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APPARENT SOIL INGESTION BY FEMALE ESMERALDAS WOODSTARS (*CHAETOCERCUS BERLEPSCHI*) IN WESTERN ECUADOR

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Resumen. – Las hembras de la estrellita esmeraldeña (*Chaetocercus berlepschi*) comen suelo rico en minerales en el occidente del Ecuador. – Los colibríes comen suelo en una variedad de hábitats tropical y templado aparentemente para suplementar su dieta con minerales. Observamos hembras de un colibrí amenazado, la estrellita esmeraldeña *Chaetocercus berlepschi* aparentemente comiendo suelo desde orillas del río en las bajuras del occidente del Ecuador cinco veces. Analizamos muestras de suelo desde sitios de comer y control (localizados aproximadamente 40 m desde sitios de comer) para cuantificar niveles de nueve minerales, pH, y material orgánica. Sitios de comer y control tuvieron niveles altos de calcio, magnesio, y potasio comparado a niveles estándares para la costa del Ecuador. Hipotetizamos que hembras de *C. berlepschi* comen suelo para neutralizar el perdido de nutrientes que empeorar por el estrés de reproducción.

Abstract. – Hummingbirds ingest soil in a variety of tropical and temperate habitats, apparently to supplement their diet with minerals. We observed females of a threatened hummingbird species, the Esmeraldas Woodstar (*Chaetocercus berlepschi*), apparently eating soil from exposed river banks in the lowlands of western Ecuador on five occasions. We analyzed soil samples from these and control sites (~ 40 m from eating sites) to quantify levels of nine minerals, pH, and organic material. Eating and control sites alike had high levels of calcium, magnesium, and potassium compared to standard values for coastal Ecuador. We hypothesize that female Esmeraldas Woodstars consume soil to counteract nutrient loss which may be exacerbated by the stresses of breeding. *Accepted 3 August 2012.*

Key words: Esmeraldas Woodstar, *Chaetocercus berlepschi*, Ecuador, geophagy, nutrient, Trochilidae.

INTRODUCTION

Birds ingest soil for a variety of reasons including absorption of dietary toxins (Diamond *et al.* 1999, Brightsmith *et al.* 2008), mineral supplementation (Schuchmann 1980, Adam & des Lauriers 1998, Brightsmith & Muñoz Najar 2004), and aiding digestion (Gionfriddo & Best 1999). The nectarivorous diet of hummingbirds leads to excess water intake and copious urine production which causes reductions of ionic salts in the blood

(Calder & Hiebert 1983, Graves 2007). Many of these salts can be recovered in trace amounts in nectar and the insect diet (Calder & Hiebert 1983), but a growing body of observations suggest that hummingbirds ingest mineral-rich compounds (soil, ashes, lime, or even sea water) to help counteract the loss of ions (e.g., Bacon 1973, Adam & des Lauriers 1998). Osmotic regulation is more difficult in regions of temperature extremes where hummingbirds must manage water excesses and shortages, in cold and hot regions, respectively (Calder 1979). Lowland and highland tropical hummingbirds are subject to such temperature extremes. At least five species of tropical hummingbirds, Glittering-throated Emerald (*Amazilia fimbriata*) (Haverschmidt 1952), Red-billed Streamertail (*Trochilus polytmus*) (Schuchmann 1980), Vervain Hummingbird (*Mellisuga minima*) (Graves 2007), Jamaican Mango (*Anthracothorax mango*) (Graves 2007), and Giant Hummingbird (*Patagona gigas*) (Estades *et al.* 2008), have been documented eating soil or ashes. So far, all records of hummingbirds eating mineral rich compounds have involved females, which suggests mineral shortages are exacerbated by egg production (Verbeek 1971, Graves 2007, Estades *et al.* 2008).

Here we report apparent soil ingestion by female Esmeraldas Woodstars (*Chaetocercus berlepschi*) on their breeding grounds in coastal western Ecuador. Esmeraldas Woodstars breed in lowland and foothill moist forest in Manabí and Esmeraldas provinces (Juiña *et al.* 2010) from December to May, and then move, at least, to the subtropical west slope of the Andes (Fogden 2012; the non-breeding range is still poorly known). Forests in the woodstar's range have been heavily fragmented (Dodson & Gentry 1991), apparently leading to a severe population decline (Ridgely & Greenfield 2001, BLI 2009). The species's IUCN global conservation status is Endangered (BLI 2009, Harris *et al.* 2009).

