

CHARACTERIZATION OF GRIT USE BY CORNFIELD BIRDS

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ABSTRACT.—Grit use (frequency, amount, size, shape, and roundness) was characterized for 22 bird species that commonly use midwestern cornfields during the breeding season. The frequencies of occurrence and the median amounts of grit found in birds' gizzards differed greatly among the species, ranging 15–100% and 0–69, respectively. The grit-size distribution profiles of most species had definite peaks, with grit use declining abruptly on either side of the preferred grit size. In general, grit size increased linearly with the $\log_{(10)}$ of body mass. Grit particles ranged in shape from spherical to oblong; species more specialized in their selection of grit shapes tended to use spherical or nearly spherical grit. Most grit found in gizzards was intermediate between having sharp, irregular surfaces and having smooth, rounded surfaces. Overlap in the characteristics of grit used by birds and the characteristics of granular insecticides can be used to evaluate the likelihood that birds will pick up insecticide granules as a source of grit. *Received 26 April 1990, accepted 25 Sept. 1990.*

Granular insecticides are used extensively for pest control, especially in the Midwest, where millions of acres of corn are treated each year to control corn rootworms, cutworms, and corn borers (U.S. Dept. Agric. 1985). All major granular insecticides used for this purpose are highly toxic to birds (Schafer et al. 1983), and there have been numerous reports of avian mortality associated with granular insecticide use (e.g., see U.S. Environ. Protect. Agency 1989). Thus, treated fields constitute a potential avian hazard. Birds foraging in cornfields may inadvertently or intentionally pick up these granules; the latter probably occurs when birds mistake the granules for grit or, less likely, food. Very little is known about the grit use of birds that commonly frequent cornfields; the best documentation of grit use is for gallinaceous species, but that focuses on the birds' needs for calcium during egg-shell formation (Sadler 1961, Harper 1964, Korschgen 1964). An understanding of avian grit-use patterns is needed to assess potential avian risks to granular insecticides. If the characteristics of grit naturally selected by the birds are known, then those characteristics can be compared to the characteristics of various insecticide granules to determine the degree of similarity, and thus, the potential for birds to mistake granules for natural grit. In this report, we systematically characterize the grit-use patterns of 22 bird species that commonly use midwestern cornfields during the breeding season. We

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collected over 16,400 grit particles obtained from 770 individual birds. Our hope is that such information will ultimately be used to reduce avian risks where granular insecticides are applied.

METHODS

Grit use was characterized for 22 bird species known to use cornfields during the late spring and summer (Best et al. 1990), the period when granular insecticides are applied to control corn pests. (See Appendix I for the list of species and their scientific names.) The species included all those that exclusively (two species) or regularly (seven species) use cornfields during the breeding season and many of the species that are occasional visitors to cornfields. In addition, the two major upland gamebirds in the Midwest (Ring-necked Pheasant and Northern Bobwhite) were included.

The birds were obtained opportunistically from a variety of sources that included roadkills, birds collected specifically for this or other research projects, and hunter-harvested birds. At least 20 individuals of each species were collected. Most birds were secured during the spring and summer; exceptions were the Northern Bobwhite (collected primarily in December and January), Ring-necked Pheasant (October–December), and American Crow (December and February). In general, birds were obtained from Iowa or other midwestern states, although most of the Horned Larks were collected in Utah.

The gizzards were removed from all collected birds, labeled, and preserved in 75% ethanol until their contents could be examined in the laboratory. In the laboratory, each gizzard was sliced in half with a razor blade and its contents flushed into a petri dish. The gizzard contents were then examined and systematically sorted under a zoom, stereo microscope. All grit particles encountered were separated from the remainder of the gizzard contents. The search for grit particles was considered complete when a complete scan of the petri dish contents resulted in no additional grit particles being found. (Particles <0.1 mm in size were excluded because they were considered soil material and not grit selected by the birds.)

The number of grit particles found in each gizzard was counted, and the particles were characterized on the basis of their size, shape, and roundness. The longest and shortest dimensions of each grit particle were measured to the nearest 0.01 mm with a digital caliper (Mitutoyo model 500 digimatic), and these two values were then averaged for an overall measure of grit size. A grit-shape index value was calculated for each grit particle by dividing the longest dimension by the shortest dimension. These values were ≥ 1.0 , with 1.0 representing a spherical shape and larger values representing oval to oblong shapes. Grit roundness, a variable used to characterize the grit surface, was classified into five categories using a scheme developed by petrologists to describe mineral grains (El-Hinnawi 1966:15) (Fig. 1).

