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Seasonal Dynamics of Salt Licks and Their Use by Wildlife in Amazonia

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ABSTRACT

In certain Amazonian regions, 25% of hunting occurs at salt licks, sites rich in natural minerals often near creeks prone to periodic flooding. Here, animals engage in geophagy for mineral supplementation and detoxification what enables local hunter to observe their behaviour while waiting their target. Our study evaluates seasonal salt lick availability and wildlife usage, using interviews and obtained information on 31 vertebrate species across 56 natural salt licks in the Central Amazon. While soil and water consumption attract wildlife, species also visit for bathing, predation, and other behaviors. In general, the season with the highest wild species abundance was the receding floodwaters season, because the creeks' water level decreases and so the salt lick is exposed. Conversely, during the flood pulse, interviewees perceived that the majority of salt licks are not visited by most species because they are often covered by water. Most of the interviewees (74,46%) said that salt licks are one of the main places where they hunt, however the hunting at salt licks is only done during the receding floodwaters season. Our findings shed light on the ecological significance of salt licks in Amazonia and their role in supporting diverse wildlife communities.

Keywords: Clay licks; Geophagy; Hunting; Mammals; Mineral supplementation.

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SIGNIFICANCE STATEMENT

Our study highlights the critical role of salt licks in Amazonian ecosystems, where 25% of hunting occurs. By examining seasonal dynamics and wildlife usage across 56 natural salt licks, we reveal the unique behaviors and ecological significance of these sites. Our findings demonstrate how salt licks support diverse wildlife communities, providing essential mineral supplementation and detoxification opportunities. This research sheds light on the intricate relationships between wildlife, habitat dynamics, and human activities in the Amazon.

INTRODUCTION

In Amazonia, some specific places are considered crucial convergence points between the hunted fauna and the hunters, where the hunting effort is usually concentrated. In some regions of Amazonia, 25% of the hunting activities occur in the salt licks (places with a higher concentration of natural minerals), where the hunters hang their nets for waiting game animals to visit salt licks to ingest the mineral-rich soil (Walschburger and Hildebrand 1988). Because of the time spent in these sites, hunters acquired a high level of knowledge about species that pass through there during the year and also about the ecological aspects of these landscapes.

Salt licks are natural geologic formations where animals visit and exhibit geophagical behaviour (Klaus et al. 1998; Lee et al. 2010; Panichev et al. 2013), in this case consuming soil or drinking water (Abrahams and Parsons 1996; Krishnamani and Mahaney 1997). Salt licks are widely used by animals around the world (Atwood and Weeks, 2002; Blake et al. 2011; Matsubayashi et al. 2007), and the main motivation behind geophagy seems to change through species. Most of animals consuming soil in mineral licks, has as propose to obtain key micronutrients missing in their diets (Atwood and Weeks 2002, 2003; Davis and Baillie 1988; Voros et al. 2001). However, since in some salt licks the minerals analysed present concentrations equal or lower than the concentrations found in untouched surrounding soil (Hladik and Gueguen 1974; Arthur and Alldredge 1979), geophagy cannot be uniquely explained by mineral supplementation (Griffiths et al. 2020). For example, clay (e.g., bentonite, zeolite), present in higher concentrations in this type of environment, help to adsorb toxins from secondary plant compounds (e.g.: alkaloids) and alleviate digestive disorders in the animals' body through the increase of the buffering capacity (Bravo et al. 2008; Brightsmith et al. 2008; Ghanem et al. 2013; Matsubayashi et al. 2007). The soil consumed also helps to reduce parasites in the animal's body (Oates 1978; Mahaney et. al. 1997; Gilardi et. al. 1999). Thus, geophagy has multiple causes that may vary geographically, seasonally, and among groups (Davies and Baillie 1988; Setz et al. 1999).

