BIOTROPICA
THE JOURNAL OF TROPICAL BIOLOGY AND CONSERVATION

BIOTROPICA 41(3): 279–282 2009 10.1111/j.1744-7429.2009.00514.x

Parrots Take it with a Grain of Salt: Available Sodium Content May Drive *Collpa* (Clay Lick) Selection in Southeastern Peru

Luke L. Powell[1,5], **Thomas U. Powell**[1,3], **George V. N. Powell**[2], and **Donald J. Brightsmith**[4]

[1]School of Biology and Ecology, University of Maine, Orono, Maine 04469, U.S.A.

[2]Conservation Science Program, World Wildlife Fund, Washington, DC 20037, U.S.A.

[3]EcoTest Laboratories, Inc., Environmental Testing, North Babylon, New York 11703, U.S.A.

[4]Schubot Exotic Bird Health Center, Department of Veterinary Pathology, Texas A&M University, College Station, Texas 77843, U.S.A.

ABSTRACT

Soils from 18 parrot *collpas* ('clay licks') in southeastern Peru averaged four times more available sodium than uneaten control soils. *Collpa* soils contained marginally more clay than control sites and clay content was uncorrelated with available sodium content. Parrots may select and ingest soils based on available sodium content.

Abstract in Spanish is available at http://www.blackwell-synergy.com/loi/btp.

Key words: Amazon; geophagy; natural lick; psittacids; salt lick; tropical wet forest.

AMAZONIAN *COLLPAS* (ALSO KNOWN AS SALT LICKS, NATURAL LICKS, OR CLAY LICKS) are locations where animals consume soil (Jones & Hanson 1985, MacQuarrie 2001, Downs 2006, Bravo 2007). In a single day, up to 1700 parrots of 17 species may congregate on some *collpas* (D. Brightsmith, unpubl. data). A number of hypotheses have been proposed to explain geophagy (the intentional consumption of soil) including: (1) mineral supplementation (Jones & Hanson 1985); (2) adsorption of dietary toxins (Johns & Duquette 1991); (3) pH buffering (Oates 1978); (4) relief from diarrhea (Vermeer & Ferrell 1985); and (5) mechanical aid to digestion (Best & Gionfrido 1991).

Research on parrots in southeastern Peru supports the first two hypotheses (Diamond *et al.* 1999, Gilardi *et al.* 1999, Brightsmith & Aramburú 2004, Brightsmith *et al.* 2008), but the conclusions drawn from them are equivocal. Gilardi *et al.* (1999) found that *collpa* soils bound alkaloid toxins and suggested that sodium was not a primary factor for geophagy because, while sodium levels were elevated at *collpa* sites, they were not significantly different from unused layers on the same riverbank. Later research at one of the same sites concluded that while consumed soil provided a source of dietary sodium, clay content in the soil explained more variation in bird use than either sodium concentration or the soil's ability to bind toxins (Brightsmith *et al.* 2008). As clay is negatively charged and has a relatively large surface area, it is a strong adsorber of positively charged toxins such as the alkaloids that are common in the diets of Amazonian parrots (Gilardi 1996, Boul *et al.* 1997). Though acknowledging the potential value of sodium supplementation, Brightsmith *et al.* (2008) and Gilardi *et al.* (1999) propose that parrots may cue on unctuous (smooth and greasy) soils high in clay content, thereby gaining the advantages of detoxifying effects thought to be associated with clay consumption.

If parrots eat soil to supplement mineral intake, mineral content at *collpas* should be higher than in: (1) other accessible soil horizons within the same riverbank that are not consumed; (2) accessible yet unused soil horizons on nearby riverbanks; and (3) the diets of parrots in the region. We hypothesized that high sodium concentration would explain selection of *collpa* locations, and that by sampling 18 *collpas*, we would reduce the correlations among variables (*e.g.*, percent clay and sodium) that limited the conclusions of Brightsmith *et al.* (2008).