Gizzards completely devoid of food were not included in the data presented here because of the potential that they represented abnormal conditions. Furthermore, gizzards containing appreciable amounts of soil (i.e., hundreds of grit particles <0.2 mm in size) were excluded because they likely resulted from conditions where soil had been ingested inadvertently with the food (e.g., soil adhering to food surfaces) rather than being intentionally picked up by birds as grit. Less than 2% of the gizzards collected were discarded for the latter reason.

RESULTS

Frequency and quantity of grit use. — The 22 bird species studied differed both in the amounts of grit present in their gizzards and in the proportions of their gizzards containing grit (Fig. 2). The frequencies of occurrence of grit in gizzards of Dickcissels (15%, $N = 20$), Eastern Kingbirds (19%, N

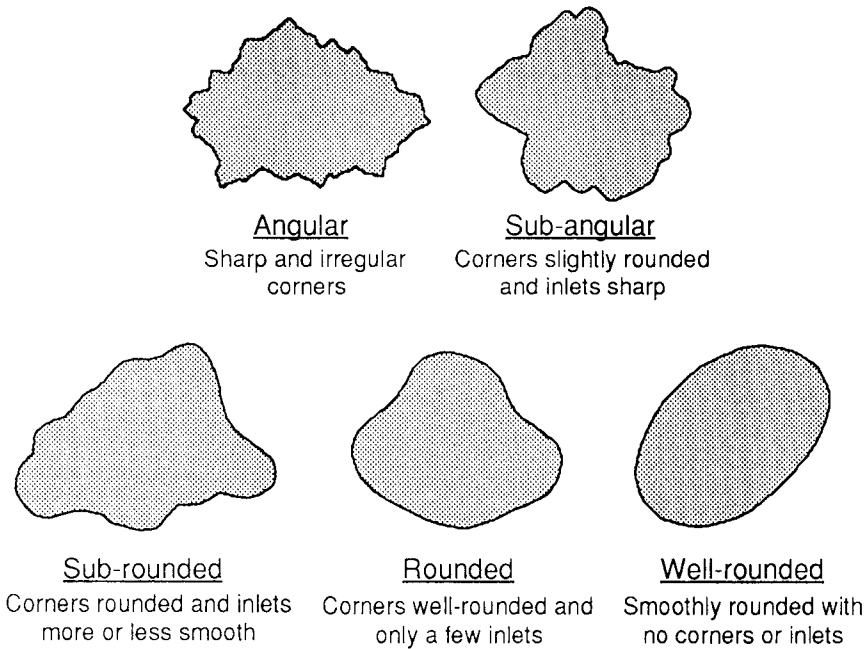


FIG. 1. Five categories used to characterize grit roundness.

= 26), and Barn Swallows (22%, $N = 23$) were particularly low, and less than 30 grit particles were obtained from each of these species. In addition, less than half of the gizzards of European Starlings, Red-headed Woodpeckers, and American Robins contained grit. The low occurrence of grit in Barn Swallows and Eastern Kingbirds was expected, in that these species are aerially feeding insectivores (De Graaf et al. 1985), and there is evidence that insectivorous birds often use less grit than birds with other diets (Alonso 1985; Best and Gionfriddo, unpubl. data). In contrast, the relatively infrequent grit use by Dickcissels and European Starlings was surprising because these birds are ground-foraging omnivores, as are most of the other species studied. The frequency of occurrence of grit in gizzards of several species was relatively high (Fig. 2), notably the Ring-necked Pheasant, Savannah Sparrow, House Sparrow, and Horned Lark.

The amount of grit found in the birds' gizzards differed greatly (Fig. 2). House Sparrow and Ring-necked Pheasant gizzards generally had the greatest amounts of grit; median grit counts in Savannah Sparrow, Blue Jay, and Northern Bobwhite gizzards also were relatively high. (The largest grit count documented for a single gizzard was of a female Ring-necked Pheasant in April, at the beginning of the nesting season.) As expected,

the species with the lowest proportions of gizzards with grit also had the lowest grit counts per gizzard. Median grit counts per gizzard for the Dickcissel, Eastern Kingbird, and Barn Swallow were all 0 (the ranges were 0–2, 0–1, and 0–21, respectively). When all species were compared simultaneously, an exponential relationship was found between the median number of grit particles per gizzard and the proportion of gizzards containing grit (Fig. 3). The amount of grit in the gizzards of most species was highly variable (Fig. 2). For example, median grit counts for Red-headed Woodpeckers, American Crows, and American Robins were all two or less, yet individual grit counts per gizzard ranged to over 100.

