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Relative efficiency of fecal versus regurgitated samples for assessing diet and the deleterious effects of a tartar emetic on migratory birds

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ABSTRACT. We describe the deleterious effects of using an antimony potassium tartrate emetic to obtain diet samples from birds, and compare information obtained from regurgitated samples versus fecal samples in describing diets of autumn migrants. We also examined dose effectiveness in captive Dark-eyed Juncos (*Junco hyemalis*) subjected to the same emetic technique used in the field. Over 70% of migrants given an emetic at a study site in Idaho regurgitated useful samples. For 5 of 7 species analyzed, regurgitated samples produced significantly more arthropods per sample than fecal samples, and one species, Warbling Vireo, showed higher numbers of distinct arthropod taxa per sample. In most species, regurgitated samples accumulated arthropod taxa more quickly than fecal samples. However, increasing the number of fecal samples by 5–17 produced a similar number of taxa. Diet composition based on fecal versus regurgitated samples was generally similar, but there were significant differences. Two of 130 treated migrants died soon after treatment. Recapture frequency for treated birds was less than half that for untreated birds, but it is not clear whether this difference was due to treatment-related mortality or emigration. Each treated bird that we recaptured had lost mass and this suggests a deleterious effect because untreated migrants tended to gain mass. In captivity, 18 Dark-eyed Juncos were treated with emetic: 6 with the full mass-specific recommended dose, 6 with half the recommended dose, and the final 6 with one quarter the recommended dose. All were alive 15–20 min posttreatment (recommended release time), but 17 of 18 died within 30 min after receiving the emetic. Together, our data suggest that although the emetic technique may be slightly more information-rich in assessing diet, it is more harmful than previously reported especially in certain species and should be used only after adequate consideration of the immediate mortality and short-term physiological effects on birds to be studied.

SINOPSIS. **Eficiencia relativa de muestras productos de la regurgitación versos heces fecales, para determinar la dieta y el efecto dañino del tartrato de potasio en aves migratorias**

Describimos efectos dañinos del uso del emético tartrato de potasio para obtener muestras de la dieta de aves silvestres (en Idaho) y cautivas (en Mississippi). Además comparamos la información obtenida de muestras vomitadas versus muestras fecales con respecto a la dieta de migratorios otoñales. También examinamos la efectividad de la dosis del emético usado en el campo, en un grupo cautivo de individuos de *Junco hyemalis*. En Idaho, el 70% de los migratorios expuestos al emético produjeron regurgitaciones útiles para ser estudiadas. En cinco de siete especies, las muestras regurgitadas expusieron un número mayor de artrópodos por muestra que las muestras fecales. Una de las especies, *Vireo gilvus* mostró además un mayor número de grupos de insectos por muestra que los otros. En la mayoría de las especies las regurgitaciones mostraron una mayor acumulación en el número de especies de artrópodos que las heces fecales. Sin embargo, si se incrementaba el número de muestras de heces fecales entre 5–17 muestras, estas ofrecían resultados similares a las regurgitaciones. A tales efectos, la composición de la dieta de aves utilizando regurgitaciones versus muestras en heces fecales resultó similar pero con algunas diferencias significativas. Dos de las 130 aves tratadas murieron poco después de darles el emético. La frecuencia de captura de las aves tratadas fue sólo la mitad con respecto a aves que no fueron tratadas; aunque no podemos decir que los resultados fueron el efecto de mortalidad por el emético o de los movimientos migratorios de las aves. Sin embargo, cada ave recapturada que había sido tratada con el emético, resultó con perdida de peso, lo que sugiere un efecto detrimental, dado el caso de que las aves se detienen en ellugar estudiado a alimentarse y a ganar peso. En cautiverio se trataron a 18 Juncos, con el vomitivo. Seis con la dosis recomendada, seis con la mitad de la dosis y seis con un cuarto de esta. Todos sobre vivieronel periodo de 15–20 minutos, recomendado previo a liberar a las aves tratadas. Sin embargo,

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a los 30 minutos, 17 de las aves habían muerto. Los datos que recopilamos sugieren que el uso del emético puede ofrecer un poco más de información sobre la dieta de aves que el análisis de heces fecales, pero que es más dañino que previamente informado, particularmente para algunas especies. El método del vomitivo debe ser utilizado solamente luego de considerar el efecto fisiológico y la mortalidad que pudiera causarle a las aves a estudiarse.

