

## **Nutrients Drive Termite Nest Geophagy in Yellow-chevroned Parakeets (*Brotogeris chiriri*)**

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## Nutrients Drive Termite Nest Geophagy in Yellow-chevrons Parakeets (*Brotogeris chiriri*)

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**ABSTRACT.**—We observed Yellow-chevrons Parakeets (*Brotogeris chiriri*) consuming soil from arboreal termite nests while excavating a nest cavity.

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As most observations of parrot geophagy come from clay licks, this observation prompted questions about the benefits of consuming termite nest soil rather than ground soil. We compared nutrient contents and chemical properties (organic matter, pH, cation exchange capacity, macro and micronutrients) from these two types of soil. Termite nest soil had higher concentrations of macronutrients and cation exchange capacity than ground soil, which may be related to mineral supplementation and binding of toxins present in fruits consumed by the Yellow-chevrons Parakeet. Received 20 September 2014. Accepted 17 January 2015.

**Key words:** *Brotogeris chiriri*, cation exchange capacity, macronutrients, micronutrients, mineral supplementation, Yellow-chevrons Parakeet.

Geophagy, the deliberate ingestion of soil, is carried out by a wide range of vertebrates (Abrahams and Parsons 1996, Krishnamani and Mahaney 2000). Several physiological benefits have been proposed to explain geophagy, such as mineral supplementation, attenuation of dietary toxins, gastrointestinal cytoprotection, mechanical aid to digestion, pH buffering, and treatment for parasites and diarrhea (Mahaney et al. 1996, Diamond et al. 1999, Brightsmith and Muñoz-Najar 2004). Most of these hypotheses remain insufficiently tested, and many studies focus on observational studies of geophagy (Wilson 2003). Field studies that combine behavioral observations with ecological and chemical analysis have provided evidence that mineral supplementation and adsorption of dietary toxins are the main drivers of geophagy in natural populations of vertebrates (Gilardi et al. 1999, Brightsmith and Muñoz-Najar 2004, Brightsmith et al. 2008).

An effective way to evaluate the role of geophagy is to analyze the characteristics of the consumed soil. Depending on the chemical composition and nutrients present, the ingested soil may have different properties and act on different physiological functions (Mahaney et al. 1996, Wilson 2003). Most of the information about soil traits came from clay licks, which are the main sources of soil for geophagy by mammals and birds (Jones and Hanson 1985). The importance of clay licks as sources of minerals is suggested to positively influence species richness in western lowland Amazon forests (Lee et al. 2010, Blake et al. 2011). However, clay licks form discrete patches and are not widely distributed outside of Amazonian habitats, where other sources of soil and clay are available. For instance, some Neotropical parrots consume dry ground soil (Severo-Neto 2012), while African primate species consume termite soil as a source of mineral supplementation and pH buffering (Mahaney et al. 1996, Krishnamani and Mahaney 2000, de Souza et al. 2002).

Here, we report and comment on arboreal termite nest geophagy by the Yellow-chevroned Parakeet (*Brotogeris chiriri*) during the excavation of nest cavities. We compared pH, organic matter, and macro and micronutrient contents between ground soil and termite nest to explore possible advantages in consuming soil from termite nests rather than soil from other sources.

## METHODS

The study was conducted in an urban protected area of 55 ha in the state of Mato Grosso do Sul, Brazil (20° 30' 16.29" S, 54° 36' 49.90" W). This area includes cerrado and gallery forests where arboreal termite nests are abundant. We selected a 400-m trail in the gallery forest for field observations and soil sampling, and made daily morning observations sessions from June to September in 2009 and 2010. We selected six arboreal termite nests on which we observed geophagy by *B. chiriri*, and collected samples of such nests and the ground soil immediately below the nests. Soil nutrient analyses were carried out at Agência Estadual de Defesa Sanitária Animal e Vegetal (IAGRO) to assess pH in water, concentrations of organic matter (sulfocromic solution oxidation with external heat), cation exchange capacity (H + Al, SMP-buffer solution), exchangeable Ca, Mg and Al (extractant KCl 1 mol/L), available K, P, Fe, Zn, Mn and Cu (extractant Mehlich-1) according to EMBRAPA (1997). All these nutrients are associated with physiological functions in vertebrates (Marshall and Hughes 1980). Unfortunately, we could not carry out a sodium content analysis due to logistical constraints, which has been suggested as one of the main drivers of geophagy in vertebrates (Brightsmith et al. 2008, Powell et al. 2009, Dudley et al. 2012).

