The published version of the paper is available here: https://www.sciencedirect.com/science/article/abs/pii/S2352249620300082?via%3Dihub/
doi.org/10.1016/j.fooweb.2020.e00148

Predation of a Brazilian porcupine (*Coendou prehensilis*) by an ocelot (*Leopardus pardalis*) at a mineral lick in the Peruvian Amazon

Brian Griffiths[1], Michael Gilmore[2], & Mark Bowler[3,4]

[1]Department of Environmental Science and Public Policy, George Mason University, 4400 University Drive, Fairfax, VA, 22030, USA

[2]School of Integrative Studies, George Mason University, 4400 University Drive, Fairfax, VA 22030, USA

[3]School of Science, Technology and Engineering, University of Suffolk, Waterfront Building, Neptune Quay, Ipswich, IP4 1QJ, UK

[4]Institute for Conservation Research, San Diego Zoo Global, Escondido, California, CA 92027-9614, USA

Corresponding author:

Brian Griffiths[1]

ORCID: 0000-0001-9522-7731

Email address:

Bgriffi7@gmu.edu

Abstract

Many herbivorous and frugivorous Amazonian species, including several arboreal animals, feed on earth and water at mineral licks in the Amazon region to supplement their diet with micronutrients and clays. These species are vulnerable to predation during this activity. We recorded an adult Brazilian porcupine (*Coendou prehensilis)* being predated by an adult male ocelot (*Leopardus pardalis*) while drinking water at a mineral lick in the Maijuna-Kichwa Regional Conservation Area (MKRCA) in northeastern Loreto, Peru. This observation provides direct evidence arboreal species like the porcupine, which move slowly on the ground, are particularly vulnerable to terrestrial predators while visiting mineral licks. Mineral licks are important in the diets and ecology of Amazonian mammals, but arboreal prey must balance the trade-off between using the resource and being hunted. We suggest that mineral licks may be hotspots of risk in Amazonian prey species' landscape of fear.

Keywords

Felids, predation, mineral lick, ecology, behavior, Amazonia

Declarations

Funding

This research was supported by a Fulbright U.S. Student Research Grant to Peru awarded to B. Griffiths.

Conflicts of interests

The authors declare that they have no conflict of interest.

Ethics approval

This study was approved by George Mason University's Institutional Review Board, project #1288488-1.

Consent to participate

Not applicable.

Consent to publish

Not applicable.

Availability of data and material

Our paper is an observational study, and does not include data beyond that which is presented in the paper.

Code availability

We did not use code in our study.

Authors' contributions

All authors contributed to the study conception and design. Data collection and analysis were performed by Brian Griffiths. The first draft of the manuscript was written by Brian Griffiths and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Mineral licks are naturally occurring sites where animals exhibit geophagical behavior, consuming soil or mud to supplement their diet with micronutrients or clays (Dudley et al., 2012; Kreulen, 1985). Mineral licks are visited frequently by many different Amazonian herbivores and frugivores, such as the Brazilian tapir (*Tapirus terrestris*), collared (*Pecari tajacu*) and white-lipped peccary (*Tayassu pecari*), red brocket deer (*Mazama americana*), paca (*Cuniculus paca*), black agouti (*Dasyprocta fuliginosa*), and red howler monkey (*Alouatta seniculus)* (Montenegro, 2004; Tobler, Carrillo-Percastegui, & Powell, 2009; Tobler, 2008). Results from several studies have indicated that mineral licks in Amazonia are also important sites for predators (e.g. Izawa, 1993; Link et al., 2011; Link and Fiore, 2013; Matsuda and Izawa, 2008; Montenegro, 2004) such as wild felids, seeking prey that visit the lick to consume soil. The prevalence of predators at lick sites suggests that mineral licks may act as hotspots of risk in the landscape of fear (Laundré et al., 2010) for prey species.