Key words: avian diet, emetic, fecal samples, migration, regurgitation

Emetics are widely used to acquire diet samples from wild birds (Tomback 1975, Rosenberg and Cooper 1990, Poulin and Lefebvre 1995). Because of their less digested state, regurgitated samples may provide more information about diet than fecal samples (Poulin and Lefebvre 1995). However, emetics are known to cause mortality, especially for birds weighing less than 10 g, and Rosenberg and Cooper (1990) cited mortality rates ranging from 12.5% to 50%. Although recent refinement of emetic-based techniques has reduced mortality rates to ≤2.8% (Poulin and Lefebvre 1995, Poulin et al. 2002, D. L. Swanson, pers. comm.), rates remain higher for small birds. Despite the information that can be collected, the safety of emetics has been questioned (Zach and Falls 1976, Lederer and Crane 1978, Johnson et al. 2002, Durães and Marini 2003). Recently, Johnson et al. (2002) reported direct mortality and significantly lower resighting rates of emetic-treated Warblers wintering in Jamaica, and Durães and Marini (2003) documented 10% mortality among birds in Brazil. Collectively, these studies suggest that the technique is not as innocuous as some have suggested. Nonetheless, inducing regurgitation with emetics has been proposed as a safe and noninvasive alternative for assessing diet when collecting and sacrificing birds is undesirable or impossible (Poulin et al. 1994, Poulin and Lefebvre 1995).

Due to the relative dearth of field or laboratory tests on the safety of this technique, further examination of the relative utility of fecal versus regurgitated samples and the safety of tartar emetic would help investigators select the best approach for their studies. Here, we report results from two studies where the use of an emetic was either a major focus or preliminary to further work: one involving free-living autumn migrants captured during stopover in Idaho and another involving captive Dark-eyed Juncos (*Junco hyemalis*). Specifically, we (1) determined the effectiveness of the technique at producing usable regurgitated samples, (2) compared the information contained in regurgitated versus fecal samples collected from free-living migrants captured at a stopover site in Idaho, and (3) measured the emetic's direct effects on survival of these birds as well as those held in captivity as part of a larger study.

METHODS

Idaho migrants. Autumn migrants were captured at Idaho Bird Observatory's fall migration monitoring station at Lucky Peak (1845 m; 43°36′N, 116°05′W) in southwestern Idaho from 2000 to 2003 (see Carlisle et al. 2005 for details about the study site and capture methods). Captured birds were identified and fitted with individually numbered U.S. Geological Survey aluminum bands. We subjected individuals of 17 species of migrant passerines to an emetic technique (see below) during 2000 and 2001 ("treated" birds), whereas we released untreated birds after banding and routine morphological measurements. Handling of emetic-treated and untreated birds was similar except for use of the emetic that typically increased handling time by 10–20 min. An ideal control, that is, administering a saline solution or inserting an empty tube into untreated birds, was not performed because our original goal was to collect samples for diet studies.

Treated birds were given an emetic solution to cause regurgitation following methods used by Tomback (1975), Poulin et al. (1994), Poulin and Lefebvre (1995), and Johnson et al. (2002). Using a syringe and plastic tube, approximately 0.8 ml of a 1.5% solution of antimony potassium tartrate per 100 g of body mass (Poulin et al. 1994) was delivered into the stomach of each bird. Solution concentration and volume were adjusted for body size following Poulin and Lefebvre (1995). Birds were then placed in a box lined with wax paper that allowed sample collection following regurgitation. Birds usually regurgitated within 10 min after treatment and most treated birds were released within 20 min. However, a few individuals weakened by the emetic (see below) were held in a box for

≥60 min. During 2001, the use of emetics was discontinued because mortality and other visible impacts on migrants occurred (see "Results"). In addition, fecal samples from birds not treated with the emetic were collected during the course of routine capture and handling from 2000 to 2003. Fecal and regurgitated samples were stored in 70% ethanol for later analysis.