Mineral deficiency occurs because most of the Amazon rainforest is characterized by acid soils with a low level of available nutrients and a high concentration of toxic Al (Griffiths et al. 2020). Moreover, the western Amazon is a region deprived geographically of salt, as aerosol deposition of salt declines with distance from oceanic sources (Dudley et al. 2012). In this type of environment, herbivorous species may face mineral limitations if their only source of minerals is plant resources. If salt licks in the Amazonian region provides some minerals with nutritional importance for herbivores, their existence can reduce the cost of maintaining health and/or obtaining adequate nutrition and, thus, can be fundamental for the sufferance of wild species.

In addition to the benefits for the herbivorous and omnivorous' nutrition and health, these landscapes may also work as places for carnivores to easily find their prey, among other social encounters (Griffiths et al. 2020; Link and Fiore, 2012; Matsuda and Izawa 2008). Also, the presence of salt licks in some regions may affect population density and structure, and influence the carrying capacity of a population (Klaus and Schmid 1998). Since salt 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 reaching community-wide level with a broader ecological perspective (Montenegro 2004).

Although geophagy seems to offer diverse benefits for the animals, it also entails some costs. For instance, animals are more exposed to predation, poaching and hunting in salt licks since these sites are frequently visited by predators seeking easy preys (Griffiths et al. 2020; Montenegro 1998; Varanashi 2014) and are also important hunting sites for local people (Montenegro 1998; Tobler et al. 2009; Blake et al. 2011) and poachers (Seidensticker and McNeely 1975; Klaus and Schmidg 1998; Klaus et al. 1998). Exposure to diseases is also high, since at salt licks there is a large contact between animals (Hebert and Cowan 1971; Henshaw and Ayeni 1971), including in some cases to wild from domesticated animals (Plummer et al. 2018). Moreover, the ingestion of clay may provoke tooth wear (Mayland et al. 1975) and soil can also contain excessive concentrations of otherwise essential minerals that would lead to mineral imbalances (Kreulen 1985), or even contain toxic elements such as Pb, Cd, Hg, As or radionuclides (Mayland et al. 1975; Arthur and Alldredge 1979; Kreulen 1985). Despite all of these potential negative consequences, the animals spent high energy seeking out and visiting licks and may walk long distances and even exceed their home ranges to visit a salt lick (Tobler 2008).

This ecological importance of salt licks by Amazonian vertebrates can provide context to seasonal changes in species occupancy and movement. Visitation rates and behaviours at salt licks might be affected by environmental variables, such as the lunar cycle and seasonality (e.g., Blake et al. 2010; Griffiths et al. 2020). In the dry season an increased in salt lick visit was find for red howler monkeys (Blake et al. 2010). Seasonal salt lick use could be due to differential use of habitats throughout the year, particularly as access to and movement across some regions is restricted by rising waters in creeks and rivers during the rainy season (Griffiths et al. 2020). In this context, since, in Amazonia, salt licks are located on the edges of creeks, they are liable to periodic flooding as the level of water rises. A question we raise, therefore, is how long is this key resource available for consumption throughout the year?

Here we evaluate the temporal availability of salt licks in Amazonia and their use by the fauna through different seasons. For this, we used LEK- based methods and obtained information on 31 species of vertebrates visiting 56 salt licks in the Central Amazon. We also obtained information on the abundance rate in salt licks with different ecological characteristics, as well as on the behaviour pattern of the species visiting salt lick and on hunting practice in salt licks.