To test if the nutrient contents differ between ground soil and the arboreal nest, we performed Principal Component Analysis and compared the scores generated in the first four axes (variance explained = 91.0%) using a MANOVA. Additionally, we compared individual concentrations of nutrients between ground and arboreal nest soil using paired *t*-tests.

## RESULTS

We observed pairs of *B. chiriri* nesting in six abandoned arboreal termite nests. Arboreal termite nests do not naturally contain large holes, thus parakeets need to excavate an adequate cavity for nesting. Both males and females scrape the nest walls with their bills. During the scraping process, we observed individuals consuming pieces of the nest walls or tearing splinters and chewing them at least one time at each of the six termite nests. This behavior was observed in August and September, mainly in the early morning (0630–0730 hrs).

Ground soil and arboreal termite nests had distinct nutrient contents (MANOVA, Wilk's  $\lambda =$

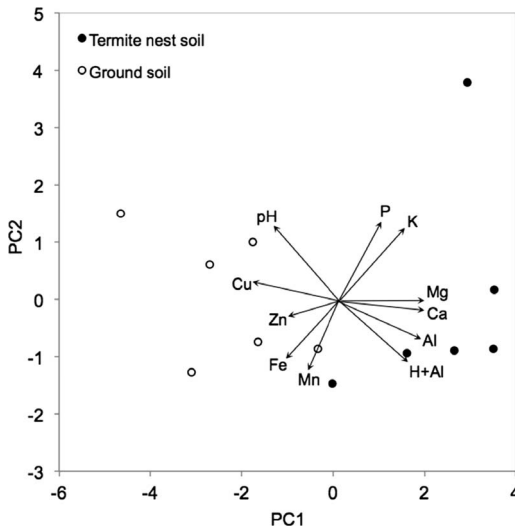


FIG. 1. PCA biplot (variance explained = 91.0%) of nutrient contents and chemical properties in termite nest soil (consumed by the Yellow-chevroned Parakeet) versus ground soil.

0.16,  $P < 0.01$ ; Fig. 1). Termite nests had significantly higher concentrations of organic matter, K, Mg, Al, H + Al, but lower pH, and lower concentrations of Fe and Cu (Table 1). Concentrations of K and Al were, respectively, almost 10 and 16 times higher in termite nests than in ground soil (Table 1).

## DISCUSSION

Nesting in arboreal termite nests is well known for small Neotropical parrots (Sick 1997, Brightsmith 2000, Paranhos and Marcondes-Machado 2000). Besides the benefits of nest protection against predators and rain, the use of arboreal nests guarantees stable and favorable temperatures and humidity for nesting (Noirot 1970, Dechmann et al. 2004). Birds usually nest in active termitaria, because abandoned ones tend to be fragile and fall more easily (Hardy 1963, Collias and Collias 1984). However in the present study, *B. chiriri* only occupied deserted termite nests, which is an occasional behavior of *Brotogeris* parakeets in the Peruvian Amazon (Brightsmith 2000). In our study area, active termite nests are occupied by an aggressive species (*Nasutitermes* spp.), and any physical damage to the nest cause massive attacks by termite soldiers (RC-P, pers. obs.); this may explain why *B. chiriri* avoid scraping the surface of active nests. Also, it is easier for birds to dig

TABLE 1. Comparison of pH, organic matter, cation exchange capacity (H + Al), macro and micronutrient contents of arboreal termite nests consumed by *Brotogeris chiriri* and ground soil. All values (less pH) are given in ppm. Higher values are in bold.

	Arboreal termite nest	Ground soil
pH	5.4 ± 0.56	<b>6.2 ± 0.63*</b>
Organic matter	<b>31,500 ± 20,000*</b>	62,800 ± 34,900
Cation exchange capacity	<b>1107 ± 5700*</b>	389 ± 208
<i>Macronutrients</i>		
Phosphorus (P)	<b>36.53 ± 27.77</b>	19.4 ± 17.7
Potassium (K)	<b>569.4 ± 487.5*</b>	58.5 ± 46.8
Calcium (Ca)	<b>2,010 ± 820</b>	1,354 ± 484
Magnesium (Mg)	<b>554.4 ± 48*</b>	308.4 ± 144
Aluminium (Al)	<b>43.2 ± 16.2*</b>	2.7 ± 4.5
<i>Micronutrients</i>		
Iron (Fe)	23.55 ± 18.28	<b>62.07 ± 37.06*</b>
Manganese (Mn)	31.87 ± 16.52	<b>42.87 ± 27.55</b>
Cooper (Cu)	0.64 ± 0.38	<b>4.56 ± 2.07*</b>
Zinc (Zn)	3.56 ± 1.59	<b>7.48 ± 6.38</b>

\* Significantly at  $p < 0.05$ .

a cavity through abandoned termite nests, since they are more fragile than active ones (Collias and Collias 1984).

