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ADDITIONAL INFORMATION ON THE USE OF TARTAR EMETIC IN DETERMINING THE DIET OF TROPICAL BIRDS

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Abstract. We evaluated the effect and effectiveness of antimony potassium tartrate (tartar emetic) on 137 bird species from 29 families and subfamilies from one humid forest site and two mangrove sites in central Panama. Of the 2,656 birds forced to regurgitate, we obtained 1,942 diet samples comprising 12,608 taxonomically identified items. Seventy birds (2.6%) died after administration of the emetic, with some Trochilidae (*Phaethornis*) and Pipridae (*Pipra, Manacus*) being especially sensitive to the chemical. No significant differences were found between the number of items regurgitated and that found in stomach contents. However, regurgitations using tartar emetic appeared to be more efficient than analyses of feces to investigate food preference. We also provide details on how to process samples of hummingbirds to permit pollen (flower) identification.

Key words: Regurgitation; tartar emetic; diet; tropical land birds; Panama.

INTRODUCTION

Previously (Poulin et al. 1994a), we evaluated the effect and effectiveness of antimony potassium tartrate (tartar emetic) on 3,419 resident and migrant land birds from 82 species inhabiting various semiarid tropical habitats in northeastern Venezuela. We concluded that tartar emetic was an efficient and harmless technique to investigate food preferences of birds from any feeding habit.

This study reports on an additional 115 bird species subjected to the chemical. Nine new bird families (Tinamidae, Ardeidae, Accipitridae, Falconidae, Jacanidae, Scolopacidae, Trogonidae, Momotidae, Rhamphastidae) are considered, in addition to several species from families that were poorly represented in our initial work, such as Alcedinidae, Formicariidae, Pipridae, Troglodytidae, and Turdinae. According to Poulin et al. (1994a), the effect and effectiveness of the method varied according to body mass, with mortality higher in smaller birds and effectiveness lower in heavier birds. Here, we present a modification of the emetic dosage to address those problems. We also compare samples made of regurgitations vs. feces in terms of their recognizable food content. Finally, we provide details on how to process emetic samples from hummingbirds to identify the flower species from pollen grains. Although hummingbirds do not generally feed intentionally on pollen (but see Carpenter and Castronova 1980), they ingest pollen that falls into nectar at the flowers (Roubik 1991), and often collect pollen on their bill and forehead while foraging (Bent 1940). Identification of pollen taken from pollinators has been done with bees (Roubik 1991, Vit and Ricciardelli d'Albore 1994), but has never been attempted with nectarivorous birds to our knowledge.

METHODS

This study was carried out in three sites in central Panama from August 1993 through November 1994. Birds were sampled in a humid forest site in the Soberania National Park near Gamboa (9°10′N, 79°7′W), as well as in black mangrove near Galeta (9°20′N, 79°9′W) and Juan Diaz (9°00′N, 79°4′W). A total trapping effort of 22,000, 500, and 575 net-hours was done at each study site, respectively. Netting sessions using 3 × 10 m, 32 mm-mesh mist-nets were carried out mostly from sunrise till noon. Each bird captured was banded, weighed, forced to regurgitate, and released.

Regurgitation samples were obtained by orally administering tartar emetic to the birds following the method of Poulin et al. (1994a). However, the dosage of 0.8 cm^3 of a 1.5% solution of antimony potassium tartrate per 100 g of body mass was modified for birds smaller than 10 g and heavier than 40 g. For small passerines (<10 g), water was added to the regular dosage of the 1.5% solution enough to reach 0.1 cm^3 of injected liq-

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uid. Birds weighing between 40 and 100 g were given 1.0 cm^3 of 1.5% solution per 100 g of body mass. Larger birds and Columbidae of any size were injected from 1.3 to 2 cm^3 of 1.5% solution per 100 g, depending on the bird's response. For hummingbirds and manakins, the concentration of emetic was lowered from 1.5 to 0.75% over the course of the study.

