13 scratches by a male can cause considerable departure from linearity. Hence correlations are more meaningful when calculated from distributions that use cumulative frequencies above some arbitrary value that excludes random fluctuations at small sample sizes. When calculated on data $f_s \geqslant 5$ bouts, the correlation coefficients are much higher: $r = -0.996$ (males) and $r = -0.990$ (females). The least-squares regression lines shown in Fig. 1 were calculated from these data. The slight difference in slopes opens a new question concerning possible differences in foraging between the sexes.

The model of scratching was tested by changing the probability of finding food. Because p in eq. (1) is a fraction, its logarithm is a negative number (hence the slope of Fig. 1 is negative). Reducing the probability of finding food should produce a flatter slope (more scratches/bout), and this prediction was tested by comparing scratching of males on the day seed was scattered ($N = 131$ bouts) and 4 days after ($N = 165$ bouts). The data were normalized to 100% for ease in comparison of the slopes, and are plotted in Fig. 2. As predicted, male towhees show more scratches/bout when food is less abundant. Based on $f_s \geqslant 5$ bouts, the correlation coefficients are $r = -0.998$ for both sets of data, and regression lines are fitted to these data. The slopes may be conveniently expressed as half-lives (equal to the medians), which are 1.4 scratches/bout on the day seed was scattered and 2.3 scratches/bout 4 days after providing seed. Data on females showed the same direction of difference, but are too few to merit formal analysis.

The model may have application to foraging behavior of other species, and is now sufficiently tested comparatively for emberizine scratching to be a useful tool in behavioral ecology. J.P.H. has begun experiments from which preliminary data indicate that a heavier leaf-litter also shifts the distributions to greater scratches/bout, suggesting that p is dependent both upon the abundance of food and the amount of litter in which it is concealed. These easily recorded data, especially if combined with measures of scratching per unit time, could therefore serve as a powerful quantitative measure of foraging efficiency for comparing individuals, sexes, habitats, seasons and so on.—EDWARD H. BURTT, JR., *Dept. of Psychology, Univ. of Tennessee, Knoxville, TN* (Present address: *Dept. of Zoology, Ohio Wesleyan Univ., Delaware, OH 43015) and* JACK P. HAILMAN, *Dept. of Zoology, Univ. of Wisconsin, Madison, WI 53706. Accepted 29 Dec. 1977.*

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Winter diet of a bark-foraging guild of birds.—Although the literature of economic ornithology is replete with qualitative descriptions of the food habits of various birds, quantitative assessment of avian diets is seldom presented (Hartley, Ibis 90:361–381, 1948). For modern ecological analysis, earlier data reported in the literature are often inadequate for any one of several reasons. Birds were usually collected over large geographic regions, and therefore, fine scale comparisons are impossible. Evaluations of stomach contents were usually only subjective estimates; therefore, quantitative comparisons among species may not be reliable. Diets were often reported for the entire year; thus, few seasonal comparisons can be made. Here we report a quantitative analysis of the diets of bark-foraging birds which coexist in central Illinois during winter. The species include Red-headed Woodpecker (*Melanerpes erythrocephalus*), Red-bellied Woodpecker (*Melanerpes carolinus*), Downy Woodpecker (*Picoides pubes-*

cens), White-breasted Nuthatch (*Sitta carolinensis*), and Brown Creeper (*Certhia familiaris*).

We collected Red-headed Woodpeckers during December through February, 1974–75 and 1975–76, and other birds during December through February, 1975–76, from upland deciduous forests in central Illinois. Almost all areas were adjacent to land used for agriculture. The dominant trees of our sites were white oak (*Quercus alba*), red oak (*Q. rubra*), black oak (*Q. velutina*), and shagbark hickory (*Carya ovata*). After collection, we immediately injected the birds with a formalin solution or placed them in an ice chest to insure curtailment of digestion (Koersveld, Proc. 10th Int. Ornithol. Congr., 1951).

Prior to quantification, all stomachs were opened and the contents identified. Stomach contents were then placed in a petri dish and food items identified at 50 random points for each sample. Because food items do not all break into the same sized pieces, frequency of points does not necessarily represent volume of diet. Volumetric determinations, however, were not possible because of the small size of many of the food items. A complete list of the families of insects identified is given in Williams (Ph.D. Thesis, Univ. of Ill., Urbana, 1977).

