The Condor 96:98–104

EFFECT AND EFFICIENCY OF TARTAR EMETIC IN DETERMINING THE DIET OF TROPICAL LAND BIRDS[1]

BRIGITTE POULIN, GAËTAN LEFEBVRE AND RAYMOND MCNEIL
Département de sciences biologiques, Université de Montréal, C.P. 6128, succursale "A", Montréal, Québec H3C 3J7 Canada

Abstract. The effect and effectiveness of tartar emetic was tested on 82 bird species from 25 families and subfamilies inhabiting seasonal habitats of northeastern Venezuela. Of the 3,419 birds forced to regurgitate, 3,033 diet samples were obtained and 2,712 of them had recognizable food. Seventy birds (2%) died after administration of the chemical, but a smaller dosage or concentration reduced mortality in species more sensitive to the emetic. Overall, 24 invertebrate taxa and 59 fruit species were identified, with an average of 6 items per sample. Pollen grains were observed in 55% of the samples from nectarivorous species. Considering the low mortality, as well as the diversity of prey types and sizes found in samples, regurgitation using tartar emetic is probably the best method for determining the diet of land birds from various feeding habits.

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

INTRODUCTION

Although knowledge of patterns of food exploitation are critical to many studies of avian ecology, direct measures of diets are rarely attempted. This is especially true for studies of land bird communities (Rosenberg and Cooper 1990). The most frequently used non-destructive methods for collecting diets of passerines are analysis of fecal samples (Davies 1977, Loiselle and Blake 1990), forced flushing (Moody 1970, Laursen 1978) and forced regurgitation (Prys-Jones et al. 1974, Radke and Frydendall 1974, Tomback 1975, Davies 1976, Lederer and Crane 1978, Ford et al. 1982, Major 1990). Collection of fecal samples is probably the simplest method but generally provides items in a highly digested and fragmented state (Major 1990, Rosenberg and Cooper 1990). Forced flushing, which consists of injecting a warm saline solution in the digestive tract until its complete evacuation through the cloaca, allowed Moody (1970) and Laursen (1978) to determine the diet of several insectivorous species. However, this method cannot be used with granivores, because of the flow inhibition of the solution by the gizzard (Moody 1970). Forced regurgitation has been attempted with water (Ford et al. 1982, Major 1990) and several emetics (Radke and Frydendall 1974), but most commonly uses antimony potassium tartrate (Prys-Jones et al. 1974, Tomback 1975, Zach and Falls 1976, Lederer and Crane 1978, Robinson and Holmes 1982, Gavett and Wakely 1986). Tartar emetic is effective in at least eight land bird families, mainly composed of insectivorous and granivorous species from the temperate zone (e.g., Paridae, Tyrannidae, Muscicapidae, Vireonidae, Corvidae, Passeridae, Fringillidae, Emberizidae). However, most studies were based on small sample size, and some of them reported high mortality (Zach and Falls 1976, Lederer and Crane 1978).

Our study is based on 3,419 tropical and migrant land birds forced to regurgitate using antimony potassium tartrate (tartar emetic). We evaluate the effects and effectiveness of this technique on 25 bird families and subfamilies from various semiarid tropical habitats.

METHODS

This study was carried out in Guarapo (10°39′00″N, 63°41′55″W) and Laguna de Cocos (10°29′33″N, 63°45′00″W) on the Araya Peninsula, in the State of Sucre, in northeastern Venezuela. In Guarapo, three study areas were chosen: a thorn scrub, a thorn woodland, and a deciduous forest (Sarmiento 1972, 1976). Birds were captured with 12 mist-nets (3 × 14 m, 32 mm mesh) during a 4-hr period beginning at dawn twice monthly from September 1986 through August 1987. At each of the three study areas, two study plots of similar vegetation were used.

[1] Received 21 April 1993. Accepted 13 October 1993.