The solution was given slowly through a 1.5-mm diameter flexible plastic tube attached to a 1-cc syringe. The tube was inserted through the bird's throat as far as possible, presumably into the gizzard. In hummingbirds, the tube was inserted to the larynx only and their bill and forehead were brushed with fine forceps to collect pollen. After administration of the chemical, the bird was kept in a small dark box lined with absorbent paper (wax paper for hummingbirds) for 20 min. Hummingbirds showing signs of torpor after the 20-minute period were given a sugar solution *ad libitum* and generally flew away within a few seconds. Samples that contained feces only were considered apart. Food items were preserved in 70% ethanol and taxonomically identified in the laboratory using a dissecting scope.

Samples from hummingbirds (coming from droppings, regurgitations and the bird's bill and forehead) were preserved in 70% ethanol in 5 ml plastic bottles. Arthropods were removed and the samples processed by acetolysis following a modified procedure of Roubik and Moreno (1991) for pollen identification. The bottles were first centrifuged for 5 min at high speed, after which the supernatant (ethanol) was carefully discarded using glass Pasteur pipette. Bottles were then two-third filled with concentrated (99%) glacial acetic acid, and centrifuged again for 5 min. After the supernatant was removed, bottles were two-third filled with a 9:1 mixture of 99% anhydrous acetic acid and 99% sulfuric acid (acetolysis solution), stirred, and placed in boiling water for approximately 15–20 min or until the sample darkened considerably. Bottles were centrifuged, and once the supernatant was removed, they were filled with distilled water, stirred, and centrifuged again. After discarding as much water as possible, bottles were kept in an oven at 60–80°C until most of the liquid was evaporated. Samples of pollen were then picked up with a dissecting needle covered with a small amount of glycerine jelly. The glycerine-pollen mixture was deposited on a microscope glass slide and topped with a coverslip surrounded by paraffin shavings. The microscope slides were heated on a hot plate, and then cooled to make permanent slides. Pollen grains were identified and counted (semi-quantitative scale) using a light microscope. Only flower species represented by at least 5 pollen grains on a slide were considered to avoid biases associated with pollen contamination (e.g., wind-dispersed pollen on the bird's feather, ingested nectar contaminated with pollen from another flower species, etc.). This technique can be used with pollen collected directly from the flowers to make a reference collection for pollen identification.

RESULTS

A total of 2,656 birds (1,953 in the humid forest, 701 in mangroves, two in captivity) representing 137 species and 29 families and subfamilies were forced to regurgitate (Table 1). Of these we obtained 1,942 (73%) emetic samples, in addition to 331 (12%) dropping samples.

Over 95% of the emetic samples contained taxonomically identified food items, compared to 80% for droppings. More importantly, the mean number of food items identified was significantly higher in regurgitations than in feces [6.5 vs. 1.5, Kruskal-Wallis ANOVA (K–W), $H = 338.8$, $df = 1$, $P < 0.001$]. Some 44 birds whose death was related to sampling hazards (predation, drowning, capture stress, emetic treatment) were dissected for stomach contents. An average of 8.4 items were found in their stomach which did not differ significantly from the numbers found in regurgitations (K–W, $H = 3.2$, $df = 1$, ns). Overall, 12,608 food items were identified, including 22 invertebrate taxa, 79 fruit species, 108 flower (pollen) species, and several vertebrate species among fishes, frogs, and lizards.

Seventy birds (2.6%) died after administration of the chemical. Birds that did not regurgitate were more likely to die ($G = 19.5$, $df = 1$, $P < 0.001$). There was no significant difference in the frequency of regurgitation ($G = 0.46$, $df = 1$, ns) and the occurrence of mortality ($G = 1.05$, $df = 1$, ns) between birds smaller than 50 g and birds of 50 g of more.

COMPARISONS AMONG BIRD FAMILIES

The effect and efficiency of the emetic technique appeared to be similar for most bird families (Table 1). No significant difference was found in the proportion of birds that regurgitated except for Trochilidae ($G = 11.7$, $df = 2$, $P < 0.05$) and

TABLE 1. Sample size and efficiency of tartar emetic for each bird family and subfamily.