In December 2006 and January 2007, we collected soils from sites on or near five Amazon River tributaries in lowland rain forest (184–265 m asl) and dispersed across about 175 km of the Department of Madre de Dios, Peru (Fig. S1). We analyzed particle size and the concentration of 22 metals from soil collected at 18 *collpas* and 18 control sites. Four *collpas* are permanently protected, four are currently part of a temporary research concession, two are within a community reserve, and eight are currently unprotected (Fig. S1). To control for regional variability in mineral concentrations, we elected to use a block design with two control treatments. Thus, there were three treatment groups for each *collpa*: (1) soil from the area of geophagy (hereafter, referred to as '*collpa* soil'); (2) soil collected from the same exposed riverbank yet from a distinct, adjacent unconsumed soil horizon ('adjacent control'); and (3) unconsumed soil collected from the nearest exposed riverbank ('nearby control bank'). At known *collpas*, we confirmed the species and the exact locations of geophagy with personal observations, the presence of beak marks in the soil, and input from biologists and/or local residents. We avoided nearby control banks that were sandy or otherwise unlikely locations for bird geophagy (*e.g.*, inaccessible,

---

Received 3 October 2008; revision accepted 23 January 2009.

[5]Corresponding author; Current address: School of Renewable Natural Resources, Louisiana State University, Baton Rouge, Louisiana 70803, U.S.A.; e-mail: luke.l.powell@gmail.com

heavy boat traffic; Gilardi *et al.* 1999). We collected at least five subsamples from each site using latex gloves and a stainless-steel screwdriver to chisel pieces of the soil directly into a plastic bag. The samples were air-dried and packaged prior to transport (Tan 1996, Mahaney & Krishnamani 2003).

We analyzed 277 subsamples for 22 available metals (aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, magnesium, manganese, iron, lead, molybdenum, nickel, potassium, silver, sodium, thallium, titanium, and zinc) at EcoTest Laboratories, Inc., North Babylon, NY. The available metals protocol included an extraction originally designed to simulate the gastric environment of a human (Hunter & Kleine 1984) and subsequently modified to simulate the gastric environment of a parrot (Gilardi 1996). We agitated 1 g of soil at 38°C with 15 ml of pH 2.0-adjusted HCl solution for 60 min. The samples were centrifuged and analyzed for the metals as per United States Environmental Protection Agency method 6010B using a Perkin Elmer model 3300 (Perkin Elmer Inc., Waltham, MA) Optima Simultaneous inductively coupled plasma spectrometer. To address the alternative hypothesis that particle size may explain parrot's choice of soils (Gilardi *et al.* 1999, Brightsmith & Aramburú 2004, Brightsmith *et al.* 2008), we analyzed samples for percent sand (2000–50 μm; wet sieve), percent clay (< 2 μm; hydrometer method; Miller *et al.* 1998), and percent silt (50–2 μm; by subtraction) at the University of Maine. Due to time and budget constraints, for each site, we used one or two randomly selected subsamples (66 total) in the particle size analysis.

We used univariate analysis of variance (ANOVA) to determine if the effect of collection site (*collpa*, adjacent control, or nearby control bank) was significant for 21 available metals (277 subsamples), percent sand, percent silt, and percent clay (66 subsamples). We checked all variables for normality (Shapiro–Wilk tests) and equality of variance (Levene's test), and where distributions were not normal (as was the case for sodium, magnesium, and percent clay), we rank-transformed the data within each block before running ANOVAs. We used Bonferroni's method to test for differences between treatment group means (Miller 1981). To compare the results of metal analyses to those of particle size, we ran additional ANOVAs on sodium and magnesium using the same data set (66 subsamples) as we used with percent clay, silt, and sand. To determine if response variables were correlated, we used Spearman's rank correlation test on all possible pairs of variables (Zar 1972).