Records of geophagy on arboreal termite nests involves primate species, which are benefited by mineral supplementation and stomach pH buffering (Mahaney et al. 1996, Krishnamani and Mahaney 2000, de Souza et al. 2002). The parakeet *Brotogeris chiriri* seems to be the first parrot species recorded consuming soil directly from arboreal termite nests. Similarly, the Blue-winged Parrotlet (*Forpus xanthopterygius*) was observed scraping the clay nests of the Rufous Hornero (*Furnarius rufus*), which may be related to mineral supplementation as well as testing the nest as a breeding site (Sazima 2008).

Termite nest composition is a mixture of soil, clay, organic matter, feces, and saliva (Noirot 1970). Components other than soil and the biochemical processes involved in termite nest building may explain the differences in chemical and nutritional composition of arboreal termite nests and ground soil. The higher percentage of organic matter in arboreal nests suggests that termites concentrate specific components available in lower amounts in the soil. Basic soils could act as an antacid, buffering low pH values in the stomach, and termite mounds may have basic pH (Krishnamani and Mahaney 2000). Although arboreal termite nests had lower pH

than ground soil in our study area, both termite nests and ground soil are acid (5.4 versus 6.2, respectively). Thus, the geophagy by Yellow-chevroned Parakeet is not likely related to gastric pH buffering, as suggested in some primates (Mahaney et al. 1996, Krishnamani and Mahaney 2000).

Because the cation exchange capacity of the studied termite nests was almost three times higher than ground soil, it may provide an important physiological function, especially for frugivorous vertebrates (Cipollini and Levey 1997). The Yellow-chevroned Parakeet consumes mainly mature and unripe fruits and complements its diet with seeds, flowers, and nectar (Ragusa-Netto 2004). These food items may have elevated concentrations of secondary compounds, such as positively charged alkaloids and tannic acids (Gilardi et al. 1999). The binding of such toxins by fine clay particles with high cation exchange capacity (Burchill et al. 1981) may explain *B. chiriri* consumption of soil from termite nests rather than from the ground.

In general, macronutrients had high values in the studied arboreal termite soil nests. Since scraping of termite nests occurs during the breeding season, geophagy may supply macronutrients to egg formation and embryo development. For instance, calcium and manganese act on the formation of eggshells and bones, and on the contraction of the uterus during egg laying, while deficiencies of iron and copper can lead to anemia and loss of pigmentation in the feathers (de Vries et al. 2010, Veum 2010). Other macronutrients are also essential to growth and have important physiological functions related to the immune and nervous systems (Barboza et al. 2009, Bicudo et al. 2010).

In conclusion, we suggest that the consumption of soil from arboreal termite nests may have multiple advantages for the Yellow-chevroned Parakeet in our study area. Apart from providing a safe site for nesting, the consumption of arboreal termitaria during nest excavation may supply nutrients with important physiological functions and bind toxins present on fruits consumed by *B. chiriri*. Further studies comparing nutrient levels in food resources versus feces versus soil, and quantifying sodium content in termite versus ground soil may help clarify the physiological advantages of termite soil consumption by *B. chiriri* (see Brightsmith et al. 2008, 2010; Dudley 2012).

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## Resting Metabolic Rates of Adult Northern Shrikes (*Lanius excubitor*) Wintering in Northern Wisconsin

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**ABSTRACT.**—Resting metabolic rate (RMR) represents a significant component of an animal’s energy budget and is correlated with ecological, physiological, and life-history parameters. We measured resting metabolic rates of 14 adult Northern Shrikes

(*Lanius excubitor*) wintering in northern Wisconsin (Ashland and Bayfield Counties) over a 2-year period (Jan–Apr 2008 and 2009). The average ( $\pm$ SE) RMR was  $3.09 \pm 0.45$  ml O<sub>2</sub>/g/hr (range 2.46–3.83) from the first reported RMR values for adults of this species from the Nearctic. Our RMR values were 50% higher than RMRs gathered from summer adult Northern Shrikes in the Palearctic. These data suggest Northern Shrikes exhibit seasonal variation in their RMR as a potential means of winter acclimatization. *Received 16 April 2014. Accepted 17 January 2015.*

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**Key words:** avian physiology, basal metabolic rate, *Lanius excubitor*, Northern Shrike, winter acclimatization.