MATERIAL

Study area

Data were collected in 9 villages in Protected Areas of Sustainable Use and in 2 villages in Indigenous lands in demarcation process: Amanã Sustainable Development Reserve;Médio Juruá Extractive Reserve Uacari Sustainable Development Reserve; and Igarapé Ueré, territory occupied by the indigenous people of the Kulina ethnic group. All sampled villages were in upland *terra firme* primary rainforest. The region has a wet, tropical climate with a mean annual rainfall of 3,679 mm (2008–2010; Bauana Field Station). Regarding the precipitation patterns, the dry season consists of the month May to October; and the rainy season of November to April (Hawes and Peres 2014). Although only two seasons (wet and dry) are often used the in the literature, people interviewed for this study described the licks visitation as occurring in four different seasons: receding floodwaters, dry phase, rising floodwaters and flood pulse (wet season), being receding floodwaters the period when floodwaters recede and the area near the creeks (where the salt licks are usually found) get exposed. The dry phase, or dry season, is the period with low water levels and lower pluviometric indexes. Rising floodwaters represents the season when when floodwaters rise and the area near the creeks, therefore, begin to be covered by water. Lastly, it is called the flood pulse phase, the period of higher river water levels and rain rates.

Ethics statement For access to Federal protected areas, this study was submitted and authorized by SISBIO (Sistema Nacional de Informação sobre Biodiversidade) (license number: 65028-2). For access to Indigenous Lands, this study was authorized by FUNAI (Fundação Nacional Indígena) (license number: 65028). For access to state protected areas, we obtain authorization from DEMUC (Departamento de Mudanças Climáticas e Unidades de Conservação), (license number:113/2019). In addition, this project is registered on Plataforma Brasil and was approved by the Research Ethics Committee of the Health Sciences Center of the Paraíba Federal University (license number:: 59846816.3.0000.5188). In order to access the area occupied by the indigenous people of the Kulina ethnic group at Ueré creek, authorization from the local leadership was used (in addition to the SISBio license), since it is not a demarcated area, FUNAI cannot give permission for entry into the place. In addition, in all the communities visited, I first requested authorization from the leaders.

Data collection Between 2018 and 2019, we interviewed 47 local people from the sampled villages (average interviewees per village = 3, SD = 6) using a snowball sampling technique (Bailey, 1994) through the indication by each interviewee of another local expert on fauna visiting salt lick.

The questions asked during the interviews were:

1) What is the name given to the sites where animals go to consume soil?

2) Make a list of these sites in your hunting area.

   For each site utilized by the hunter, an answer:

3) What is the distance of the salt lick from the nearest creeks?

4) In which month, on average, does the site start to be uncovered by water? And covered?

5) List the species that frequent the site.

6) What does each species do on the site?

7) For each listed salt lick and species that the interviewee feels comfortable describing its relative abundance, it was presented a logarithmic scale of relative abundance (Figure 1) so that the hunter can point to the population abundance that he/she perceives over the four

seasons for each species in each salt lick.

Data compilation

The salt licks were divided into 3 categories according to how they are flooded by the creek water during the flood pulse season: non-flooding (salt licks that even in the peak of flood pulse season are not covered by water); Gradual flooding (salt licks which will become slowly covered by water); and rapid flooding (salt licks that became covered by water even during the rising floodwater season.

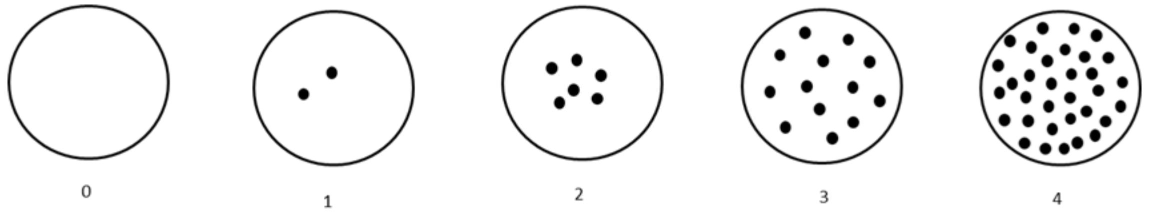

Figure 1. Quantitative visual scales presented during the interview for species abundance estimates, ranging from 0 (when the species population is "absent") to many specimens represented by each small circle.