Grit size. — Mean grit size was related to bird body size (Fig. 4); grit size increased linearly with the $\log_{(10)}$ of the body mass. (Grit size, shape, and roundness data are not presented for species from which fewer than 50 grit particles were collected.) The linear regression line derived from the data described the relationship between grit size and body size well for most species. Exceptions were the American Crow, which used larger grit than expected based on its body size, and the Common Grackle, Red-headed Woodpecker, and American Robin, which used unusually small grit for their body masses. We cannot explain why the grit-size preferences of these species differed from the others. The crow and grackle are ground-foraging omnivores; the robin also forages primarily on the ground, although it sometimes feeds in the canopies of trees and shrubs; and the Red-headed Woodpecker feeds primarily on insects, either on trees or in the air (De Graaf et al. 1985). Perhaps some of the small grit in the robins' gizzards was not actually selected by the birds as grit, but rather was eaten incidentally when they ingested earthworms. (These particles could have been inside the earthworms' guts or adhering to the surface of the worms.) Earthworms are the primary food of robins during spring and early summer (Walton 1928, Johnson et al. 1976).

The distributions of grit sizes used by the various species differed greatly (Fig. 2). Several species (Red-headed Woodpecker, American Robin, House Sparrow, Common Grackle, Brown-headed Cowbird, Indigo Bunting, and Savannah Sparrow) were relatively restricted in their selection of grit sizes. This was evaluated by determining the minimum number of 0.2-mm size classes needed to comprise 80% of the grit particles sampled for each species. The Ring-necked Pheasant and American Crow used the broadest ranges of grit sizes of the 19 species evaluated. The breadth of grit sizes used, however, was related linearly to the mean grit size; birds that generally used larger grit also were more variable in their selection of grit size (Fig. 5). Considering this, European Starlings were particularly variable in their choices of grit sizes when compared with other species whose average grit sizes were similar. Conversely, although the American