Behavioral studies provide further evidence that mineral licks form a key component of the landscape of fear, particularly for arboreal species visiting the lick that are otherwise inaccessible to terrestrial predators. For example, Link and Fiore (2013) and Ospina (2011) showed that large-bodied primates increased their group size before descending to a lick, likely to increase the probability of detecting a predator. In a study by Link et al. (2011), primates visited licks most frequently on bright sunny days when visibility was highest, and employed vigilance behavior from the trees while members of the group fed at the lick. Similar antipredator behavior has been observed in the grouping behavior of birds visiting licks, in the formation of mixed-species flocks (Brightsmith and Villalobos, 2011) that also employ vigilance and induce a dilution effect (Hamilton, 1971). One study by Montenegro (1998) described antipredator behavior of tapir at licks, although no direct observations of predation on species other than primates at mineral licks have been published.

We describe a predation event by an adult male ocelot (*Leopardus pardalis*) on an adult Brazilian porcupine (*Coendou prehensilis*) at a mineral lick in the Maijuna-Kichwa Regional Conservation Area (MKRCA) (-72.9311º W, -3.15442º S), a 391,000 hectare protected area collaboratively managed by the indigenous Maijuna people in the northern part of the state of Loreto in the northeastern Peruvian Amazon. The MKRCA is characterized by tropical, humid, primary *terra firma* forest, floodplain forest, and a terraced habitat that is unique to the region (Gilmore, 2005). The region has a mean annual rainfall of about 3100 mm and temperature of 26º C (Marengo, 1998).

Ocelots are a medium-bodied felid (6-18 kg) (de Oliveira et al., 2010) found throughout South and Central America (de Oliveira et al., 2010; Fernandez, 2002). Terrestrial mammals make up the bulk of the ocelot’s diet, but insects, crabs, reptiles, birds, sloths, monkeys, and other arboreal mammals are also common prey items. Ocelots are mainly recorded as hunting from the ground, and so their mechanisms of hunting arboreal species are unknown (Moreno et al., 2006), although it is assumed that many of these prey are hunted when they are scared to the ground by the ocelot or are at the ground by some other circumstance (Bianchi and Mendes, 2007).

The Brazilian porcupine (*Coendou prehensilis)* is an arboreal (Roberts et al., 1985), nocturnal hystricognath rodent of the Erethizontidae family that is widely distributed in moist, humid forests throughout Amazonia (Eisenberg, 1978; Mares and Ojeda, 1982). *C. prehensilis* is exclusively herbivorous, with a diet that consists of mainly buds, bark, fruits, and seeds (Charles-Dominique et al., 1981; Eisenberg, 1978). The Brazilian porcupine is known to descend to the forest floor to visit mineral lick sites across Amazonia (Gilmore and Young, 2010; Molina et al., 2014).

Images of the predation event were recorded as part of a camera trapping study on mineral licks in the Sucusari Basin, in the southern reaches of the MKRCA, on October 8, 2018 at 9:47pm. Camera traps (Bushnell Aggressor) were installed at 80 mineral licks in Sucusari from August, 2018, to June, 2019 to measure mammal visitation at licks across the region. The locations of the mineral licks were determined through participatory mapping exercises with Maijuna hunters in July, 2017. Camera traps were set to photo mode, taking a burst of three images every time the motion sensor was activated. A delay of fifteen seconds between each set of images was chosen to avoid expending the camera's batteries prematurely. Cameras were set at a minimum of 50 centimeters from the ground, facing the active "face" and entrances to the lick, following (Tobler et al., 2009). The locations of the face and entrances were determined from signs of animal activity. In mineral licks that hunters noted flooded seasonally, cameras were placed farther from the ground to avoid inundation, just above the high-water mark on nearby vegetation. Camera traps were left at mineral licks for a minimum of 82 days and were not disturbed after they were set.

Fifteen images of the ocelot stalking and attacking the porcupine were recorded (Fig. 1). The ocelot stalked the porcupine for over one minute while the porcupine was drinking water in the mineral lick and readjusted its position before pouncing on the porcupine and dragging it out of the water. Over seven minutes pass between when the ocelot pounced and when it dragged the porcupine from the water; presumably, it was killing the porcupine in the mineral lick during this time. It is likely that the camera did not sense movement for seven minutes because the camera was located behind and slightly above a fallen log and the mud in the lick was quite deep. While the ocelot is stalking the porcupine, it does not have any mud on its fur. When the ocelot pounced, dragging the porcupine into the mud behind the log, both animals were likely hidden from view of the camera. When the ocelot pulls the porcupine onto the log, both animals are covered in mud.