RESULTS AND DISCUSSION

Salt Lick classification

Through the interviews, we recorded 59 salt licks, of which 56 are natural and 3 anthropogenic, in the visited villages of Amanã Sustainable Development Reserve and Juruá basin. Considering the anthropogenic salt licks, none of them was intentionally made by the hunters (by the practice of putting salt in the soil). In these cases, two locations had oil extraction industry which provide as main waste product the called produced water, that presents a high concentration of minerals (Fakhru'l-Razi et al. 2009) and so that can attract the wildlife for soil ingestion. In another case of anthropogenic salt lick, it appeared after some weeks of local people putting the fish in salt to dry on a wood drying rack. As the fish dried up, the salty liquid dripped onto the ground and an artificial salt lick started to be formatted.

In terms of the names given to the salt licks in the sampled villages, the one most frequently recorded was *chupador*, followed by *barreiro* and *canamã* for referencing sodium-rich environments, where animals go to consume soil and water. *Canamã* is the name given to a salt lick which is large in size, as well as visited by a high diversity of animals (including parrots) through the whole year because it's not completely covered by water in the flood pulse season (non-floodable salt licks). Also, canamã are often found near to the head of creeks. On the other hand, *chupador* and *barreiro* are smaller sites with lower animal diversity, and are usually covered by water during the flood pulse season (presenting rapid or gradual flooding in this season), because they are often found closer to the main part or to the mouth of creeks channel. In addition, there is also a difference between the *chupador* and *barreiro*, as *barreiro* constituting the smallest and less diverse salt lick, which is only available during the receding floodwaters period. In addition, *barreiros* are also less used by hunters. One of the interviewees, when asked to define *chupador* and *canamã*, and explain the difference between them, in a very didactic way, answered: "both serve to treat animals´ health, but while the *chupador* is a primary care centre in our village, the *canamã* is more like a hospital in Manaus".

Richness and behaviour of species visiting salt licks

We identified 31 species visiting salt licks through interviews, which perform the visit for different purposes (Table 1). Despite soil and water consumption in salt licks being the main attraction for wild species visiting these sites, some species visit salt licks for bathing, predation and other ecological relationships and behaviours. For example, Dasypodidae (armadillo) species were only seen digging burrows in the salt lick, but not consuming the soil at the site. Some other animals indirectly consume the salt lick water even though, according to the interviewees, they do not visit the place for this main purpose. For example, the *Tayassu pecari* uses the site for bathing. For this reason, the *Tapirus terrestres* does not visit the place to consume soil on the same day of the *T. pecari.* Conversely, tapirs visit the salt licks on the same day as the *Pecari tajacu*, because this animal does not stir the water as much as the *T. pecari* does. Besides, the *P. tajacu* looks for fruits and seeds in the salt licks for a short to medium time and then leaves, while the *T. pecari* spends much more time bathing there.

According to the interviewees, the season with the highest abundance of wild animals was the receding floodwaters season, followed by a dry phase. This is because during the receding floodwaters season the animals come from the centre of the forest to near the creeks as the water level itself decreases and the salt lick is finally exposed. However, the interviewees perceived that, during the dry season, the animals also move to places far from the creek to eat more fruits. Consequently, the visitation rate for some species may decreases in this salt licks. In the rising floodwaters season, most of the salt licks presented a low abundance for all species. During the flood pulse, the majority of the salt licks were not visited by any individual, with the exception of *T. terresstris*, Quiropteros and *C. paca*, for which some interviewees noticed, although with low abundance, the presence of individuals of these taxa in the licks.