Family-subfamily (number of species)	Number of individuals injected	% Regurgitation[2]	% Feces only	% Mortality[2]	Mean number of food items[1]		
					Regurgitation[2] $n = 1,939$	Feces $n = 383$	Stomach $n = 44$
Tinamidae (1)	1	0	100	0	0	1.0	
Ardeidae (1)	1	100	0	0	10		
Accipitridae (1)	1	0	0	0	0		
Falconidae (2)	3	66.7	33.3	0	5.0	0	
Jacanidae (1)	2	100	0	0	—		
Scolopacidae (1)	3	66.7	33.3	0	3.0	0	
Columbidae (5)	37	59.5	21.6	0	5.4	0.4	
Cuculidae (1)	1	100	0	0	1.0		
Trochilidae (12)	452	57.3*	2.4	4.9*	5.7	0.8	12.2
Trogonidae (2)	9	100	0	0	7.4		
Momotidae (2)	14	78.6	7.1	0	5.4	1.0	
Alcedinidae (4)	69	60.9	14.5	2.9	1.8*	0.1	1.0
Bucconidae (2)	6	66.7	0	0	4.0		
Rhamphastidae (1)	4	75.0	25.0	0	2.7	0	
Picidae (1)	1	100	0	0	321.0*		10.0
Furnariidae (2)	41	87.8	4.9	0	6.6	1.3	
Dendrocolaptidae (11)	180	74.4	11.1	0*	9.5*	1.8	10.0
Formicariidae (14)	427	75.9	12.6	1.4	5.6*	0.9	16.3
Tyrannidae (25)	252	87.7*	9.1	2.0	5.7	1.0	3.0
Pipridae (5)	422	68.5	21.6	5.0*	2.3*	2.0	1.0
Troglodytidae (5)	69	85.5	11.6	0	6.3	1.8	
Sylviinae (2)	5	20.0	40.0	20.0	8.0	2.5	4.0
Turdinae (5)	71	85.9	9.9	2.8	7.9	1.6	0
Vireonidae (2)	4	75.0	25.0	0	4.0	1.0	
Parulinae (15)	458	76.0	17.5	1.3*	11.0*	1.9	21.4
Thraupinae (6)	55	83.6	7.3	9.1*	3.1*	1.8	1.0
Cardinalinae (2)	20	95.0	5.0	0	3.7*	0	
Emberizinae (4)	45	86.7	6.7	0	4.9	1.7	
Icterinae (2)	3	100	0	0	7.7		
Total (137)	2,656	73.1	12.5	2.6	6.5	1.5	8.4

[1] The number of items for pollen refers to the number of species found in the sample.
[2] Values for each family differing significantly from that of all other families combined (G-tests) are shown by an asterisk.

Tyrannidae ($G = 4.3$, df = 1, $P < 0.05$) respectively characterized by a lower and higher rate of regurgitation compared to other families (Table 1). The mean number of food items regurgitated, however, did vary from one family to another (Table 1). These differences mostly reflected variations in prey size (e.g., Parulinae, Alcedinidae) or in foraging activity pattern (e.g., Picidae, Formicariidae).

Families such as Tinamidae, Ardeidae, Accipitridae, and Falconidae were made up of large birds captured on few occasions. Because the amount of solution given to large birds was usually increased gradually until we got a positive response, samples are not big enough to evaluate the effectiveness of emetic on these families. The only Ardeidae submitted to the chemical (*Butorides striatus*) regurgitated a total of 10 items comprising various invertebrate taxa and one fish. The bird was injected with 1.2 cm^3/100 g of the 1.5% solution and flew out of the cage in excellent condition. The two samples collected from *Micrastur ruficollis* (Falconidae) showed that the technique works with large vertebrate prey (e.g., *Ameiva* lizard). Actually, frogs and lizards were common in the samples from other species as well (e.g., Dendrocolaptidae, Formicariidae). Identification of vertebrates was usually based on specific bones such as jaws (lizards) and legs (frogs). Experiments are underway to develop a key to determine the species and age of vertebrate prey.