Birds treated with the emetic produced a regurgitated sample, a fecal sample, or both. In about half the emetic cases, fecal and regurgitated samples could not be separated (due to breaking up of feces and mixing with regurgitated sample) and samples were combined for inspection. These combined samples were lumped with pure regurgitated samples and considered together as "regurgitated" samples and compared to pure fecal samples (thus potentially slightly biasing regurgitated samples toward containing more arthropod parts). During processing, each sample was placed in a glass dish, rinsed with 70% ethanol, and examined using a microscope (Leica GZ6; 10–80×). Samples were initially scanned using low power (10×) while searching for arthropod parts (e.g., heads and elytra). Once these parts were counted and separated, samples were viewed at higher magnification (40–80×) to identify parts. All samples were examined by JDC and arthropod parts were compared with those in a reference collection from the study site as well as Ralph et al. (1985), Borror et al. (1989), and Chapman and Rosenberg (1991). Arthropod parts were classified to order, and to suborder or family when possible (2% of arthropods could not be identified to order). Arthropods that frequently occurred in samples were more likely to be identified to family due to their abundance and familiarity to the observer. The minimum number of arthropods of each prey type was calculated by counting body parts (e.g., one head or two forelegs). In general, we followed current arthropod taxonomy (Maddison and Schulz 2004). However, due to differing abundances between the major groups of the recently merged order *Hemiptera*, we use the former term *Homoptera* (including suborders *Sternorryncha* and *Auchenorrhyncha*) to distinguish these groups from the *Heteroptera* (true bugs).

Captive juncos. Male Dark-eyed Juncos were captured from September to December 1997 in Lafayette and Yalobusha counties, Mississippi. Birds were captured in mist nets or potter traps and held in indoor aviaries until moved to individual cages (40 cm^3) in anticipation of field studies on migratory feeding and fattening in this and other species. All birds were maintained on the natural photoperiod for that region and provided food (equal mix of commercial turkey starter and white millet), water, and water-soluble vitamins ad libitum. In January 1998, to test the effectiveness of previously published doses for birds of this size (~18.0 g), birds were treated with approximately 100 μl of either 0.9% sterile physiological saline solution (controls) or with a mass-specific dose of the emetic made on the morning of its use (Poulin et al. 1994, Poulin and Lefebvre 1995). Saline and emetic solutions were delivered into the stomach using a 1-cc syringe attached to small, soft tygon tubing with a slightly beveled end. The tube was gently inserted toward the back of the throat region and gentle pressure was then applied to pass the tube 3–4 cm further into the stomach. Once the fluid was delivered, the tubing was removed and the time of dosing recorded before returning each bird to its cage. Initially, six birds received saline solutions and six were treated with the emetic. However, the study was modified (see below) to include an additional 12 birds treated with emetic.

Statistical analysis. Chi-square (χ^2) tests were used to examine differences in recapture proportions and mortality rates between treated and control birds. A recapture was a bird captured again at least 1 d after original capture, but some recaptures occurred several days later. Comparisons of diet data between regurgitated and fecal samples were limited to 7 bird species with sample sizes ≥5 of each diet sample type. The number of individual arthropods per sample and the number of distinct arthropod taxa per sample in the fecal and regurgitated samples were compared with Student's *t*-tests (two-tailed). We defined distinct arthropod taxa as any arthropod order, suborder grouping (such as wasps of the order Hymenoptera), or family that could be identified with certainty. Only families or other taxa that occurred commonly (>1% of arthropod items in a species diet) were included in analyses. Arthropod (order and identifiable families) composition of diet samples was compared with χ^2 tests. When overall comparisons

were significant for a bird species, single degree-of-freedom comparison tests were run for each taxon and a sequential Bonferroni correction was used to maintain an overall error rate of $P < 0.05$ (Rice 1989).

To determine the effectiveness of fecal and regurgitated samples in describing diets, relative numbers of prey taxa in cumulative, randomly selected diet samples were examined following Chapman and Rosenberg (1991) and Strong (2000). Samples were selected randomly, with replacement, from the pooled dataset (Strong 2000). Ten iterations were run at each sample size for diet samples from each technique. Because fewer regurgitated samples were collected than fecal samples, direct comparisons of the number of taxa included at given sample sizes were generally limited to 10 or fewer samples. Paired *t*-tests were used to test for differences between regurgitated and fecal values at each comparable sample size and the sequential Bonferroni method was used to control the overall error rate at $P = 0.05$ (Rice 1989). Taxa numbers at higher sample sizes for fecal samples are also presented to show continued taxa accumulation and to show the number of fecal samples required to generate a similar taxa output as regurgitated samples.