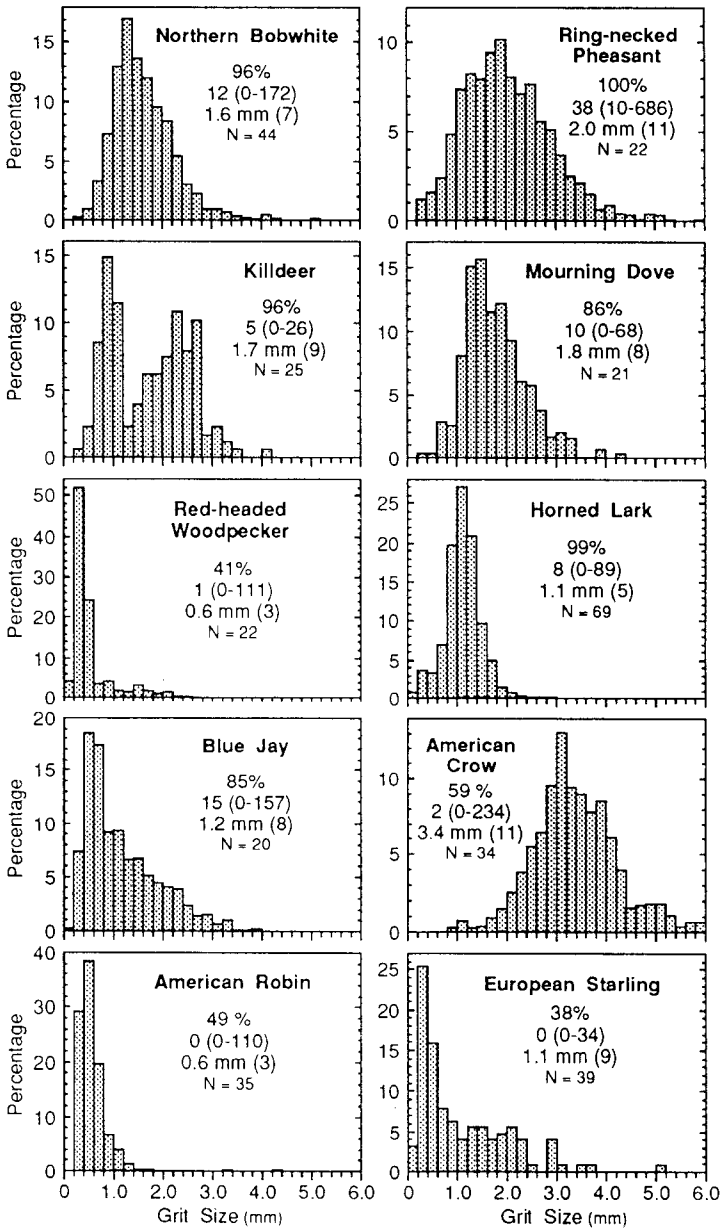
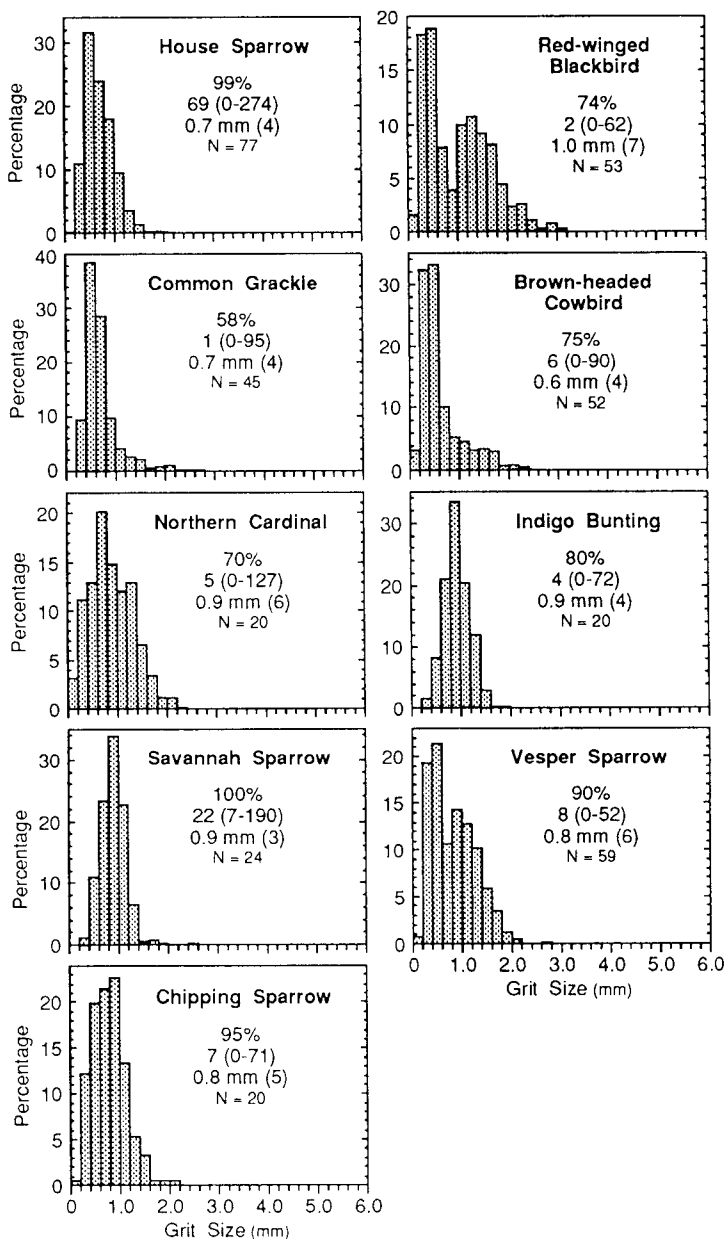


FIG. 2. Size distributions of grit particles found in cornfield bird gizzards. Also given are the proportion (%) of gizzards in which grit particles were found, the median (range) number of grit particles found per gizzard, the mean grit particle size, the number of 0.2-



mm size classes comprising 80% of the grit particles sampled (in parentheses), and the number of birds sampled.

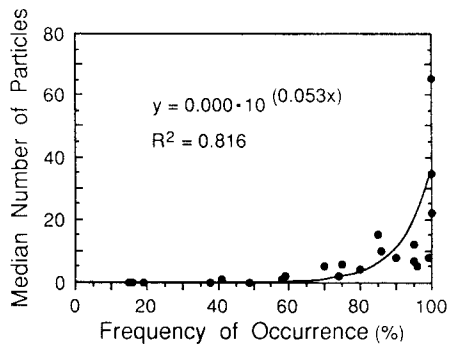


FIG. 3. Relationship between the median number of grit particles per bird and the proportion (%) of birds with grit. Each dot represents a species.