There are no previous reports on emetic used with shorebirds. Three *Actitis macularia* (Scolopacidae) were subjected to the chemical. Two individuals out of three regurgitated a total of 10 items which is comparable to results found in other bird families (Table 1). We also treated two *Jacana jacana* (Jacanidae) held in captivity and fed with mealworms. Both individuals regurgi-

tated and ate spontaneously after treatment. During the three-day period when they were kept captive, they showed no sign of illness.

The method had previously been judged unsuccessful with Columbidae (Poulin et al. 1994a). However, by increasing the dosage (2.0 cm^3 of a 1.5% solution per 100 g of body mass) and keeping the birds up to 50 minutes in the cage, the proportion of samples with recognizable food obtained was comparable to that of other families ($G = 0.6$, df = 2, ns). Up to 42 items, including insects (adult and larval stages), gastropods, vertebrate eggs, and seeds were found in a single sample from *Leptotila cassinii*.

Among Trochilidae, *Phaethornis superciliosus* was the most frequently sampled species. This bird was especially sensitive to the chemical, which explains the high mortality rate ($G = 76.5$, df = 1, $P < 0.05$) for this family. Accordingly, we decreased the dosage (see methods) which explains the lower percentage of regurgitation obtained for Trochilidae in comparison with other families (Table 1). Of the 399 hummingbirds injected and brushed, 259 (65%) samples had pollen from one to 11 plant species. Pollen from an average of 0.4, 0.7, 2.1, and 2.5 species were found in samples coming from brushing, feces, regurgitation, and stomach, respectively. Regurgitation was more efficient than feces (K–W, H = 42.4, df = 1, $P < 0.001$) and brushing (K–W, H = 60.5, df = 1, $P < 0.001$) to sample pollen grains. However, there was no difference in the occurrence and diversity of pollen grains coming from regurgitations vs. stomach contents (K–W, H = 0.75, df = 1, $P = 0.387$).

Four species of kingfishers were tested. The significantly lower number of items regurgitated in this family compared to others ($G = 32.2$, df = 11, $P < 0.05$) reflects fish intake, with most samples containing only one or two fishes. Because fish identification was generally based on bones and scales only, we evaluated the number of prey items taken by counting the crystalline lens in the sample.

The highest number of items found in a sample came from the only Picidae (*Celeus loricatus*) forced to regurgitate (Table 1). All 321 items were ants at different developmental stages (eggs, larvae, adults), probably taken from a single nest.

The technique worked especially well with the Dendrocolaptidae and Parulinae. These two families were characterized by both a lower rate of mortality ($G = 9.7$ and 4.2, df = 1, $P < 0.05$) and a higher mean number of items regurgitated ($G = 22$ and 142.2, df = 1, $P < 0.05$) compared to other families (Table 1).

The mean number of items regurgitated was lower in Formicariidae than in other families ($G = 5.8$, df = 1, $P < 0.05$). Some 123 out of the 427 birds sampled were *Gymnopithys leucapsis* which forages almost exclusively at army ant swarms (Willis 1967). Although some birds regurgitated large amount of food, most samples were made up of only a few highly digested items, suggesting that the gut was empty. When not attending ant swarms, this species wanders in search of army ants and has a low foraging rate (Willis 1967). Because wanderers were more likely to be captured than the birds foraging at swarms, the lower number of items regurgitated for this family is mainly related to the particular foraging pattern of *Gymnopithys*.