In the first plot, birds were captured, banded, and released. In the second plot, birds were captured, banded, weighed, forced to regurgitate, and released. In Laguna de Cocos, regurgitations were carried out monthly in a thorn forest and twice monthly in mangroves (*Avicennia germinans*). Although two study plots were also used in these habitats, they will not be used to compare recapture rates because the netting effort was different between plots.

Regurgitation samples were obtained by administering tartar emetic to wild caught birds following the method of Tomback (1975). Immediately after capture (mist-nets were visited at 20-min intervals), birds were given 0.8 cm^3 of a 1.5% solution of antimony potassium tartrate per 100 g of body mass. The solution was given orally through a 1.5-mm diameter flexible plastic tube attached to a 1-cc syringe. The tube was inserted into the bird's mouth and gently pushed along the esophagus until it would go no further. In hummingbirds, the tube was inserted to the larynx only. The emetic was then administered slowly. This procedure could be easily performed by one person. After administration of the chemical, the bird was placed in a small dark box lined with absorbent paper. Birds were released 15 to 20 min later, which allowed them to regurgitate and also to recover after the regurgitation. Food items were preserved in 70% ethanol. Using a dissecting scope, items were identified to order or family (invertebrates) or to species (fleshy fruits). Because most arthropods were fragmented, their identification was generally based on the least digestible or the most characteristic parts of their body (see Borror et al. 1976). These might include wing structures (elytra in Coleoptera; scales in Lepidoptera; stigma in wasps; thickened front wings in Homoptera and Hemiptera), mouth parts (chelicerae in spiders, coiled proboscis in Lepidoptera), shape of the head (Diptera, Coleoptera, Homoptera, Hemiptera, Orthoptera, Odonata), or other (pronotum in Orthoptera, prolegs in Lepidoptera larvae, cephalothorax with coxae of legs in spiders, etc.). A phenological study carried out in Guarapo (Poulin et al. 1992) allowed us to identify 88% of all fleshy fruits taken by birds. Dry fruits were counted when possible and assigned to species, but most of them were not identified taxonomically. Because nectar is 100% assimilable and passes directly from esophagus to intestine (Remsen et al. 1986), its consumption was evaluated through the presence of pollen grains in emetic samples, using a microscope. Of 430 samples with pollen, nectar was observed in only two.

RESULTS

Of the 3,419 birds forced to regurgitate, we obtained 3,033 (89%) diet samples: 153 (4.5%) samples had liquid only and on 233 occasions (7.0%) birds failed to regurgitate. Of the 3,033 diet samples, 2,712 (88%) had recognizable food. Seventy birds (2.0%) were found either dead or weak in the box. In the latter case, they died soon after released. Mortality did not differ among birds that regurgitated food and those that did not regurgitate ($G_1 = 0.86$ and 1.80, ns), but was significantly higher for birds that regurgitated only liquid ($G_1 = 5.10$, $P < 0.05$).

COMPARISON OF RECAPTURE RATES

The number of birds recaptured on several occasions was consistently lower in the plots where birds were forced to regurgitate (Table 1). However, for all three habitats, those differences were not significant (thorn scrub: $G_4 = 1.98$; thorn woodland: $G_6 = 1.23$; deciduous forest: $G_4 = 2.12$).

COMPARISONS BETWEEN BIRD FAMILIES

The effect and efficiency of the emetic technique was generally similar between the different bird families and subfamilies (Table 2). However, the number of samples with recognizable food was significantly lower in the Columbidae ($G_1 = 10.5$, $P < 0.001$) compared to other families. All diet samples were probably made of seeds, but these were completely pounded in a paste mixture. Consequently, we stopped forcing these birds to regurgitate, which explains the small sample size for this family although some species (e.g., *Columbina passerina, Scardafella squammata, Leptotila verreauxi*) were quite abundant at our study sites. Of the other 486 granivores (Emberizinae, Thraupinae, Cardinalinae) treated with emetic, we obtained 367 (76%) samples with recognizable food. In comparison with other bird families, the proportion of individuals that did not regurgitate was significantly higher in the Bucconidae and Formicariidae ($G_1 = 6.7$ and 9.8, $P < 0.01$), and significantly lower in the Vireonidae and Coerebinae ($G_1 = 17.2$ and 10.3, $P < 0.001$). The Formicariidae were also characterized by a higher proportion of samples with liquid only ($G_1 = 9.4$, $P < 0.01$). Bird mortality was signif-

TABLE 1. Comparison of capture frequencies standardized at 100 net-hours between study plots where birds were forced to regurgitate (R) and where they were not (N) for each habitat in Guarapo.