At the 18 *collpas*, we obtained records of 30 avian species (including 19 psittacids) consuming soil, 29 of which we observed personally (Table S1). Of the 22 available metals we analyzed (Table S2), only sodium and magnesium occurred at significantly higher concentrations in *collpa* soils versus control soils. *Collpa* soils had significantly more available sodium than both types of control soils ($F_2 = 61.2$, $P < 0.0001$; Fig. 1A). The mean available sodium concentration of 18 *collpas* was 1137 ppm (parts per million), 33 times the mean total concentration of sodium in foods of 18 psittacine species in southeastern Peru ($N = 65$ plant species, 89 unique parts, $\bar{x} = 35$ ppm, $SD = 32$; Gilardi 1996,

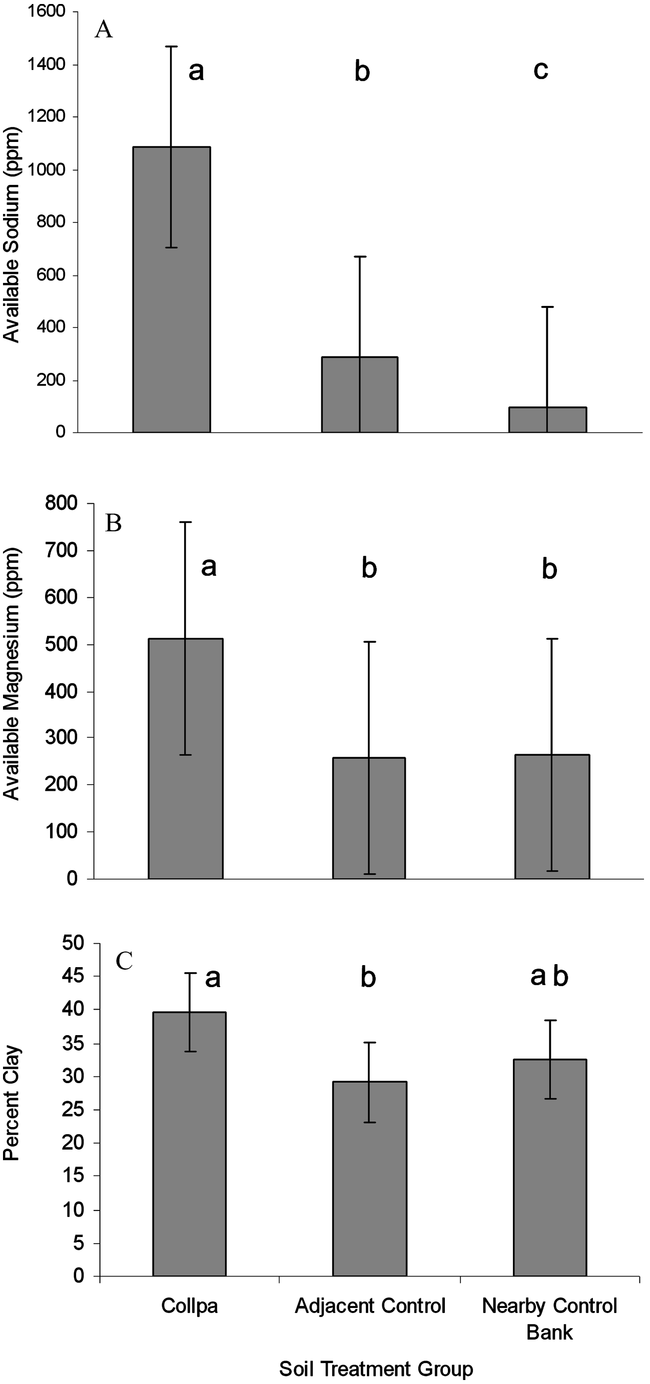

FIGURE 1. (A) Mean available sodium concentration, (B) mean available magnesium concentration, and (C) percent clay of soils in three treatments: *collpa*, adjacent controls, and nearby control banks ($N = 18$ for each). Error bars represent mean ± 95% CI calculated using error terms in the ANOVA models. Treatment groups with the same lowercase letter indicate that rank-transformed values were not significantly different ($\alpha = 0.05$). Treatment group comparisons shown for percent clay despite marginal overall model significance ($P = 0.075$).

Brightsmith *et al.* 2008). The mean available magnesium concentration of *collpas* (527 ppm) was significantly greater than in control soils (F_2 = 10.8, $P < 0.0002$; Fig. 1B) and five times less than the total magnesium concentration in foods of psittacine birds in southeastern Peru ($N = 65$ plant species, 90 unique parts, $\bar{x} = 2786$ ppm, SD = 2050; Gilardi 1996, Brightsmith *et al.* 2008).