Pipridae includes the most abundant species at our study sites, *Pipra mentalis*. Manakins from the genera *Pipra* and *Manacus* appeared to be very sensitive to the chemical. These birds actually suffer high stress from capture alone and will often flush out their gut content while still in the net. Accordingly, we did not force these birds to regurgitate whenever a good dropping sample was found on the ground or in the bird holding bag. There was no significant difference in the number of items found in regurgitations and feces (K–W, H = 0.86, df = 1, $P = 0.353$) for this family. However, it was often difficult to distinguish regurgitations from feces when the birds were injected and held in the cage and, because of the very low concentration used, the proportion of birds that really regurgitated might have been low.

Thraupinae were characterized by a higher rate of mortality ($G = 5.24$, df = 1, $P < 0.05$) compared to other families. Mortality occurred only in *Euphonia fulvicrissa* and did not decrease after a modification of dosage (100% mortality after five attempts). Because we noticed that this species had a much reduced stomach, we tested two individuals by injecting the solution in the beak only. Both birds regurgitated and flew away with no apparent ill effects.

DISCUSSION

Based on 137 bird species distributed in 29 families and subfamilies, tartar emetic appears to be an excellent technique to investigate food preference. With the exception of Trochilidae, no

bird family was less likely to regurgitate than another. The various food items regurgitated reflected the diversity of food resources at our study sites, comprising several invertebrate and vertebrate taxa, as well as fruit and flower species. Furthermore, no significant differences were found between stomach contents and regurgitations in mean number of items per sample. On the other hand, regurgitation using tartar emetic appeared to be much more efficient than examination of feces to determine diet.

However, the dosage of emetic needs to be adjusted for some species (see also Poulin et al. 1994a). A modification of the concentration to increase positive response in large birds gave good results since no difference was found in the frequency of regurgitation between small and large birds in contrast to what was reported earlier (Poulin et al. 1994a). A concentration lowered from 1.5 to 0.75% in hummingbirds and manakins reduced mortality but also reduced the proportion of birds that regurgitated.

Overall, the mortality rate was similar (2.0 vs. 2.6%) to the one reported in Poulin et al. (1994a), and lower than those reported in previous studies based on small sample size (e.g., Zach and Falls 1976, Lederer and Crane 1978). Comparison of recapture rates between birds treated and not treated with emetic further suggests that post-release effects of emetic are small and that mortality occurs primarily during the first 30 min after administration of the chemical (Poulin et al. 1994a). Six individuals from six species were treated with emetic on two occasions within a five-hour period or less, and the proportion of birds with food in their gut (5/6) was the same for the first and the second treatment.

Birds that did not regurgitate were more likely to die. Species such as *Phaethornis superciliosus, Pipra mentalis, P. coronata, Manacus vitellinus,* and *Euphonia fulvicrissa* were especially sensitive to the chemical. Dissection of dead birds suggests that mortality might be related to the emetic reaching the small intestine. The much reduced gizzard in *Euphonia* (Ziswiler and Farner 1972), as well as in some nectivores and frugivores, could explain the higher occurrence of mortality in these birds. However, administration of the emetic through the beak instead of the stomach with *Euphonia* provided good results without affecting the efficiency of the technique.

Apomorphine administered through the eyes could be a good alternative for bird species sensitive to a stomach irritant such as tartar emetic. Apomorphine was tested with granivorous species only and revealed a success rate varying from 22 to 70% depending on the bird family (Schluter 1988, Díaz Esteban 1989). Since no mortality was reported in these studies, apomorphine is probably preferable to the method suggested by Zann and Straw (1984) for seed-eating birds, which consists of inserting a tube into the crop and sucking up the contents with a large syringe.

Although processing samples of pollen grains involves much work, regurgitation using tartar emetic appears as an original and efficient technique to evaluate the diet of nectarivores. Our preliminary results show that pollen from over 100 plant species were found in the regurgitations. Pollen from as many as 40 plant species was found in 50 samples from *Damophila julie.* While observation of birds foraging at flowers makes plant identification easier, regurgitations might provide a better approximation of the diversity of flowers visited by a nectarivorous species, also providing information on arthropod intake which can represent an important part of the diet (Remsen et al. 1986, Poulin et al. 1994b).

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