The diet of the *T. terrestris* is made up of fruit

Table 1. Motivations perceived by interviews for animal visits in salt licks

Species	Soil ingestion	Passing	Bathing	Foraging	Predation	Gnawing tree roots on site	Other
Alouatta seniculus	X	X		X			
Aotus infulatus	X	X		X			
Aramides cajaneus							X
Ateles chamek	X						
Cacajao melanocephalus				X			
Callicebus torquatus	X						
Cebus albifrons				X			
Chelonoidis	X	X					
Chiroptera	x						
Coendou prehensilis						X	
Cuniculus paca	X	X		X		X	
Dasyprocta fuliginosa	X	X		X			
Leopardus wiedii					X		
Leopardus pardalis					X		
Mazama nemorivaga	X						
Mitu tuberosum	X			X			
Nothocrax urumutum				X			
Panthera onca					X		
Pecari tajacu				X		X	
Penelope jacquacu		X		X			
Pipile cujubi		X		X			
Potos flavus							X
Priodontes maximus		X					X
Psophia leucoptera				X			
Puma concolor					X		
Saimiri sciureus				X			
Sapajus macrocephalus	X			X			
Tapirus terrestres	X						
Tayassu pecari	X	X	X	X			
Tinamus guttatus	X			X			

and foliage (Montenegro 2004) and a main food source for the them is aguaje palm fruit (*Mauritia flexuosa*) (Bodmer, 1990; Virapongse et al. 2017). Similarly to our result, a study conducted in Maijuna-Kichwa Regional Conservation Area (in Loreto, Peru) where the aguaje palm fruits from approximately May to August (Gilmore et al. 2013) shows that possible during this time, *T. terrestris* are consuming fruit as a larger proportion of their diet and so, they visit salt licks less frequently (Griffiths et al. 2020). However, Griffiths et al. (2020) found a higher abundance of tapir in the salt licks during flood pulse season. Although we recorded that *T. terrestris* is one of the few species visiting salt lick during flood pulse season, we found that receding floodwaters season is the most important visit period of salt licks by *T. terrestris*. Griffiths et al.

(2020) however, considered the year as having only two seasons and the fact that the analyses were not carried out for the receding floodwater season separately of the dry season may have influenced this difference in the results.

On the other hand, our result is in accordance with a study carried out at the Madre de Dios River in Southern Peruvian Amazon, in which a very high visitation rate to the salt licks was recorded for *T. terresstris* during the dry season (Montenegro 1998). Similar results were also recorded for *A. seniculus* visiting salt licks often in the dry season, with a visit peak between June and July (Blake et al. 2011; Griffiths et al. 2020). The higher visit rate recorded for *A. seniculus* in the dry season might be related to a shift in its diet when a greater proportion of leaves is consumed (Blake et al. 2010). In the case of *Mazama nemorivaga* the low visit rate recorded during the interviews is might because species of *M. americana* (species close to that recorded in our study) avoids flooded forest during the wet season, and those located in floodplain forest shift their diet to include woodier foods during that time due to resource scarcity (Bodmer 1990).

At the peak of the dry season, salt lick of rapid flooding (often found closer to the main part of creeks channel or to the creek's mouth) are more visited when compared to non- floodable salt licks (often placed near to the head of creeks). This occurs because salt licks distant from the creeks become very dry during the dry season, which makes it difficult for the animals to consume the soil. On the other hand, during the flood pulse season non-floodable salt licks (*canamãs)* have higher species abundance when compared to the other salt licks. This is because, once in the flood pulse season the majority of salt licks are covered by water, non-floodable salt licks are the only to provide mineral sources for animals that depend on this key source. However, the interviewees explain that during the flood pulse season, even in these salt licks, *T. terrestris* and *C. paca* visits flow decrease because minerals concentration in the soil reduces, as a consequence of higher leaching caused by the rain (Figure 2).

Game species visiting salt licks The interviewed hunters listed the following species as those hunted in salt licks: *Tapirus terrestris* (VU); *Priodontes maximus* (VU); *Tayassu pecari* (VU); *Ateles chamek* (EN); *Pecari tajacu* (LC); *Cuniculus paca* (LC); *Mazama nemorivaga* (LC).