One previous study reports ocelots preying on porcupines, from a single scat sample (Emmons, 1987), but it is thought that ocelots hunt arboreal species opportunistically from the ground, including at mineral lick sites (Izawa, 1993; Link et al., 2011; Matsuda and Izawa, 2008). Arboreal species like the Brazilian porcupine, which move slowly on the ground may be particularly vulnerable to terrestrial predators while visiting mineral licks, highlighting the importance of mineral licks in the diets of Amazonian mammals.

While the importance of mineral licks to the diets of herbivorous mammals has been well studied, the ecological role of Amazonian mineral licks to predators is largely unknown. Studies targeting mineral licks in other regions have described predation risk at licks for other prey species. For example, Couturier and Barrette (1988) observed moose in Quebec, Canada exhibiting vigilance behavior at mineral licks. A seminal work by Cowan and Brink (1949) described heavy predation on wild goats by bears and mountain lion at mineral licks in Canada. Large felids were recorded visiting mineral licks in Nepal by Moe (1993), likely looking for prey. Behavioral studies at Amazonian mineral licks have largely been limited to large-bodied primates although they make up only a small portion of the species that frequent the licks. One exception is a study done by Montenegro (1998), which described antipredator behavior by the tapir at Amazonian licks.

Given the observations of predators and direct predation events at mineral licks, including this one, we suggest that further research is needed to understand predator-prey interactions at mineral licks for species beyond primates. Further behavioral studies in particular will provide context as to what extent mineral licks present hotspots of risk in prey species' landscape of fear in Amazonia.

Acknowledgements

We would like to thank the Maijuna community of Sucusari for their knowledge and expertise on local mineral licks and the Peruvian Fulbright Commission, who awarded a Fulbright U.S. Student Research Grant to B. Griffiths to conduct mineral lick research in the MKRCA.

Literature Cited

Bianchi, R.D.C., Mendes, S.L., 2007. Ocelot (Leopardus pardalis) predation on primates in Caratinga Biological Station, southeast Brazil. Am. J. Primatol. Off. J. Am. Soc. Primatol. 69, 1173–1178.

Brightsmith, D.J., Villalobos, E.M., 2011. Parrot Behavior at a Peruvian clay lick. Wilson J. Ornithol. 123, 595–602.

Charles-Dominique, P., Atramentowicz, M., Charles-Dominique, M., Gerard, H., Hladik, A., Hladik, C.M., Prévost, M.-F., 1981. Les mammiferes frugivores arboricoles nocturnes d'une foret guyanaise: inter-relations plantes-animaux. Rev. Décologie.

Couturier, S., Barrette, C., 1988. The behavior of moose at natural mineral springs in Quebec. Can. J. Zool. 66, 522–528.

Cowan, M., Brink, V.C., 1949. Natural game licks in the rocky mountain national parks of Canada. J. Mammal. 30, 379–387.

de Oliveira, T.G., Tortato, M.A., Silveira, L., Kasper, C.B., Mazim, F.D., Lucherini, M., Jácomo, A.T., Soares, J.B.G., Marques, R.V., Sunquist, M., 2010. Ocelot ecology and its effect on the small-felid guild in the lowland neotropics. Biol. Conserv. Wild Felids 559–580.

Dudley, R., Kaspari, M., Yanoviak, S.P., 2012. Lust for salt in the western Amazon. Biotropica 44, 6–9. https://doi.org/10.1111/j.1744-7429.2011.00818.x

Eisenberg, J.F., 1978. The evolution of arboreal herbivores in the class Mammalia. Ecol. Arboreal Folivores 135–152.

Emmons, L., 1987. Comparative feeding ecology of felids in a neotropical rainforest. Behav. Ecol. Sociobiol. 20, 271–283. https://doi.org/10.1007/BF00292180

Fernandez, E.C., 2002. Ocelot (Leopardus pardalis) ecology in the Chamela-Cuixmala Biosphere Reserve, Jalisco, Mexico (M.S.). University of Wyoming, United States -- Wyoming.