Numbers of insects in each sample were quantified by counting head capsules or wings (divided by 2). Since it was impossible to ascertain the number of some seeds, we used the frequency of occurrence in point samples as an indication of number. This assumes that large and small seeds break into a similar number of parts. Since large seeds appear to break more, this procedure overestimates numbers of large seeds. We determined sizes of insects by placing parts together and sizes of seeds from a reference collection. Data were then combined to give frequency of occurrence of each food size in the diets of the birds, and mean food sizes were calculated.

We are cognizant of problems inherent in any gut content analysis such as differential digestion rates (Mook and Marshall, Can. Entomol. 97:1144–1149, 1965). Since we failed to keep members of this guild alive in captivity and thus could not perform experiments on digestion rates, we deem stomach content analysis the best estimate of relative proportions of food items in their diets until further experimentation.

Our results indicate that Red-headed Woodpeckers consumed acorns during a winter with good mast crops (1974–75), but foraged more on corn and other seeds when mast crops were low (Table 1). Most of the arthropods taken were adult beetles.

The diet of the Red-bellied Woodpecker also contained mostly vegetable material (Table 1). Mast was relatively unavailable during the winter of 1975–76, and these birds foraged mostly on corn and other seeds. Two Red-bellied Woodpeckers collected 15 November 1976 when mast was abundant (not included in Table 1), had eaten 70% acorns, suggesting that this species may also prefer acorns when available. Most of the remaining items were adult beetles. Considering the difference in sample size, diets of these 2 species were remarkably similar in 1975–76. Differences were not significant for percent animal and vegetable foods taken but were significant (χ^2, $P < 0.05$) for the categories in Table 1.

Downy Woodpeckers consumed relatively more insects than the previous 2 species (Table 1). Ants, adult beetles, and small homopterans composed the bulk of the animal food. In addition, some larvae, especially from wood-boring families, were found. Vegetable foods consisted mostly of corn, poison ivy seeds (*Rhus radicans*), and some mast.

White-breasted Nuthatches were mainly vegetarian during winter (Table 1), but less so than Red-headed and Red-bellied woodpeckers. Seeds such as corn, acorns, wheat

TABLE 1

RELATIVE FREQUENCY (PERCENT) OF EACH FOOD CATEGORY FOUND IN STOMACHS OF BARK-FORAGING BIRDS DURING WINTER

Category	Red-headed[1] (N = 21)	Red-headed[2] (N = 6)	Red-bellied[2] (N = 20)	Downy[2] (N = 20)	White-breasted Nuthatch[2] (N = 20)	Brown Creeper[2] (N = 5)
Orthoptera	—	—	0.3	0.1	2.9	—
Hemiptera	0.2	—	—	3.4	3.0	22.8
Homoptera	—	—	0.3	7.6	0.3	34.4
Coleoptera (adults)	2.2	3.3	4.0	15.9	6.5	12.4
Coleoptera (larvae)	—	—	—	4.2	—	—
Lepidoptera (larvae)	—	—	—	1.4	2.7	—
Diptera (larvae)	—	—	—	0.6	—	—
Hymenoptera (adults)	1.1	—	0.8	20.7	7.2	4.4
Hymenoptera (larvae)	—	—	—	0.6	1.1	—
Araneida	0.2	1.2	—	4.5	1.0	11.6
Other	—	—	—	0.3	0.2	2.8
Unknown	0.2	—	0.6	1.8	3.3	3.6
Total Animal	3.9	4.5	6.0	61.1	28.2	92.0
Mast[3]	51.6	14.6	8.8	5.1	6.6	2.0
Zea mays	41.8	67.3	70.9	19.7	49.7	5.6
Helianthus sp.	0.1	—	—	0.4	5.5	—
Crataegus sp.	—	—	0.6	—	0.3	—
Triticum aestivum	0.1	—	—	2.0	5.7	—
Vitis sp.	—	6.3	9.4	1.7	0.1	—
Rhus radicans	0.2	—	—	7.1	—	—
Celtis occidentalis	—	—	2.4	—	—	—
Cornus sp.	—	5.5	—	—	—	—
Other	—	—	—	0.1	0.1	—
Unknown	2.3	1.8	1.9	2.8	3.8	0.4
Total Vegetable	96.1	95.5	94.0	38.9	71.8	8.0
Grit[4]	+	+	+	—	+	—

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[1] Birds collected during a relatively high mast year (1974–75).