For the overall model, percent clay was only marginally different between *collpa* and control soils ($F_2 = 2.80$, $P = 0.075$). *Collpa* soils had more clay than adjacent control soils, but no more than nearby control bank soils (Bonferroni $t_{33} = 2.5, \alpha = 0.05$; Fig. 1C). In contrast, when run on this same smaller data set (66 subsamples total), available sodium and available magnesium concentrations were still significantly greater in *collpa* soils compared with either of the two control soils (Na: $F_2 = 46.0$, $P < 0.0001$; Mg: $F_2 = 8.17$, $P < 0.0013$). There was no difference in percent sand or percent silt between *collpa* soils and control soils ($P = 0.55$ and $P = 0.30$, respectively; Table S1).

The concentrations of sodium and magnesium ions in the soil were positively correlated ($r = 0.15$, $P = 0.015$), while percent clay was not correlated with sodium ($r = 0.04$, $P = 0.74$) or magnesium ($r = 0.16$, $P = 0.19$) concentration.

The available sodium concentration in *collpa* soils was four times higher than in adjacent control soils, 12 times higher than in nearby control bank soils, and 33 times higher than the mean total sodium of psittacine diets in southeastern Peru (Gilardi 1996, Brightsmith *et al.* 2008). Available magnesium concentration was also greater in *collpa* soils than in control soils. However, we doubt the importance of *collpas* as a biologically significant source of magnesium as foods of psittacine birds in the region had total magnesium concentrations approximately five times greater than available magnesium at *collpas* (Gilardi 1996, Brightsmith *et al.* 2008). Although we compare total magnesium to biologically available magnesium, we believe this is a valid comparison as Henry and Benz (1995) found that 95 percent of the total magnesium in plants is available to galliform birds. We suspect that high magnesium concentrations are the result of a correlation with sodium and not an explanation for *collpa* selection by parrots.

Given that *collpas* were only marginally higher in percent clay, our data suggest that parrots are not targeting the most unctuous soils. Rather, the strong correlation between available sodium and soil consumption suggests that sodium may be driving the selection of *collpa* soils in the southern Peruvian Amazon. The mechanism behind this selection remains unknown as no studies have adequately tested parrots' ability to detect sodium.

The attraction to sodium is by no means unique to parrots. Sodium accounts for more than 90 percent of extracellular fluid cations in vertebrate bodies in which it is required for the regulation of blood pressure, the conduction of nerve impulses, and muscle contraction (Guyton 1976, Randall *et al.* 1997). In domestic chickens, sodium deficiency results in weight loss, decreased egg production, increased susceptibility of chicks to disease, and cannibalism (Begin & Johnson 1976, Enos & Monsi 1977, Berger 1987, Pimentel & Cook 1987). Frugivorous and granivorous species (*e.g.*, parrots) may be particularly vulnerable (Symes *et al.* 2006), as sodium is not required by many plants (Epstein 1972, Klaus & Schmidt 1998) and, along with other soluble nutrients, is generally in low abundance in the Amazonian soils (Stark 1971a, Terborgh 1992) and flora (Stark 1971b).

Presumably, parrots that risk predation and pay the metabolic price of traveling to *collpas* (as much as 2 h and many kilometers; Munn 1992) are increasing their fitness in some way. In fact, Brightsmith (2004) and G. Powell (pers. obs.) have reported increased *collpa* use during the macaw nesting season, and *collpa* soil has been collected from the crops of macaw chicks in the region (D. Brightsmith, pers. obs.). While sodium is likely playing a key role in the selection of soils by parrots, we acknowledge that there are likely multiple physiological benefits of geophagy. We recommend that future work address the detoxifying potential of *collpa* soils, with bioassays that both accurately represent the gastrointestinal environment of psittacids and account for the variety of toxins in psittacid diets (Gilardi 1996). To assess the conservation value of this important yet commonly unprotected resource, future studies should determine if parrots obtain sodium from alternative sources and must ultimately comprehend how *collpa* use affects psittacid fitness.