Number of recaptures	Number of individuals							
	Thorn scrub		Thorn woodland		Deciduous forest		Total	
	N	R	N	R	N	R	N	R
0	79.1	71.0	71.9	42.7	21.6	1.6	172.6	154.4
1	10.4	4.9	5.2	4.3	4.0	4.2	19.6	13.5
2	2.3	1.7	1.6	1.0	1.2	0.6	5.1	3.3
3	1.0	0.7	0.8	0.2	1.0	0.4	2.9	1.3
4	0.5	0.0	0.5	0.0	0.3	0.2	1.4	0.2
5	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
6	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.0

icantly lower in the Tyrannidae ($G_I = 20.5$, $P < 0.001$) and Vireonidae ($G_I = 7.4$, $P < 0.01$), but significantly higher in the Furnariidae and Coerebinae ($G_I = 10.9$ and 36.7, $P < 0.001$).

COMPARISONS RELATIVE TO BIRD BODY MASS

The quantity of emetic solution given to a bird is traditionally calculated as a linear function of its body mass. This suggests that the effect and efficiency of tartar emetic is expected to be the same for birds of different weights. Our results, however, showed an inverse relationship between bird mortality and body mass ($r = -0.923$, $n = 8$ class intervals, $P < 0.001$). Mortality was higher in birds smaller than 10 g, relatively constant in mid-size birds, and lower in birds heavier than 50 g (Fig. 1). While no mortality occurred in larger birds, a higher proportion of them failed to regurgitate (Fig. 1).

FOOD ITEMS

From 1 to 153 food items were identified in emetic samples, with two and three items as the most common values (Fig. 2). Overall, an average of six items (2.1 plant, 3.9 animal) were taxonomically identified within each sample. The emetic technique seemed particularly efficient with the only member of the Picidae family (*Melanerpes rubricapillus*) for which 21 arthropods and 10 fruits were identified on average per sample.

Food items have been categorized in 24 invertebrate taxa distributed in four size classes (Table 3). Coleoptera, Hymenoptera, and insect larvae (mostly caterpillars) were the most frequent in emetic samples, followed by Diptera,

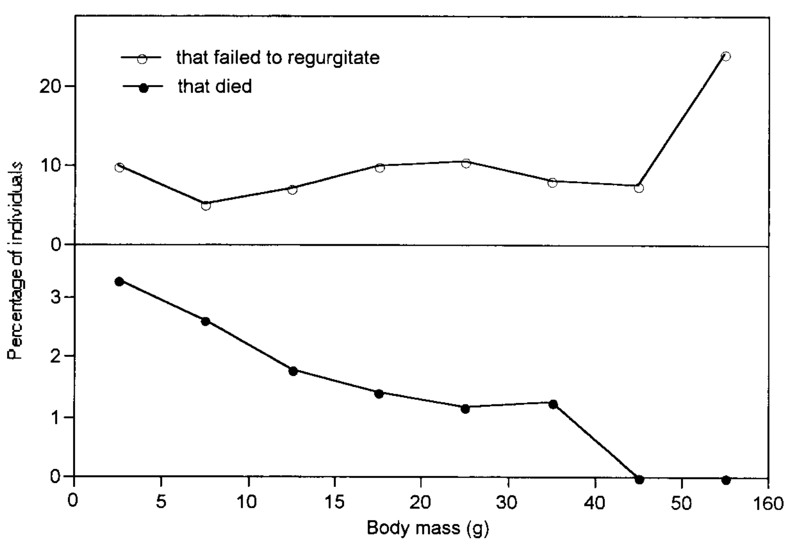

FIGURE 1. Variation in the proportion of birds that failed to regurgitate and died according to their body mass.

