads to a decline in their participation in hunting or logging activities. It achieves the objective of increasing awareness among the local communities as well as the numerous tourists who visit.

The most important method to ensure long term sustainability is to work with and educate the local people on how it would benefit them if their activities were monitored, which in turn would help sustain hunting or logging for longer periods at a sustainable rate. Working with local communities will make it easier to keep track of who is entering the forest, how much hunting or disturbance is actually taking place and so on. Hence, the best way to monitor such activities would be to directly work with the people. The local communities think of the forest as their plain old backyard and do not consider clay licks as a valued resource since they have grown up using it only to hunt at times. They lack knowledge on how it is intricately connected to the rest of the life cycle in the rainforest or how it is essential for animals. Education is key to create awareness among local people to achieve a better treatment of the forest and animals around clay licks by the communities. It is also important to teach them why their backyards are so special and important in a regional, national and global level. The more the local communities recognize

the importance of conserving the forest, the more they will engage in conservation projects and environmentally friendly activities.

The ultimate desired goal would be using multiple methods to protect Las Piedras and eventually have it become a national park. This would complete the final piece to the national park system, mentioned in chapter 1, in the Madre de Dios region of Peru and ensure a large piece of land made up of four national parks that would be protected. Falling under the banner of "national park" does not necessarily mean an absolute end to hunting or logging but it will definitely inhibit large settlements, buildings and large scale development as it is illegal to do so by law. Eco-tourist lodges are the only developments allowed in national parks and this would assist in monitoring what goes on in national parks. Therefore, eco-tourism companies working in national parks are helping with enforcing the laws within that area and so companies working with local people and the park systems would produce the best outcomes.

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APPENDIX

Galliwasp. Copyright by Emma Hume.

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Cracker the squirrel monkey. Copyright by Gowri Varanashi.