RESULTS

Relative information contained in fecal versus regurgitated samples. Of 118 birds treated with the emetic and whose regurgitated samples were examined for diet composition, 91 (77.1%) produced large samples with numerous arthropod parts, 15 (12.7%) produced small samples with few recognizable items, and 12 (10.2%) did not regurgitate during the post-treatment observation period. The success rate for producing large samples was high for *Empidonax* flycatchers (2 species; 15 of 16, or 93.8%), Warbling Vireo (*Vireo gilvus*; 19 of 21, or 90.5%), and Ruby-crowned Kinglet (*Regulus calendula*; 14 of 15, or 93.3%) whereas success was lower for Western Tanagers (*Piranga ludoviciana*; 9 of 11, or 81.8%), sparrows (8 of 11, or 72.7%), and warblers (6 species pooled; 30 of 46, or 65.2%).

For five of seven species examined, regurgitated samples contained significantly more individual arthropods per sample than fecal samples (Table 1). This relationship was largely driven

Table 1. Comparison of number of arthropods and number of distinct arthropod taxa in fecal and regurgitation diet samples from 7 autumn migrant species in the Boise Foothills, Idaho with > 5 samples for both emetic and fecal treatments. Data are presented as mean ± SD with sample size (*N*) given parenthetically. An asterisk (*) is placed for significantly higher values.

Species	Number of arthropods/sample			Number of taxa/sample		
	Emetic	Fecal	*P*	Emetic	Fecal	*P*
Dusky Flycatcher (*Empidonax oberholseri*)	10.82 ± 4.2 (11)	9.83 ± 5.0 (46)	0.55	5.09 ± 1.3 (11)	5.13 ± 1.4 (46)	0.93
Warbling Vireo	19.68 ± 12.8* (19)	6.82 ± 3.5 (34)	<0.001	6.16 ± 2.0* (19)	4.32 ± 1.1 (34)	<0.001
Ruby-crowned Kinglet	17.20 ± 11.1* (15)	10.71 ± 3.9 (21)	0.02	3.27 ± 0.8 (15)	3.76 ± 0.9 (21)	0.11
Nashville Warbler	21.93 ± 15.9* (15)	14.33 ± 7.3 (27)	0.04	3.73 ± 1.0 (15)	4.30 ± 1.6 (27)	0.21
Orange-crowned Warbler	21.50 ± 18.7* (6)	11.14 ± 6.8 (28)	0.02	5.33 ± 1.8 (6)	4.86 ± 1.6 (28)	0.52
MacGillivray's Warbler	28.82 ± 25.3* (11)	14.07 ± 6.4 (29)	0.005	6.36 ± 3.4 (11)	5.69 ± 1.3 (29)	0.37
Western Tanager	2.73 ± 1.7 (11)	3.07 ± 2.1 (43)	0.62	1.81 ± 1.0 (11)	2.06 ± 1.4 (43)	0.57

by the occurrence of more psyllid (*Homoptera*, *Psyllidae*) parts in regurgitated than fecal samples. Numbers of distinct arthropod taxa per sample were significantly higher in regurgitated samples only for Warbling Vireos and were similar between sample types for the other species (Table 1). Thus, regurgitated samples generally contained more arthropods, but similar numbers of taxa per sample relative to fecal samples. In five of seven species (those listed in Table 1), regurgitated samples accumulated prey taxa more rapidly than fecal samples (not significantly so for Western Tanagers) whereas both Nashville (*Vermivora ruficapilla*) and Orange-crowned (*V. celata*) warblers exhibited generally similar taxa accumulation between sample types (Fig. 1).