TABLE 2. Sample size and efficiency of tartar emetic in determining the diet for each bird family and subfamily.

Family or subfamily	Number of species	Number of individuals	Mortality (%)	Number of samples (%) With recognizable food	With liquid only	Failed to regurgitate
Columbidae	3	9	0	0	0	2 (22)
Cuculidae	2	6	0	3 (50)	0	1 (17)
Trochilidae	8	279	5 (1.8)	230 (82)	20 (7)	21 (7)
Bucconidae	1	16	0	8 (50)	0	5 (31)
Galbulidae	1	8	0	3 (37)	1 (12)	2 (25)
Alcedinidae	2	7	0	1 (14)	0	1 (14)
Picidae	1	13	0	9 (69)	1 (8)	2 (15)
Furnariidae	3	36	5 (13.9)	18 (50)	4 (11)	6 (17)
Dendrocolaptidae	3	60	1 (1.7)	43 (72)	1 (2)	10 (17)
Formicariidae	3	224	3 (1.3)	142 (63)	21 (9)	29 (13)
Tyrannidae	20	659	1 (0.2)	556 (84)	22 (3)	43 (7)
Cotingidae	1	1	0	0	0	0
Pipridae	1	1	0	1 (100)	0	0
Hirundinidae	1	2	0	1 (50)	0	1 (50)
Troglodytidae	1	12	0	8 (67)	1 (8)	0
Turdinae	2	3	0	2 (67)	0	1 (33)
Sylviinae	1	93	2 (2.2)	79 (85)	2 (2)	5 (5)
Mimidae	1	123	0	100 (81)	3 (2)	9 (7)
Vireonidae	4	187	0	173 (93)	4 (2)	1 (1)
Parulinae	7	201	3 (1.5)	152 (76)	8 (4)	15 (7)
Coerebinae	1	616	34 (5.5)	503 (82)	36 (6)	19 (3)
Thraupinae	4	432	6 (1.4)	342 (79)	11 (3)	20 (5)
Cardinalinae	4	100	1 (1.0)	83 (83)	5 (5)	8 (8)
Emberezinae	4	315	9 (2.9)	240 (76)	13 (4)	32 (10)
Icterinae	3	16	0	15 (94)	0	0
Total	82	3,419	70 (2.0)	2,712 (79)	153 (4)	233 (7)

Araneae (spiders), and Homoptera. Overall, 29 species of fleshy fruits, showing a great variety of seed shape and size, were identified in emetic samples. *Lycium nodosum, Tournefortia scandeus, Erythroxylum cumanense*, and *Pilosocereus moritzianus* were the most important plants in the birds' diet (see Poulin et al. 1992 for more details). Some 30 species of dry fruits were found in emetic samples, mostly from granivorous species. In nectarivorous birds, 430 out of 771 samples had pollen grains. Young leaves were found in three samples.

DISCUSSION

Mortality caused by tartar emetic on wild caught birds can be high. Lederer and Crane (1978) re-

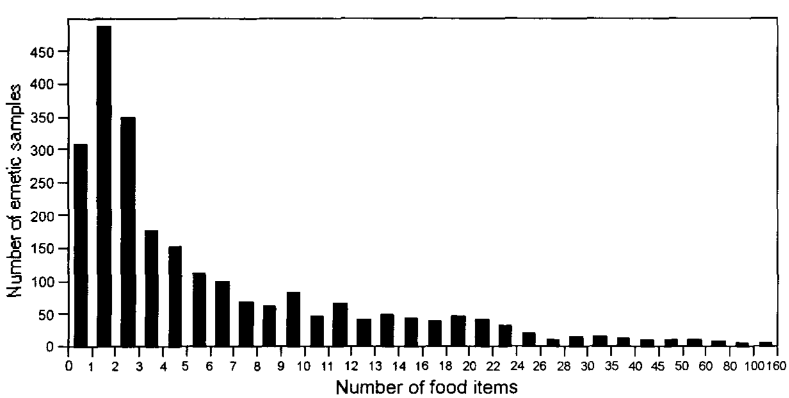

FIGURE 2. Frequency distribution of the number of food items found in emetic samples.