METHODS

We observed female Esmeraldas Woodstars apparently ingesting soil on nine occasions: from 08:00–10:00 h EST on 8 and 9 January 2008 at Río Ayampe (1°40.98'S, 80°48.05'W; 40 m a.s.l.), from 14:30–16:30 h on 6 April 2008 at Río Chico (1°36.45'S, 80°49.50'W; 60 m a.s.l.), at 09:45 h on 20 March 2008 and at 17:30 h on 6 March 2009 at Salango (1°35.37'S, 80°49.60'W; 50 m a.s.l.), and at 15:00 h on 22 March 2008 at San José (1°44.93'S, 80°45.44'W; 30 m a.s.l.) (see Juiña *et al.* 2010 for a map of the species' breeding area). Female woodstars were seen apparently ingesting soil from exposed river banks from 2–4.5 m above the river. At some eating sites there were a few spider webs, but no insects, so it seems unlikely that the birds were foraging. It is possible that spider webs were collected for nest construction at some sites, but we never observed woodstars targeting spider webs. The birds are so tiny (among the smallest birds in the world) that it is unlikely foraging individuals would leave marks where they harvested soil; we found no such marks. We postulated that the woodstars were ingesting soil for its mineral content.

We collected soil samples from eating and nearby control sites (30–50 m away) in order to (1) compare mineral concentrations at both eating and control sites to standard mineral concentrations for coastal Ecuador, and (2) evaluate if the eating sites were localized foci of mineral resources compared to the nearby controls. Given the tendency for hummingbirds to ingest mineral-rich soil (e.g., Verbeek 1971, Estades *et al.* 2008), we hypothesized that eating and control sites would have higher concentrations of minerals, such as calcium, compared to average soils in the region, and that the eating sites would have higher concentrations of minerals compared to controls.

We collected 0.5 kg of soil from the surface of eating and control sites at Ayampe, Río Chico, and Salango (group 1, Table 1) from 5–6 March 2009. We collected additional samples from the same sites in 14 January 2011 (group 2, Table 1). The second sampling session was done in an effort to provide some control for seasonal variation in mineral composition, perhaps due to leaching from rainfall. The small sample sizes and pseudoreplication from sampling near the same sites a year later make it inappropriate to make statistical comparisons of the data.

Mineral concentrations were analyzed at the Laboratorio de suelos y aguas, Agencia Ecuatoriana de Aseguramiento de la Calidad del Agro, Tumbaco, Ecuador. Several methods were used to measure soil composition and physical attributes in the laboratory. Soil was added to 2.5-fold (by volume) of water (pH 6.5) to measure pH. The amounts of total organic material and total nitrogen were calculated from a Walkley Black analysis (Nelson & Sommers 1982, Krishnan *et al.* 2009). A modified Olsen method (Olsen *et al.* 1954; sodium bicarbonate, pH 8.5, with colorometry and photometry) was used for phosphorus and potassium. A modified Olsen method (sodium bicarbonate + EDTA, pH 8.5 with atomic absorption) was used for intermediates or secondaries (calcium and magnesium) and micro elements (iron, magnesium, copper, and zinc). Atomic absorption was used for base saturation and extracted bases (calcium, magnesium, sodium, potassium). Titration with sulphuric acid was used for extraction with ammonium acetate (pH 7) CIC. The Yuan method (extraction with potassium chloride N) was used total acidity (aluminum and changing hydrogen).

RESULTS

Soils apparently ingested by Esmeraldas Woodstars have high concentrations of calcium (mean of 36.1 cmol/kg ± 9.0 SE, 4 times higher than the threshold for high calcium content in coastal Ecuador, 9 cmol/kg), and magnesium (mean of 13.4 cmol/kg ± 4.2 SE, 5.8 times higher than the threshold for coastal Ecuador of 2.3 cmol/kg) (Table 1, Appendix 1). Average potassium concentrations (mean 0.88 cmol/kg ± 0.3 SE) were approximately double the threshold value for high concentrations in coastal Ecuador (0.4 cmol/kg), although two of the six eating sites had moderate to low potassium concentrations. High values of phosphorus and copper were found in two of the six eating samples, and one eating sample had elevated manganese. Eating and control sites had similar mineral concentrations, although calcium and magnesium, but not potassium, concentrations were higher at eating sites compared to controls. Results were similar in group 1 (collected in 2009) and group 2 (collected in 2011) although calcium concentrations tended to be higher in group 2 samples. Although we could not make statistical comparisons, the results indicate control and eating sites had broadly similar mineral levels.