[2] Birds collected in a low mast year (1975–76).

[3] Mostly *Quercus* sp.

[4] Indicates presence or absence of grit in stomachs examined.

TABLE 2

NICHE BREADTHS AND NICHE OVERLAPS FOR FOOD USE AMONG BARK-FORAGING BIRDS

	Food Breadth		Food overlap	C.D.*
RH (1974–75)	.05	RH × RB	.86	1.06
RH (1975–76)	.05	RH × DW	.29	1.63
RB (1975–76)	.04	RH × WBN	.62	1.62
DW (1975–76)	.30	RH × BC	.13	2.08
WBN (1975–76)	.11	RB × DW	.32	1.72
BC (1975–76)	.17	RB × WBN	.65	1.71
		RB × BC	.14	2.20
		DW × WBN	.49	1.01
		DW × BC	.42	1.23
		WBN × BC	.27	1.29

* C.D. = Character Difference, i.e., the ratio of larger bill length to shorter. Symbols represent species of guild.

(*Triticum aestivum*), and sunflower (*Helianthus* sp.) comprised most of the vegetable diet. Insects taken were mostly adult beetles, small bugs, adult orthopterans (Acrididae), and lepidopteran larvae.

Brown Creepers foraged more on insects during winter (Table 1) than any other guild member. Small homopterans (usually Psyllidae) and hemipteran insects were most frequently identified. Other significant prey items included beetle adults, spiders, and ants. For vegetable foods, Brown Creepers ate only small quantities of corn and acorns. The diets of all species were significantly different from one another (χ^2, $P < 0.05$).

Niche breadth values (Levins, Evolution in Changing Environments, Princeton Univ. Press, Princeton, N.J., 1968) for diet (categories of Table 1) indicate that guild members can be ranked from most to least specialized as follows: Red-headed and Red-bellied woodpeckers; White-breasted Nuthatches and Brown Creepers; and Downy Woodpeckers (Table 2). Species which concentrated on vegetable resources were the most specialized. Previously Williams (Am. Midl. Nat. 93:354–367, 1975) adduced that Downy Woodpeckers are generalists compared to other guild members. Data presented here lend credence to this hypothesis.

Because of their behavioral and morphological similarity, Red-headed and Red-bellied woodpeckers have recently been placed in the same genus (Mayr and Short, Publ. Nuttall Ornithol. Club, No. 9, 1970). Dietary overlap patterns further point out the similarity between these species and suggest that they are potentially strong competitors (Table 2). Elsewhere, we have hypothesized that these species exploit many resources in common during winter and that horizontal separation into different habitats permits coexistence (Williams and Batzli, Condor in press). These data augment our previous contention.

We found a correlation between mean food size and bill length among bark-foraging birds in central Illinois (Fig. 1). Body weight was also positively correlated with mean food size ($r^2 = .74$, $P < 0.02$). Larger birds tended to consume larger prey items.