ACKNOWLEDGMENTS

For their help with this project, we owe our gratitude to R. Amable, D. Cruz, E. Humme, A. Mishaja, K. Quinteros, and D. Ttito, (sample collection), C. Munn (lodging), M. Hunter, A. Drake, J. Gilardi, M. Kinneson and R. Holberton (editing and consultation), W. Broussard and B. Hoskins (laboratory work), G. Vigo Trauco (abstract translation), A. Lee and K. Adamek (*collpa* species diversity), W. Halteman (statistics), and two anonymous reviewers. We conducted this study in association with World Wildlife Fund's AREAS-Amazonia project, with funding from the Gordon and Betty Moore Foundation and the Amazon Conservation Association. Permit number for Los Amigos research concession and other nonpermanently protected areas: Autorización no. 0071–2006-INRENA-IFFS-DCB. Permit number for Tambopata National Reserve and Bahuaja Sonene National Park: Autorizacion no. 036 C/C-2006-INRENA-IANP. Samples were handled in compliance with Maine Soil Testing Service and the United States Department of Agriculture under permit number S-73788.

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

TABLE S1. *Avian species recorded eating soil at 18 collpas sampled in Southeastern Peru, 2006–2007.*

TABLE S2. *Mean (± SD) particle size percentages and available metal concentrations (in parts per million) of soils at 18 parrot collpas in southeastern Peru.*

FIGURE S1. Distribution of *collpa* and nearby control sites sampled in the Department of Madre de Dios, Peru.

LITERATURE CITED

BEGIN, J. J., AND T. H. JOHNSON. 1976. Effect of dietary salt on the performance of laying hens. Poultry Sci. 55: 2395.

BERGER, L. L. 1987. Salt and trace minerals for livestock, poultry and other animals, The Salt Institute, Alexandria, Virginia.

BEST, L. B., AND J. P. GIONFRIDO. 1991. Characterization of grit use by cornfield birds. Wilson Bull. 103: 68–82.

BOUL, S. W., F. D. HOLE, R. J. MCCRACKEN, AND R. J. SOUTHLAND. 1997. Soil genesis and classification, Iowa State University Press, Ames, Iowa.

BRAVO, A., K. E. HARMS, R. D. STEPHENS, AND L. H. EMMONS. 2008. *Collpas:* Activity hotspots for frugivorous bats (phyllostomidae) in the Peruvian Amazon. Biotropica 40: 203–210. [Correction added after online publication 3/25/09: correction to reference Bravo, A. 2008]

BRIGHTSMITH, D. J. 2004. Effects of weather on avian geophagy in Tambopata, Peru. Wilson Bull. 116: 134–145.

BRIGHTSMITH, D. J., AND R. ARAMBURÚ. 2004. Avian geophagy and soil characteristics in southeastern Peru. Biotropica 36: 534–543.

BRIGHTSMITH, D. J., J. TAYLOR, AND T. D. PHILLIPS. 2008. The roles of soil characteristics and toxin adsorption in avian geophagy. Biotropica 40: 766–774.

DIAMOND, J., K. D. BISHOP, AND J. D. GILARDI. 1999. Geophagy in New Guinea birds. Ibis 141: 181–193.

DOWNS C. T. 2006. Geophagy in the African Olive Pigeon *Columba arquatrix*. Ostrich 77: 40–44.

ENOS, H. L., AND A. MONSI. 1977. The effects of low dietary salt on egg production. Poultry Sci. 56: 1373.

EPSTEIN, E. 1972. Mineral nutrition of plants: Principles and perspectives, John Wiley and Sons, Inc., New York, New York.

GILARDI, J. D. 1996. Ecology of parrots in the Peruvian Amazon: Habitat use, nutrition, and geophagy. PhD Dissertation. University of California, Davis, California.

GILARDI, J. D., S. S. DUFFEY, C. A. MUNN, AND L. A. TELL. 1999. Biochemical functions of geophagy in parrots: Detoxification of dietary toxins and cytoprotective effects. J. Chem. Ecol. 25: 897–922.