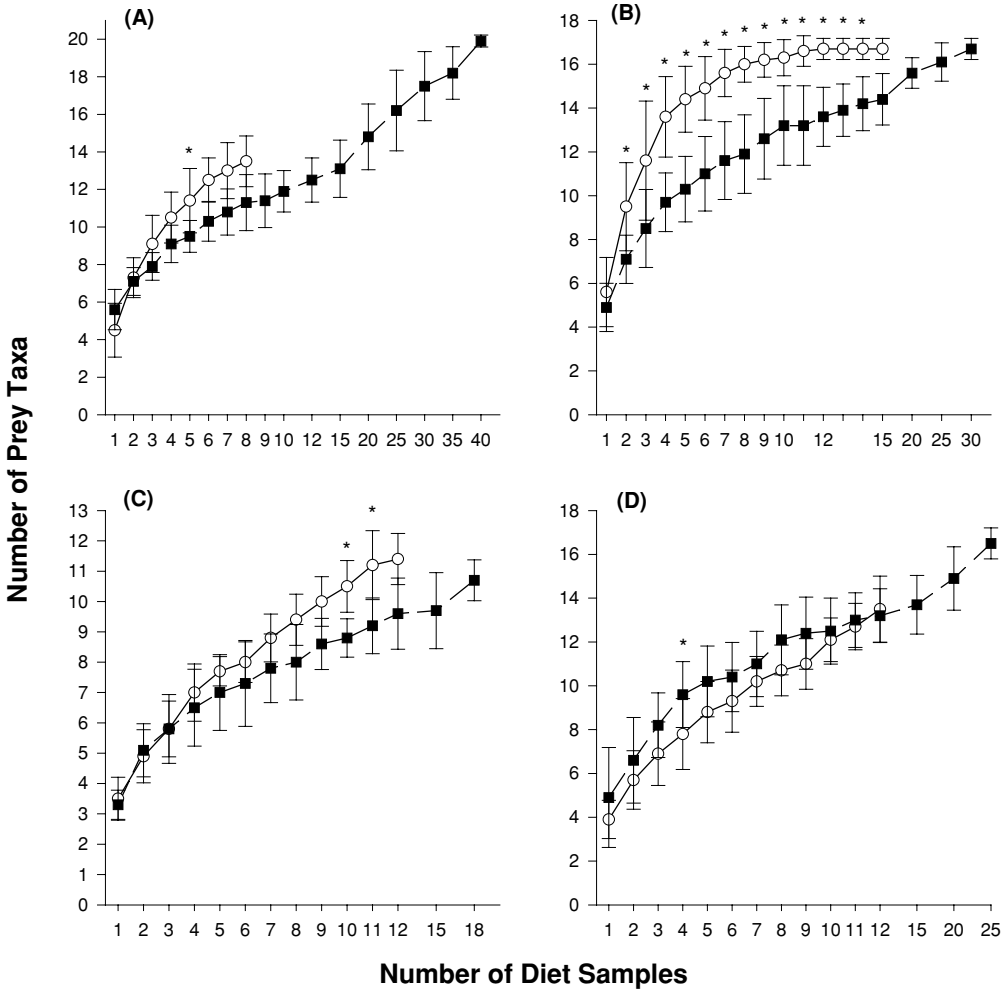

Fig. 1. Number of prey taxa in cumulative diet samples, from either regurgitated or fecal samples, for: (A) Dusky Flycatcher, (B) Warbling Vireo, (C) Ruby-crowned Kinglet, and (D) Nashville Warbler. Each point is a mean (± 1 SD) based on 10 random sampling iterations at each diet sample size. Note change in scale on X-axes. An asterisk (*) is placed over sample sizes in which numbers of prey taxa differ significantly between methods. Open circles = regurgitated samples; filled squares = fecal samples.

Note that curves for three species (Orange-crowned and MacGillivray's [*Oporornis tolmiei*] warblers and Western Tanager) are not included in Figure 1, but the curves shown are representative. For the five species where regurgitated samples accumulated taxa more rapidly, an additional 5–17 fecal samples were required to describe as many taxa as with regurgitated samples (Fig. 1). For both techniques, commonly occurring arthropod taxa in diets were represented after five or fewer diet samples; gains in taxa after this point tended to be infrequently occurring families or orders.

The proportion of key taxa between regurgitated and fecal samples differed in six of the seven bird species examined (Table 2). Only Western Tanagers showed no differences in arthropod composition between regurgitated and fecal samples ($\chi^2_6 = 2.65$, $P = 0.85$; Table 2). In most species, dominant taxa were the same for the two sample types and differences of a few percentage points tended to be found among less commonly occurring taxa. The only exception was Warbling Vireos where *Psyllidae* were dominant in regurgitated samples, but *Cicadellidae* were more numerous in fecal samples (Table 2). Overall, common arthropod taxa were detected using both fecal and emetic sampling. However, several taxa were detected more frequently by one method, including moths (*Lepidoptera*), flies (*Diptera*), spiders (*Araneae*), and ants (*Hymenoptera, Formicidae*) in fecal samples, and *Heteroptera* in regurgitated samples.