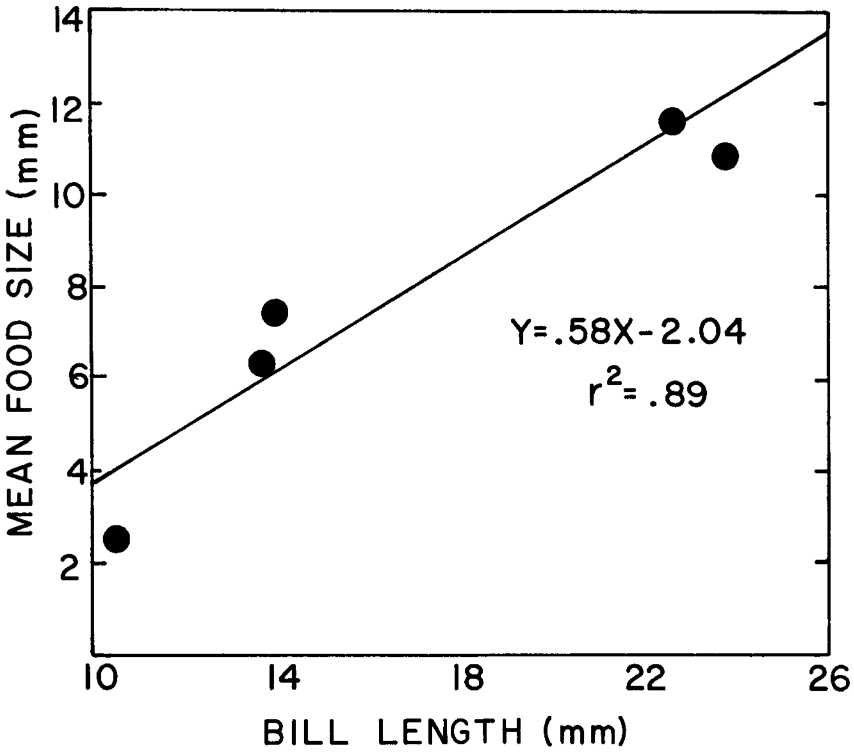

FIG. 1. Relationship between mean food size and bill length in bark-foraging birds in central Illinois during winter. Bill size for each species was RH = 22.6 ± 0.3 mm (1 SE), RB = 23.9 ± 0.3 mm, DW = 13.9 ± 0.1 mm, WBN = 14.0 ± 0.1 mm, and BC = 10.9 ± 0.2 mm. The slope was significantly different from zero ($P < 0.01$).

Several authors have used differences in culmen length to estimate the degree of niche overlap in birds (e.g., Schoener, Evolution 19:189–213, 1965). In the bark-foraging guild, we found a weak negative correlation between ratios of culmen length (large to small) and diet overlap ($P = 0.05$, $r^2 = .42$). We point out, however, that single comparisons should be made with caution, especially for interfamilial comparisons. For example, the relatively high C.D. (Table 2) for Red-headed Woodpeckers and White-breasted Nuthatches would not accurately predict the dietary overlap between these species. If White-breasted Nuthatches were collected during a winter of high mast availability, we suspect dietary overlap with Red-headed Woodpeckers would be even greater. Determination of diet overlap for Downy Woodpeckers and White-breasted Nuthatches from C.D. values would also be problematical.

Hespenheide (Ibis 113:59–72, 1971) indicated that food size is an increasing function of body size among some bird species. Our results generally agree with his findings. Bill length was the best predictor of food size, but bill length and body size were highly correlated. Food size for this guild may reflect the type of food which the birds must take in order to meet their energetic requirements.

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Mantids selected as prey by Blue Grosbeaks.—I observed Blue Grosbeaks (*Guiraca caerulea*) at their nests in Hawkins County in upper eastern Tennessee to feed their nestlings on mantids almost exclusively. Two active nests 1.65 km apart were photographed from blinds, each over a period of 3–4 consecutive days. Observations began on 29 June and 5 July 1977 when the nestlings were approximately 1 day old. In addition Rick A. Phillips and I observed 3 other nesting pairs of grosbeaks while they were feeding nestlings at sites 1.0, 9.7, and 38.7 km from the 2 photographed nests. The behavior of the adult birds was essentially the same at all nests in over 100 observed feedings.

Almost all the mantids these birds were gathering were very large, in excess of 75 mm, and were probably the introduced Chinese Mantid (*Tenodera aridisolia*). The head and wings had been removed from all the carcasses as had all, or most, of the legs before the insect was brought to the nest-site. This 1 food was almost the exclusive prey item (greater than 96%) brought to the young at all nests observed. The only other known food presented was an occasional grasshopper.

Males showed no strong tendency to feed and were easily discouraged by the sounds of the camera and strobes, often eating the food they carried. Females seemed little disturbed by the photographer's activities once I was concealed in the blind. They fed more often than the males, averaging 3–5 trips to each made by the male (if the male was feeding the young at all). Frequency of feeding depended, at least in part, on how far the birds went from the nest to gather food and how quickly they found it once there. Usually they would return to the same area in which the previous insect was taken upon completing a feeding. Mantids were brought to the nest as often as 5–10 min apart, but the average time between feedings was approximately 25–30 min. Most active feeding periods were the first 3 h after daylight and the last 2 h before dark. There were periods in each day when both birds would be absent from the nest and out of sight of the observer for more than an hour followed by intense activities of feeding the young.

The methods used by Blue Grosbeaks to catch mantids consisted principally of 1 or both birds flying to a weed-top perch and sitting motionless for a few seconds. The birds then either made low short flights and hovered over or adjacent to the weedy vegetation, plucking the insect from the leaves and stems, or flew to the ground and hopped among the grasses until a capture was made. The male often followed the female from place to place as she hunted and accompanied her return to the nest though not having made a kill himself.