Gilmore, M., 2005. An ethnoecological and ethnobotanical study of the Maijuna Indians of the Peruvian Amazon (PhD Thesis). Miami University.

Gilmore, M.P., Young, J.C., 2010. The Maijuna participatory mapping project: mapping the past and the present for the future. Perú Maijuna Rapid Biol. Soc. Invent. Rep. 22, 233.

Hamilton, W.D., 1971. Geometry for the selfish herd. J. Theor. Biol. 31, 295–311.

Izawa, K., 1993. Soil-eating by Alouatta and Ateles. Int. J. Primatol. 14, 229–242.

Kreulen, D.A., 1985. Lick use by large herbivores: a review of benefits and banes of soil consumption. Mammal Rev. 15, 107–123. https://doi.org/10.1111/j.1365-2907.1985.tb00391.x

Laundré, J.W., Hernández, L., Ripple, W.J., 2010. The landscape of fear: ecological implications of being afraid. Open Ecol. J. 3, 1–7.

Link, A., De Luna, A.G., Arango, R., Diaz, M.C., 2011. Geophagy in brown spider monkeys (Ateles hybridus) in a lowland tropical rainforest in Colombia. Folia Primatol. Basel 82, 25–32. http://dx.doi.org.mutex.gmu.edu/10.1159/000326056

Link, A., Fiore, A.D., 2013. Effects of predation risk on the grouping patterns of white-bellied spider monkeys (Ateles belzebuth belzebuth) in Western Amazonia. Am. J. Phys. Anthropol. 150, 579–590. https://doi.org/10.1002/ajpa.22230

Link, A., Galvis, N., Fleming, E., Di Fiore, A., 2011. Patterns of mineral lick visitation by spider monkeys and howler monkeys in Amazonia: are licks perceived as risky areas? Am. J. Primatol. 73, 386–396.

Mares, M.A., Ojeda, R.A., 1982. Patterns of diversity and adaptation in South American hystricognath rodents. Mamm. Biol. S. Am. 6, 393–432.

Matsuda, I., Izawa, K., 2008. Predation of wild spider monkeys at La Macarena, Colombia. Primates 49, 65–68.

Moe, S.R., 1993. Mineral content and wildlife use of soil licks in southwestern Nepal. Canadian Journal of Zoology 71, 933–936.

Molina, E., León, T., Armenteras, D., 2014. Characteristics of natural salt licks located in the Colombian Amazon foothills. Environ. Geochem. Health 36, 117–129. https://doi.org/10.1007/s10653-013-9523-1

Montenegro, O.L., 1998. The behavior of Lowland Tapir (Tapirus terrestris) at a natural mineral lick in the Peruvian Amazon (Master’s Thesis). University of Florida.

Montenegro, O.L., 2004. Natural licks as keystone resources for wildlife and people in Amazonia (Ph.D.). University of Florida, United States -- Florida.

Moreno, R.S., Kays, R.W., Samudio, R., 2006. Competitive release in diets of ocelot (Leopardus pardalis) and puma (Puma concolor) after jaguar (Panthera onca) decline. J. Mammal. 87, 808–816.

Ospina, A.L., 2011. Social and ecological determinants of "fission-fusion" sociality and grouping strategies in the white bellied spider monkey (Ateles belzebuth belzebuth) in a lowland rainforest in Western Amazonia (Ph.D.). New York University, United States -- New York.

Roberts, M., Brand, S., Maliniak, E., 1985. The biology of captive prehensile-tailed porcupines, Coendou prehensilis. J. Mammal. 66, 476–482. https://doi.org/10.2307/1380922

Tobler, M.W., 2008. The ecology of the lowland tapir in Madre de Dios, Peru: using new technologies to study large rainforest mammals. Texas A&M University.

Tobler, M.W., Carrillo-Percastegui, S.E., Powell, G., 2009. Habitat use, activity patterns and use of mineral licks by five species of ungulate in south-eastern Peru. J. Trop. Ecol. 25, 261–270.