Crow selected, on average, the largest grit, its variation in grit-size use was less than expected based on the pattern of the other species.

The grit-size distribution profiles of most species had definite peaks, with grit use declining noticeably on either side of the preferred grit size (Fig. 2). Typically, the decline was more abrupt on the lower end of the size range than on the upper. The grit-size distributions of the Killdeer and Red-winged Blackbird are noteworthy because they did not exhibit a single grit-size preference; both seemed to have two preferred grit sizes. The bimodal distribution of grit sizes found in Killdeer and redwing gizzards was not related to differences in grit use between males and females (Killdeer mean grit size: males = 1.9 mm, females = 1.7 mm, *t*-test, $P > 0.1$; Red-winged Blackbird: males = 1.1 mm, females = 1.2

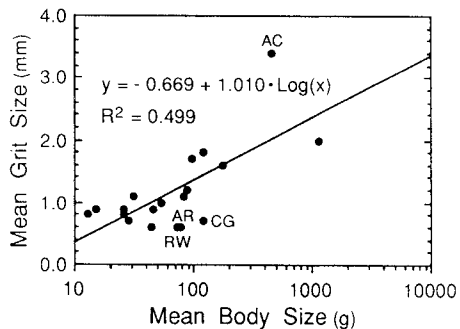


FIG. 4. Relationship between mean grit size and mean bird body mass. Body masses were obtained from Dunning (1984); for sexually dimorphic species, male and female body masses were weighted equally in determining means. Each dot represents a species; species for which fewer than 50 grit particles were collected are not included.

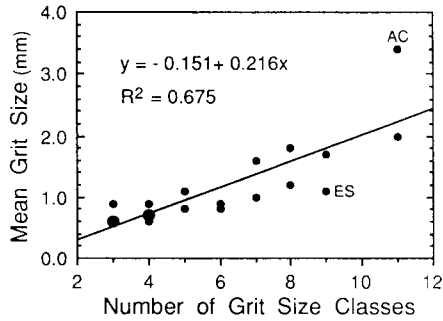


FIG. 5. Relationship between mean grit size and the number of 0.2-mm size classes comprising 80% of the grit particles sampled. Each small dot represents a species; the large dots each represent two species. Species for which fewer than 50 grit particles were collected are not included.

mm, $P > 0.1$) and did not seem to be related to other factors (e.g., month when the bird was collected). The grit-use pattern of these two species may be a sampling artifact, although the distinctness of the two peaks (particularly for the Killdeer) and the numbers of birds sampled argue against this supposition.

The amount of grit in the gizzards of some species seemed to be related to the size of grit. When this occurred, gizzards with more grit tended to have smaller-sized grit particles. This pattern was most evident in Brown-headed Cowbirds, but it also seemed to occur in other species (e.g., Blue Jays and Red-winged Blackbirds). For cowbirds, when the mean size of grit in gizzards was ≤ 0.7 mm, the average number of grit particles was 29.8; but when the mean size was > 0.7 mm, the average number of grit particles was 8.4 ($t = 3.22$, 37 df, $P < 0.01$). Similar measures for the Blue Jay were mean grit size ≤ 1.0 mm, mean grit count 72.0; mean grit size > 1.0 mm, mean count 28.4. For the Red-winged Blackbird the values were: mean grit size ≤ 1.0 mm, mean grit count 14.1; mean grit size > 1.0 mm, mean count 7.4. Neither of the differences for the latter two species, however, were statistically significant (t -test, $P > 0.1$).

Grit shape.—Grit particles can range in shape from nearly spherical (shape index approaching 1.0) to oblong, in which the longest dimension may exceed the shortest by several times (Fig. 6). The grit shapes selected by the 19 cornfield birds differed considerably. The American Crow showed the strongest tendency to use spherical grit; almost 40% of the grit found in gizzards of this species had a shape index of less than 1.2. Grit used by Red-headed Woodpeckers and American Robins also tended to be spherical or nearly spherical. The grit particles most frequently used by