Emetic effects on migrants during stopover. Of 6686 captured birds of 17 species used in our study, 130 were treated with the emetic. Two treated birds died soon after treatment: one Nashville Warbler and one Western Tanager. This mortality rate (1.54%) was 4.3 times the incidental mortality rate for these same species during the same period (0.36%) from causes such as predation in nets, handling or capture stress, and net-inflicted injuries ($\chi^2_1 = 4.58$, $P = 0.032$). Most (~99%) untreated birds flew off immediately after processing, but at least 10% of the emetic-treated birds appeared weak or in shock (not alert or unable to perch upright) and were unable or unwilling to fly after treatment. These birds did fly away after an additional 20–60 min. Because recapture rates for most species during migratory stopover are naturally low, and recapture proportions can vary with species (Carlisle et al. 2005), all recapture data from treated species were pooled (both years combined) to provide large enough sample sizes for comparing recapture proportions between treated and untreated birds. Although not statistically significant ($\chi^2_1 = 2.84$, $P = 0.092$), the probability of recapturing emetic-treated birds (3.1%) was about half that for untreated birds (6.9%). Four treated birds were recaptured and each had lost mass (corrected for time of day; e.g., Carlisle et al. 2005): Warbling Vireo (lost 0.1 g in 24 h), Ruby-crowned Kinglet (lost 0.3 g in 24 h), Orange-crowned Warbler (lost 0.8 g in 24 h), and MacGillivray's Warbler (lost 0.8 g in 13 d). In contrast, untreated individuals of these warbler species and Ruby-crowned Kinglets were more likely to gain mass (ranging from 0.08 to 0.41 g) at this stopover site and the mass losses among treated birds were out of the normal range experienced by these species (Carlisle et al. 2005).

Emetic effects on captive Dark-eyed Juncos. Treatments began at least 1 h after lights came on to allow the birds to break their nocturnal fast. All six saline-control birds survived the study (to be released several months later) and none regurgitated. Six birds given the mass-specific recommended dose of emetic were alive 15–20 min after emetic administration. While all regurgitated, all died within another 10 min. Six additional juncos were then given half-strength emetic solutions. As with the first group, all of these birds appeared healthy 15–20 min posttreatment, but died within another 10 min. Finally, six more birds were given an emetic solution 1/4 of the original dose, and five of these birds died within 30 min. Thus, 17 of 18 (94.4%) birds given emetic solutions died soon after the 15–20 min posttreatment period.

DISCUSSION

Relative information contained in fecal versus regurgitated samples. Examination of fecal samples is an established method for studying the diets of small birds (Calver and Wooller 1982, Ralph et al. 1985, Rosenberg and Cooper 1990, Parrish 1997). However, limitations in using fecal samples include differences in digestion times and processing of various food types (Major 1990, Parrish 1997). Specifically, soft-bodied insects may not be detected

Table 2. Relative arthropod taxa numeric composition of diet samples comprised of either fecal- or emetic-induced regurgitated samples from autumn migrants in Idaho. Data shown are percentages of total diet (pooled across all diet samples of similar source—fecal versus regurgitated); sample sizes for each sample type are shown below each species name. An asterisk indicates a significantly higher value within a species. Arthropod taxa included here are those composing >1% of arthropods and with expected cell frequencies >5.