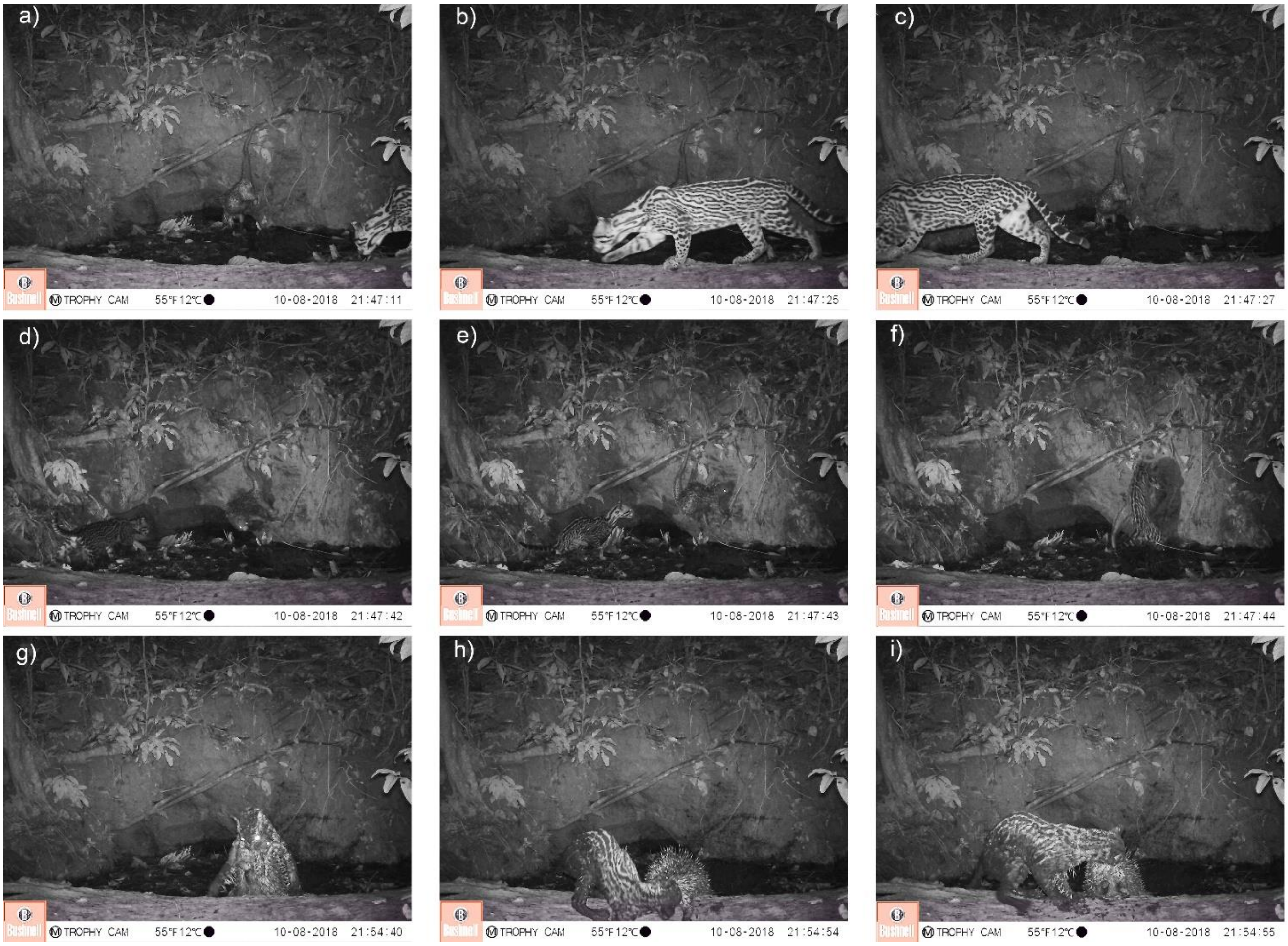

Fig. 1 a-b) Adult porcupine (*Coendou prehensilis*) can be seen drinking water at the lick while a male ocelot (*Leopardus pardalis*) looks on; **c-d)** Ocelot walks along a lot to approach the porcupine from the left; **e-f)** Ocelot pounces on the back of the porcupine, biting behind the head; **g-i)** Ocelot drags porcupine onto log and twists its neck