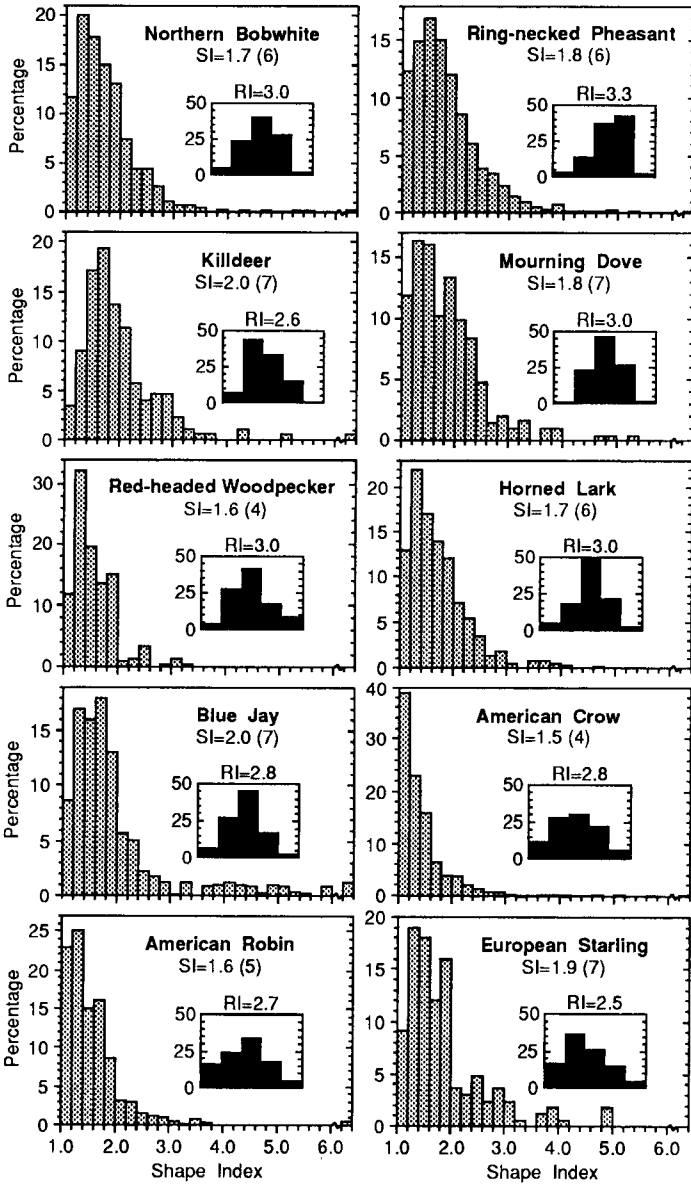
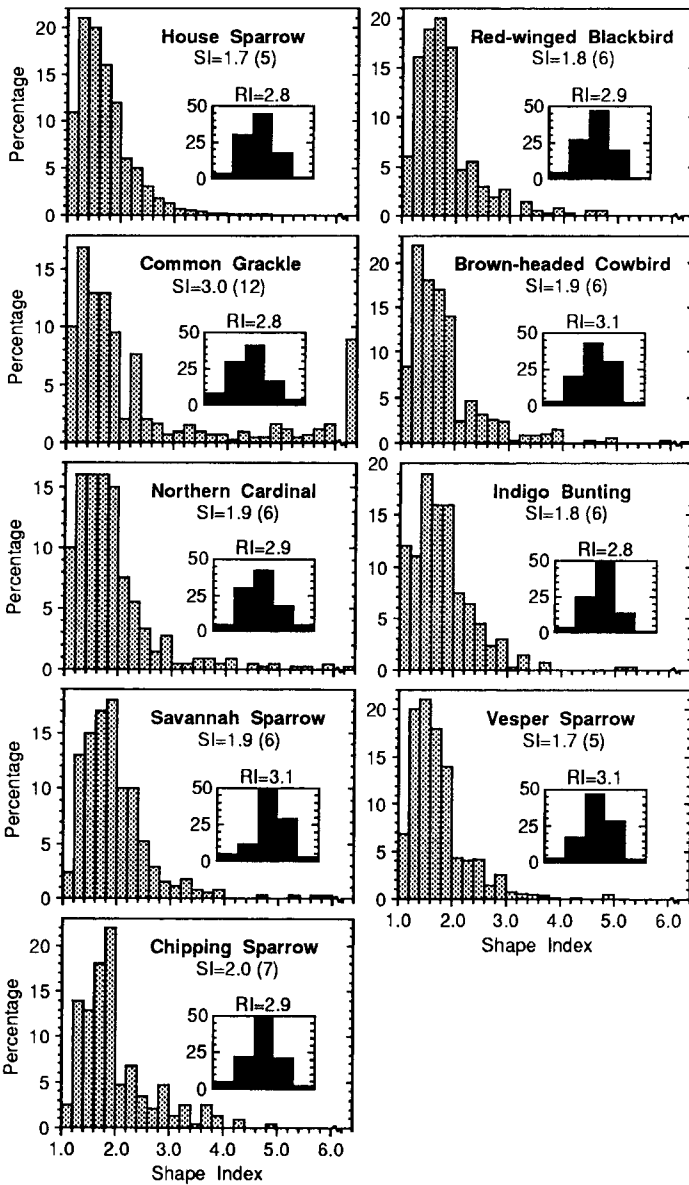