TABLE 3. Frequency and size of invertebrate taxa found in emetic samples.

Invertebrate taxa	Number of items from each size class (mm)				Percent of items
	0–5	5–10	10–15	15–30	
Gastropoda	45	6			0.46
Decapoda; crabs		17			0.15
Isopoda	4	120		4	1.15
Scorpionoidea		1		2	0.03
Araneae	360	47	1		3.66
Ixodidae	6				0.05
Diplopoda				14	0.13
Chilopoda			1	3	0.04
Ephemoptera	1				0.01
Odonata		4		8	0.11
Orthoptera	19	23	1	2	0.40
Isoptera	1	87	10		0.88
Psocoptera	3				0.03
Hemiptera	82	80	19	6	1.68
Homoptera	229	20	2	6	2.31
Neuroptera			2		0.02
Coleoptera	2,913	297	10	1	28.91
Lepidoptera	43	34		1	0.70
Diptera	588	8	10	1	5.45
Hymenoptera; ants	2,116	979	64	4	28.39
Hymenoptera; winged ants	26	189			1.93
Hymenoptera; wasps	522	126	13		5.93
Hymenoptera; bees			1		0.01
Insect eggs	250				2.24
Insect pupae	5	10			0.13
Insect larvae	404	268	168	218	9.49
Non identified					5.73
Total	7,617	2,316	302	270	100

ported mortality of 20% (2/10) in House Sparrows (*Passer domesticus*) and Zach and Falls (1976) a rate of 12.5% (6/48) in Ovenbirds (*Seiurus aurocapillus*) acclimated to captivity. However, most Ovenbirds died two or three days after the administration of emetic as a result of birds refusing to feed. On three occasions, we forced an individual bird [*Conirostrum bicolor* (2) and *Leucippus fallax*] to regurgitate twice within a 2–3 hr period, and all six emetic samples had recognizable food (arthropods). Although this is a small sample, it suggests that birds released in the wild do not avoid eating soon after administration of the chemical. Dosage and concentration used when administering emetic are very important (Lederer and Crane 1978). We based our measures on the method of Tomback (1975) and it appeared to provide a rapid answer with minimal damage to the birds. However, effect and effectiveness of the method varied according to body mass, with mortality higher in smaller birds, and effectiveness lower in heavier birds. Because a certain amount of liquid seems necessary to induce regurgitation, a modification of the concentration is probably the best alternative. A concentration lowered from 1.5% to 1.0% in birds smaller than 10 g would probably reduce mortality, while an increase from 1.5 to 2.0–2.5 in birds heavier than 50 g would probably enhance the number of successful regurgitations. Because birds with empty digestive tracts are more likely to die, sampling should be conducted during the period of highest feeding activity. Mortality was also significantly higher in the Furnariidae and Coerebinae compared to other groups. The species showing the highest mortality rate was *Certhiaxis cinnamomea* (Furnariidae) with 12% (4/33). However, when four of the first six individuals forced to regurgitate died, we reduced the dosage by 50% and none of the following 27 individuals died after treatment. Bananaquits (*Coereba flaveola*, Coerebinae) also seemed particularly sensitive to tartar emetic (5.5% mortality) and a dosage reduced from 0.8 to 0.6 cc per 100 g of body mass decreased mortality. In recent experiments, we found that manakins were particularly sensitive to the emetic and we reduced the concentration by 50%. These adjustments might explain the higher mortality rates observed in most studies, in which sample sizes are quite small. Based on our experience, the next most important aspect of the methodology is the rate at which the solution is given. For example, the administration of 0.1 cc was done intermittently with 10 pauses of 2–3 sec each. We strongly suspect that some birds died only because the solution was administered at a slightly more rapid rate.