GUYTON, A. C. 1976. Textbook of medical physiology, 5th edition. W. B. Saunders Co., Philadelphia, Pennsylvania.

HENRY, P. R., AND S. A. BENZ. 1995. Magnesium bioavailability. *In* C. B. Ammerman and A. J. Lewis (Eds.). Bioavailability of nutrients for animals, pp. 201–237. Academic Press, New York, New York.

HUNTER, J. M., AND R. D. KLEINE. 1984. Geophagy in Central America. Geogr. Rev. 74: 157–169.

JOHNS, T., AND M. DUQUETTE. 1991. Traditional detoxification of acorn bread with clay. Ecol. Food Nutr. 25: 221–228.

JONES, R. L., AND H. C. HANSON. 1985. Mineral licks, geophagy, and biogeochemistry of North American ungulates. Iowa State University Press, Ames, Iowa.

KLAUS, G., AND B. SCHMIDT. 1998. Geophagy at natural licks and mammal ecology: A review. Mammalia 62: 481–497.

MACQUARRIE, K. 2001. Where the Andes meet the Amazon, Peru and Bolivia's Bahuaja Sonene and Madidi National Park, Jordi Blassi, Barcelona, Spain.

MAHANEY, W. C., AND R. KRISHNAMANI. 2003. Understanding geophagy in animals: Standard procedures for sampling soils. J. Chem. Ecol. 29: 1503–1523.

MILLER, R. G. 1981. Simultaneous statistical inference, 2nd edition. Springer-Verlag, New York, New York.

MILLER, R. O., J. KOTUBY-AMACHER, AND J. B. RODRIGUEZ. 1998. Western states laboratory proficiency testing program: Soil and plant analytical methods, version 4.10. Utah State University, Logan, Utah.

MUNN, C. A. 1992. Macaw biology and ecotourism, or when a bird in the bush is worth two in the hand. S. R. Beissinger and N. F. R. Snyder (Eds.). *In* New world parrots in crisis, pp. 47–72. Smithsonian Institution Press, Washington, DC.

OATES, J. F. 1978. Water-plant and soil consumption by guereza monkeys *Colobus guereza*: A relationship with minerals and toxins in the diet? Biotropica 10: 241–253.

PIMENTEL, J. L., AND M. E. COOK. 1987. Suppressed hormonal immunity in chicks fed diets deficient in sodium, chloride, or both sodium and chloride. Poultry Sci. 66: 2005–2010.

REMSEN, J. V., JR., C. D. CADENA, A. JARAMILLO, M. NORES, J. F. PACHECO, M. B. ROBBINS, T. S. SCHULENBERG, F. G. STILES, D. F. STOTZ, AND K. J. ZIMMER. 2009. A classification of the bird species of South America. American Ornithologists' Union. (Version: January). Available at: http://www.museum.lsu.edu/~Remsen/SACCBaseline.html (accessed January 2009).

RANDALL, D., W. BURGGREN, AND K. FRENCH. 1997. Eckert animal physiology: Mechanisms and adaptations, 4th edition. W. H. Freeman and Company, New York, New York.

STARK, N. M. 1971a. Nutrient cycling: I. Nutrient distribution in some Amazonian soils. Trop. Ecol. 12: 24–50.

STARK, N. M. 1971b. Nutrient cycling: II. Nutrient distribution in some Amazonian vegetation. Trop. Ecol. 12: 177–207.

SYMES, C. T., J. C. HUGHES, A. L. MACK, AND S. J. MARSDEN. 2006. Geophagy in birds of Crater Mountain Wildlife Management Area, Papua New Guinea. J. Zool. 268: 87–96.

TAN, K. H. 1996. Soil sampling, preparation and analysis, Marcel Dekker, New York, New York.

TERBORGH, J. 1992. Diversity and the tropical rain forest, Scientific American Library, New York, New York.

VERMEER, D. E., AND R. R. J. FERRELL. 1985. Nigerian geophagical clay: A traditional antidiarrheal pharmaceutical. Science 227: 634–636.

ZAR, J. H. 1972. Significance testing of the spearman rank correlation coefficient. J. Am. Stat. Assoc. 67: 578–580.