	Dusky Flycatcher		Warbling Vireo		Ruby-crowned Kinglet		Nashville Warbler		Orange-crowned Warbler		MacGillivray's Warbler		Western Tanager	
Arthropod taxa	Fecal $N = 46$	Emetic $N = 11$	Fecal $N = 34$	Emetic $N = 19$	Fecal $N = 21$	Emetic $N = 15$	Fecal $N = 27$	Emetic $N = 15$	Fecal $N = 28$	Emetic $N = 6$	Fecal $N = 29$	Emetic $N = 12$	Fecal $N = 43$	Emetic $N = 11$
Araneae	—	—	3.9	1.9	3.6*	0.0	2.3	1.2	4.2	3.1	2.0	0.6	—	—
Heteroptera (all)	6.9	7.6	7.8	10.0	0.0	4.7*	4.7	5.2	8.7	6.2	5.4	9.8*	5.3	10.0
Pentatomidae	—	—	2.2	7.5*	—	—	—	—	—	—	—	—	—	—
Rhopalidae	—	—	—	—	—	—	—	—	—	—	1.2	4.4*	—	—
Homoptera (all)													6.8	3.3
Cercopidae	—	—	3.5	9.9	—	—	—	—	—	—	—	—	—	—
Cicadellidae[a]	2.9	0.0	32.8*	2.9	4.9*	1.6	12.9*	0.6	9.3*	1.6	7.8*	2.2	—	—
Psyllidae	27.0	31.1	22.0	52.9*	66.7	83.7*	65.4	80.9*	54.8	72.1*	51.5	57.4	—	—
Coleoptera (all)	6.2	14.3*	10.4	9.1	10.2	7.8	6.7	3.7	9.6	13.2	7.4	3.8	7.6	6.7
Coccinellidae	—	—	2.6	3.7	—	—	—	—	—	—	—	—	—	—
Hymenoptera (all)	—	—	—	—	8.0*	0.8	—	—	—	—	—	—	—	—
Formicidae	30.8	28.6	1.3	1.9			1.3	1.2	5.8	1.6	14.5	11.0	18.2	10.0
Vespidae	—	—	—	—	—	—	—	—	—	—	—	—	45.5	50.0
Wasp[b]	7.3	8.4	2.6	2.4	—	—	3.1	6.1	—	—	4.7	8.2*	6.1	6.7
Lepidoptera (all)	4.0	3.4	5.2	4.0	—	—	—	—	—	—	—	—	—	—
Larva	—	—	1.3	4.0	—	—	—	—	—	—	—	—	—	—
Moth	—	—	3.9*	0.0	—	—	—	—	—	—	—	—	—	—
Diptera	9.5*	3.4	7.8*	1.3	5.8*	0.8	—	—	—	—	2.7	2.2	—	—

[a]The difference in this taxa is most likely a year effect as opposed to a true difference in detection between the methods; *Cicadellidae* were more numerous in fecal samples in 2002 and 2003 versus 2000 and 2001.

[b]Includes all families of wasps except in Western Tanager analysis where it includes all wasps other than *Vespidae*.

in fecal samples. These concerns have given rise to alternative techniques, including the use of emetics (e.g., Tomback 1975) or stomach-flushing (Major 1990) to induce regurgitation. Major (1990) and Poulin and Lefebvre (1995) indicated that fecal samples were less effective than regurgitated samples, especially on a per sample basis. However, many soft-bodied insects have chitinous parts (i.e., mandibles of *Lepidoptera* larvae) that allow detection via careful examination of fecal samples (Ralph et al. 1985, Rosenberg and Cooper 1990) and these items were found in fecal samples in our study. Ralph et al. (1985) analyzed a large number of fecal samples and found no bias against small or soft-bodied insects. Additionally, close correspondence has been found between fecal data and stomach content analysis (Rosenberg and Cooper 1990) and observational data (Calver and Wooller 1982).

Because arthropods were classified into different taxonomic levels (family, suborder, order), a central assumption of our study was that taxonomic resolution was similar for both techniques. Our results suggest that individual regurgitated samples provide more information than individual fecal samples. Regurgitated samples typically contained more arthropods, had similar numbers of arthropod taxa per sample, and tended to accumulate taxa more rapidly than fecal samples. These data are consistent with previous reports showing greater numbers of individual arthropods per sample in regurgitated samples (Major 1990, Poulin and Lefebvre 1995). However, the number of arthropods per fecal sample in our study (3–14 depending on bird species) tended to be higher than reported for regurgitated samples by Poulin et al. (1994) and Poulin and Lefebvre (1995). The higher arthropod numbers in samples in our study may be due to the frequent consumption of small arthropod items by migrants in Idaho.

Also, to our knowledge, no previous study has compared complete (pooled) diet descriptions from fecal versus regurgitated samples of wild birds. When considering pooled diet descriptions in our study, the two sampling techniques overlapped in arthropod taxa proportions. Moreover, all commonly occurring taxa were detected in combinations of five (or fewer) diet samples using both sampling techniques. Lastly, taxa accumulation curves demonstrated that small increases in the sample size of feces allowed description of a similar arthropod community. Considering that an experienced observer can usually process a diet sample in 5–20 min (depending on bird species and the proportion of arthropods versus fruit in the sample; JDC, pers. obs.), increasing sample size by 5–17 samples means an additional 1–3-h processing time per bird species. Thus, our data support the contention that fecal sampling generates large sample sizes and, with thorough and careful examination of samples, can provide relatively accurate estimates of dietary composition and proportions of prey types (Ralph et al. 1985, Parrish 1997) with less risk to birds.