Although differences were not significant, recapture rates were consistently lower in the plots used for regurgitation. There are two possible explanations for a lower recapture rate: the birds left the area or their mortality was higher. Because the manipulations associated with capture already represent a trauma to the birds, we do not think that birds treated with a chemical avoid more systematically nets than birds that were captured only. However we suspect that the additional stress associated with the administration of emetic led more birds to leave the area, especially as nomadism was quite important at our study sites (Poulin et al. 1993). Consequently, mortality and desertion are probably both responsible for lower recapture rates.

The number of food items regurgitated was frequently high in our samples. Even though some regurgitations might not have been complete (Gavett and Wakely 1986), the diversity of prey type and size suggests that no food category is less likely to be regurgitated than others. An assessment of arthropod abundance in the three study sites of Guarapo over two annual cycles (Poulin et al. 1992) demonstrates that all taxonomical categories of invertebrates captured with sweep-net, Malaise, pitfall and light traps were found in emetic samples. Coleoptera were the most abundant prey. Fragments of Coleoptera, especially the elytra, are the most durable items in birds' digestive tracts (Custer and Pitelka 1975, Major 1990). However, Coleoptera also represent the most abundant taxon in both sweep-net and light-trap samples. Although insect larvae (mostly caterpillars) were abundant from June through August only, they represent the third-most important arthropod taxa in samples. Most large caterpillars were found intact in emetic samples. This suggests that tartar emetic is more efficient than water (stomach flushing) to induce regurgitation for some prey types. During experiments with captive birds, Major (1990) found only fragments of caterpillars as soon as 5–10 min after ingestion. According to Ford et al. (1982), larger insects are less likely to be regurgitated with stomach flushing. Although prey with higher digestibility are likely to be underestimated, our samples included several small soft-bodied arthropods, spiders, insect eggs, and even nectar.

The low number of fruit species identified in emetic samples most probably reflects the low plant diversity at our study sites, since 29 species represented 88% of all fleshy fruits taken by birds. Regurgitations are undoubtedly more effective than fecal samples in determining the diet of frugivores because fruit identification is not based only on the seeds that are defecated, but also on those that are naturally regurgitated and on fruit pulp.

The high proportion of samples with recognizable food in granivorous species demonstrates that tartar emetic is effective for that feeding group as well. Granivores frequently regurgitated a large amount of dry fruits and although most seeds were fragmented, their identification was generally possible.

Regurgitations had never been attempted with neotropical nectarivorous birds. For each species, the proportion of samples with pollen was inversely related to the number of arthropod items, suggesting that the presence of pollen reflects a reasonable overall estimate of nectar intake. While observations at flowering plants are undoubtedly the best method to evaluate the consumption of nectar by hummingbirds, tartar emetic is important in determining arthropod intake. Hummingbirds fed primarily on small soft-bodied arthropods and most of them were found intact in emetic samples.

In conclusion, the tartar emetic sampling technique is successful, reasonably harmless to the birds, easy to use in the field, and an excellent alternative to sacrificing birds for dietary studies. Great care must be given to the administration of the chemical and some adjustment in emetic concentration and dosage can be necessary for some species. The variety of prey types and sizes found in samples suggests that it is the best non-destructive method for determining the diet of terrestrial birds with different feeding habits.

ACKNOWLEDGMENTS

This study was supported by the Natural Sciences and Engineering Research Council of Canada, Fonds F.C.A.R. (Gouvernement du Québec), and the Université de Montréal. We are also grateful to colleagues of the Universidad de Oriente, in particular Luis José Cumaná for his invaluable assistance in identifying plants specimens and José Ramón Rodríguez S. who was responsible with Raymond McNeil for the collaborative agreement between both universities.

LITERATURE CITED

BORROR, D. J., D. M. DELONG, AND C. A. TRIPLEHORN. 1976. An introduction to the study of insects. Fourth ed. Holt, Rinehart and Winston, New York.

CUSTER, T. W., AND F. A. PITELKA. 1975. Correction factors for digestion rates for prey taken by Snow Buntings (*Plectrophenax nivalis*). Condor 77:210–212.