DISCUSSION

Our results show that sites where Esmeraldas Woodstars ingested soil have very high concentrations of calcium and magnesium, and high concentrations of potassium compared to standard concentrations for coastal Ecuador. There is also some evidence for high concentrations of phosphorus, copper, and manganese. A previous study found that soils ingested by Rufous Hummingbirds (*Selasphorus rufus*) in Oregon, USA showed high levels of calcium [11.2 cmol/kg (4480 ppm) and 21.2 cmol/kg (8500 ppm)], magnesium [4.2 cmol/kg (1020 ppm)], and potassium [0.86 cmol/kg (335 ppm)], and low/moderate levels of phosphorus (6 and 16 ppm) (Adam & des Lauriers 1998). In addition, soils eaten by

TABLE 1. Mineral levels in soil collected at sites where Esmeraldas Woodstars were seen ingesting soil ("eating") and at sites c. 40 m away from eating sites ("control"). Site names are abbreviated followed by an E for eating sites or a C for control sites. RA = Río Ayampe; RC = Río Chico; S = Salango. All sites were sampled in March 2009 (group 1) and January 2011 (group 2). Bold indicates high concentrations of minerals relative to baseline soil in coastal Ecuador (see Appendix 1).

Site	Group	pH	Calcium (Ca, cmol/kg)	Potassium (K, cmol/kg)	Nitrogen (N, %)	Phosphorus (P, PPM)	Magnesium (Mg, cmol/kg)	Iron (Fe, PPM)	Manganese (Mn, PPM)	Copper (Cu, PPM)	Zinc (Zn, PPM)	Organic Material (O. M., %)
RAE	1	7.16	**19.85**	0.2	trace	3	**27.16**	8.8	8.1	2.2	0.8	trace
RAC	1	7.55	**16.3**	0.35	0.14	3.4	**21.81**	9.1	8.9	**4.2**	1.2	2.85
RCE	1	6.74	**15.6**	**2.04**	0.01	**33.7**	**3.7**	7.4	10.1	**4.3**	1.2	0.21
RCC	1	7.87	**13.4**	**8.18**	0.01	**27.3**	**3.29**	7.2	4.8	3.5	1	0.28
SE	1	5.8	**19.3**	**0.86**	0.06	1.8	**21.39**	17.9	**17.5**	**5.8**	2.9	1.26
SC	1	7.88	**14.3**	**1.78**	**0.35**	**21.9**	**5.18**	8.8	9	3.6	1	0.7
RAE	2	7.59	**72**	0.15	0.02	1	**18.51**	12	4	3	1	0.48
RAC	2	7.86	**17.15**	**2.09**	0.09	2	**4.93**	12	2	2	1	1.84
RCE	2	7	**42.75**	**1.37**	0.01	**22**	**3.29**	11	9	3	1	0.28
RCC	2	7.47	**44.25**	0.15	0.03	1	**16.88**	4	3	1	1	0.62
SE	2	6.68	**47.25**	**0.66**	0.15	1	**6.5**	31	18	3	2	2.98
SC	2	7.67	**16.55**	**1.37**	0.06	11	**4.28**	24	11	3	1	1.3
Eating Mean ± SE		6.8 ± 0.25	**36.1 ± 9.0**	**0.88 ± 0.3**	0.04 ± 0.02	10.4 ± 5.7	**13.4 ± 4.2**	14.7 ± 3.6	11.1 ± 2.3	3.6 ± 0.53	1.5 ± 0.33	0.87 ± 0.46
Control Mean ± SE		7.7 ± 0.07	**20.3 ± 4.8**	**2.3 ± 1.2**	0.11 ± 0.05	11.1 ± 4.6	**9.4 ± 3.2**	10.9 ± 2.8	6.5 ± 1.5	2.9 ± 0.48	1 ± 0.03	1.3 ± 0.39

an Anna's Hummingbird (*Calypte anna*) had high calcium levels [58.6 cmol/kg (23,500 ppm)] (Verbeek 1971). We did not test for sodium levels, but avian geophagy sites are often important sources of sodium (Brightsmith & Muñoz Najar 2004, Powell *et al.* 2009). We hypothesize that Esmeraldas Woodstars ingest soil to recover minerals lost during reproduction and diuresis, and perhaps to aid digestion.

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APPENDIX 1. Reference mineral concentrations in coastal Ecuador. Values in Table 1 are bold if they exceed the threshold for a high concentration in coastal Ecuador. Data are from the Laboratorio de suelos y aguas, Agencia Ecuatoriana de Aseguramiento de la Calidad del Agro, Ecuador.

	Ca, cmol/kg	K, cmol/kg	N, %	P, PPM	Mg, cmol/kg	Fe, PPM	Mn, PPM	Cu, PPM	Zn, PPM	O. M., %
Low	< 5	< 0.2	0-0.15	0-10	< 1.6	0-20	0-5	0-1	0-3	< 3.1
Medium	5-9.0	0.2-0.38	0.15-0.3	10-20.0	1.6-2.3	21-40	6-15.0	1.1-4	3.1-6	3.1-5.0
High	> 9	> 0.4	>0.3	> 21	> 2.3	> 41	> 16	> 4.1	> 6.1	5