Emetic effects on migrants during stopover. The proportion of treated birds recaptured in our study was about half that for untreated birds, suggesting that emetic treatment may increase mortality or cause changes in behavior (such as emigration from the netting area). We do not have data on whether regurgitation success (a factor known to affect health of treated birds; Poulin and Lefebvre 1995) affected recapture probability in our study. Although based on relatively small sample sizes, these results are consistent with previous reports of lower recapture proportions for emetic-treated birds (Lederer and Crane 1978, Poulin et al. 1994, Durães and Marini 2003), and lower resighting rates of emetic-treated wintering birds (Johnson et al. 2002). We also observed mortality of treated birds and three of four treated birds that were recaptured exhibited uncharacteristic mass losses.

Taken together, these data suggest that, at least during fall migration, the antimony potassium tartrate emetic was not safe for most birds in our study. This may be especially true for warblers and tanagers, which exhibited mortality, mass losses, and lower rates of regurgitation. One exception may be Warbling Vireos. This species produced usable emetic samples at a high rate and the one recaptured bird that had been treated with the emetic had not lost significant mass. Similarly, Poulin et al. (1994) found that vireos (*Vireonidae*) showed the highest rate of usable samples and lowest mortality among all taxa sampled. This pattern suggests that investigators should consider species differences when designing diet studies.

Emetic effects on captive Dark-eyed Juncos. Our results suggest that investigators should conduct preliminary trials under

controlled conditions, such as captivity, in preparation for field studies. In this way, immediate and longer-term effects of the treatment on the birds' health and survivorship can be assessed. Then, doses can be adjusted or other approaches developed. Whereas reported mortality rates due to emetics have varied, the 94.4% mortality rate for juncos in our study was much higher than previously reported in the field, even for omnivorous or granivorous birds (Lederer and Crane 1978, Poulin et al. 1994, Johnson et al. 2002). Such mortality rates make its use in research unfeasible and unethical. Although the use of a different emetic (apomorphine) has been proposed for granivores (e.g., Valera et al. 1997), such as juncos who rely on seeds for much of the year, Poulin et al. (1994) found that the emetic technique was generally effective for granivores (although birds in their study exhibited slightly higher mortality and lower regurgitation rates than nongranivorous species). Thus, this high mortality rate for juncos in our study could not have been predicted based on previous use of antimony potassium tartrate emetic with granivores. A factor potentially influencing mortality rate in juncos may be the possible confounding effect of stress due to captivity that may have impacted their ability to counter the emetic's toxicity. However, birds in our study had been captive for several months. Most importantly, none of the six saline-treated birds suffered ill effects, providing evidence that the emetic treatment, regardless of the dilution used, was the cause of death.

In most banding studies, the fate of birds is unknown and one can only assume that capture and banding activities do not affect their well-being. However, this is based on their ability to fly away after a short period of time. Our results, in conjunction with those of Johnson et al. (2002), suggest that this assumption cannot be made if based on a bird's behavior at the time of release. All juncos in our study, regardless of treatment, were alive and appeared normal (alert and sitting upright in the cage, on a perch, or on the cage floor) at 15–20 min posttreatment, by which time birds treated in the wild have been released (e.g., Poulin et al. 1994). Although regurgitation may occur within 15–20 min, the toxin may take longer to enter the bloodstream and cause death. Our results suggest that free-living birds that fly off after treatment may experience continued effects of the emetic, including mortality, either directly from its toxicity, as in our study, by increased predation risk, or inability to maintain energy reserves due to the reduced time able to spend foraging. Thus, investigators who release emetic-treated birds quickly may underestimate mortality rates. The degree of toxicity may vary with gut function (pre- versus post-absorptive state and migratory condition) and further studies would be needed to understand variation in regurgitation rates and the likelihood of causing death if this method is to be used extensively, and, particularly, on species of concern.

Implications. We provide further evidence of the deleterious effects of tartar emetic on both wild and captive migratory birds and found that fecal samples produced only slightly less information than regurgitated samples. We conclude, as others have, that the emetic technique is not as safe as previously proposed (Poulin and Lefebvre 1995), at least not for most species in our study. Investigators considering the use of emetics should conduct preliminary studies to determine their effect on the target species, consider experimental designs that include time of day and time of year, and make sure that the solutions used are the most effective and least toxic (e.g., Poulin et al. 2002). Based on our results, we concur with Parrish (1997) that, for safely assessing diets, fecal sampling may be more appropriate or acceptable than either the use of emetics or the collection of birds to obtain stomach samples.

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