DAVIES, N. B. 1976. Food flocking and territorial behaviour of the Pied Wagtail (*Motacilla alba yarrellii* Gould) in winter. J. Anim. Ecol. 45:235–253.

DAVIES, N. B. 1977. Prey selection and social behaviour in wagtails (Aves: Motacillidae). J. Anim. Ecol. 46:37–57.

FORD, H. A., N. FORDE, AND S. HARRINGTON. 1982. Non-destructive methods to determine the diets of birds. Corella 6:6–10.

GAVETT, A. P., AND J. S. WAKELY. 1986. Diets of House Sparrows in urban and rural habitats. Wilson Bull. 98:137–144.

HOYOS, F. J. 1985. Flora de la Isla de Margarita. Monografia no. 34, Sociedad y Fundación La Salle de Ciencias Naturales, Caracas.

LAURSEN, K. 1978. Interspecific relationships between some insectivorous passerine species, illustrated by their diet during spring migration. Ornis Scand. 9:178–192.

LEDERER, R. J., AND R. CRANE. 1978. The effects of emetics on wild birds. N. Am. Bird Bander 3:3–5.

LOISELLE, B. A., AND J. G. BLAKE. 1990. Diets of understory fruit-eating birds in Costa Rica: seasonality and resource abundance. Stud. Avian Biol. 13:91–103.

MAJOR, R. E. 1990. Stomach flushing of an insectivorous bird. An assessment of differential digestibility of prey and the risk to the birds. Austr. Wildl. Res. 17:647–657.

MOODY, D. T. 1970. A method for obtaining food samples from insectivorous birds. Auk 87:579.

POULIN, B., G. LEFEBVRE, AND R. MCNEIL. 1992. Tropical avian phenology in relation to abundance and exploitation of food resources. Ecology 73: 2295–2309.

POULIN, B., G. LEFEBVRE, AND R. MCNEIL. 1993. Bird abundance variation in tropical arid and semiarid habitats. Ibis 135:432–441.

POULIN, B., G. LEFEBVRE, AND R. MCNEIL. In press. Feeding guild characteristics and species diet variation in birds of three adjacent tropical sites. Biotropica.

PRYS-JONES, R. P., L. SCHIFFERLY, AND D. W. MACDONALD. 1974. The use of an emetic in obtaining food samples from passerines. Ibis 116:90–94.

RADKE, W. J., AND M. J. FRYDENDALL. 1974. A survey of emetics for use in stomach contents recovery in the House Sparrow. Am. Midl. Nat. 92:164–172.

REMSEN, J. V., F. G. STILES, AND P. E. SCOTT. 1986. Frequency of arthropods in stomachs of tropical hummingbirds. Auk 103:436–444.

ROBINSON, S. K., AND R. T. HOLMES. 1982. Foraging behavior of forest birds: the relationships among search tactics, diets, and habitat structure. Ecology 63:1918–1931.

ROSENBERG, K. V., AND R. J. COOPER. 1990. Approaches to avian diet analysis. Stud. Avian Biol. 13:80–90.

SARMIENTO, G. 1972. Ecological and floristic convergence between seasonal plant formation of tropical and subtropical South America. J. Ecol. 60:367–410.

SARMIENTO, G. 1976. Evolution of arid vegetation in tropical America, p. 65–99. *In* D. W. Goodall [ed.], Evolution of desert biota. Univ. of Texas Press, Austin, TX.

TOMBACK, D. F. 1975. An emetic technique to investigate food preferences. Auk 92:581–583.

WENDELKEN, P. W., AND R. F. MARTIN. 1988. Avian consumption of the fruit of the cacti *Stenocereus eichlamii* and *Pilocereus maxonii* in Guatemala. Am. Midl. Nat. 119:235–243.

ZACH, R., AND J. B. FALLS. 1976. Bias and mortality in the use of tartar emetic to determine the diet of Ovenbirds (Aves: Parulidae). Can. J. Zool. 54: 1599–1603.