Most of the interviewees (74,46%) said that salt licks are one of the main places where they hunt. However, the hunting at salt licks is only performed during the receding floodwaters season, when it is easier to find the animals in the salt licks. In addition, as during this season it rains less, it is possible for the hunter to stay dry during the long hours of waiting in the salt lick. Also, fishing is more difficult during this season and game meat becomes the main source of protein for local residents. We hypothesise, however, that in more defaunated or regions of lower species abundance (like clearwater basins in Amazonia), the hunting practice of waiting at salt licks will be of a greater importance. That is why actively finding animals is difficult in environments of low availability of game species, and waiting at a salt lick becomes a less energy-intensive way to find and kill the target animal. Regarding that, a study conducted in the Piagaçu-Purus Sustainable Development Reserve revealed a high number of anthropogenic salt licks built by hunters (adding salt to the soil) in order to facilitate

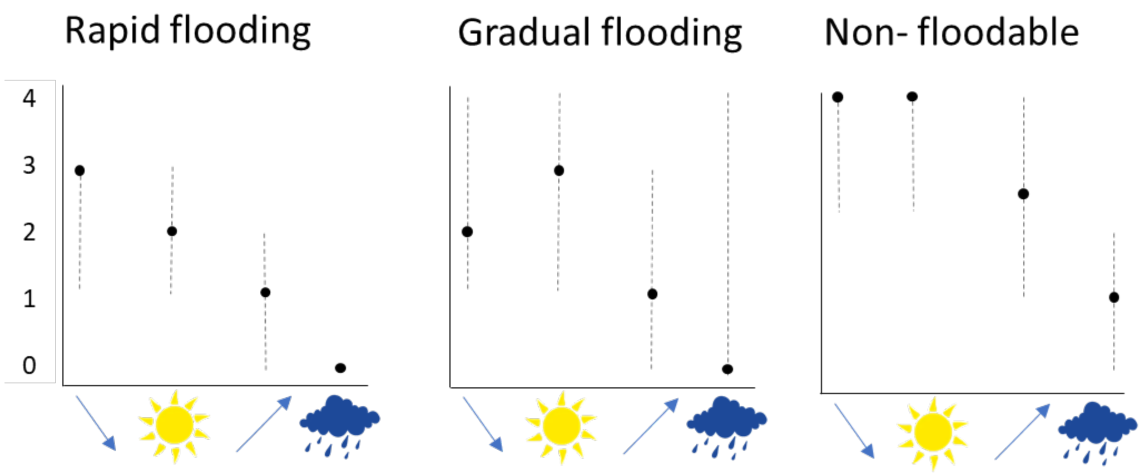

Figure 2. Abundance of species (x axis) visiting different types of salt lick as defined by flooding receding type when floodwaters recede (down arrow symbol), dry phase (sun symbol), rising floodwaters (up arrow symbol) and flood pulse seasons (raincloud symbol).

encounters with game mammals (Vieira et al. 2016). Since the Purus basin is historically more exploited than the Juruá basin and Amanã Sustainable Development Reserve, this data supports our hypothesis, which will be tested with future studies in additional areas. Furthermore, the practice of hunting that consists of waiting in trees whose falling fruits are eaten by animals, or in trees whose roots are gnawed by animals like *T. terrestris*, *C. paca* and *C. prehensilis* is common in lowland places with low species richness, where salt licks are uncommon.

Overall, our results showed that based on local ecological knowledge salt licks have numerous socioecological functions for many species of birds and mammals. Visits at these sites were linked to soil consumption, but also for other ecological relationships. Another important result is that the visit in different salt licks will depend not only the species needs, but also of the salt lick flooding period.

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DATA AVAILABILITY

CONFLICT OF INTEREST

We declare no conflict of interest.

CONTRIBUTION STATEMENT

F.B.-P, C.P, R.R.N.A conceived the ideas and designed the methodology; F.B.-P collected and compiled the data; F.B.-P analysed the data; F.B.-P wrote the original draft; F.B.-P., C.P, R.R.N.A edited the manuscript. All authors gave final approval for publication.

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