FIG. 6. Distribution of grit particles found in cornfield bird gizzards among the shape-index classes (stippled histogram) and among the roundness categories (black histogram). The last shape category represents grit particles with index values >6.0. The five roundness categories are (left to right): angular, sub-angular, sub-rounded, rounded, and well-rounded.



The SI (shape index) is the overall mean shape-index value, and the value in parentheses is the number of shape classes comprising 80% of the grit particles sampled. The RI (roundness index) is an overall mean roundness value computed by giving grit particles in the angular category a value of 1, those in the sub-angular category a value of 2, etc.

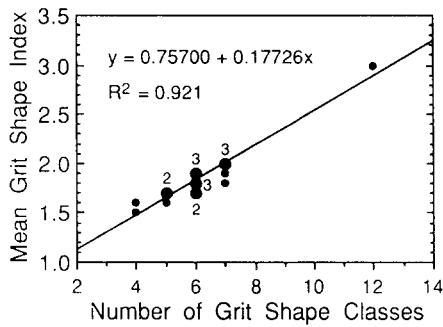


FIG. 7. Relationship between the mean grit shape-index value and the number of grit shape classes comprising 80% of the grit particles sampled. Each dot represents a species unless indicated otherwise. Species for which fewer than 50 grit particles were collected are not included.

other species (e.g., Killdeers, Blue Jays, Common Grackles, and Chipping Sparrows) tended to be more oblong.

The variability of grit shapes found in gizzards also differed among the 19 bird species sampled (Fig. 6). As with grit size, variation in grit shape was determined by counting the minimum number of grit-shape index classes needed to comprise 80% of the grit particles sampled for each species. The American Crow and Red-headed Woodpecker exhibited the most restricted use of grit shapes. American Robins, House Sparrows, and Vesper Sparrows also were relatively specialized in their choices of grit shapes. In contrast, the Common Grackle, and to a lesser degree the Blue Jay, tended to use wide ranges of grit shapes. Nine percent of the grit particles found in grackle gizzards had shape index values >6.0 , and 12 shape classes were needed to comprise 80% of the grit sampled for this species. When all species were compared, a general pattern became evident (Fig. 7). Species specializing in their selection of grit shapes tended to use spherical or nearly spherical grit, whereas species using disproportionately more oblong grit tended to be more generalized in their choice of grit shapes.

Grit roundness.—Grit particles ranged from having surfaces with sharp and irregular “corners” (i.e., projections) to having surfaces that were very round and devoid of irregularities (Figs. 1 and 6). In general, most grit particles found in gizzards had intermediate surface characteristics, that is, most were classified as sub-angular, sub-rounded, or rounded. Very few particles were categorized as well-rounded. Of the bird species studied, the Killdeer, American Robin, and European Starling had the highest proportions of angular-shaped (angular and sub-angular) grit in their giz-

zards. This was particularly true for starlings and Killdeers, whose gizzards contained over 50% angular and sub-angular grit. Ring-necked Pheasants, Brown-headed Cowbirds, Savannah Sparrows, and Vesper Sparrows generally used more rounded, smooth-surfaced grit than did the other species, but even in these species, very few grit particles were classified as well-rounded.

DISCUSSION

Comparisons across species revealed no consistent relationships between grit use with respect to one grit characteristic and grit use relative to other characteristics. This was true both for comparisons of overall mean values and for comparisons of the ranges of values chosen. That is, mean grit size was not related to mean grit shape, range in grit size was not related to range in grit shape, etc. Some individual species, however, did show certain noteworthy patterns. For example, although the American Robin and Red-headed Woodpecker had comparatively low proportions of gizzards containing grit (<50%), they were very restrictive in their choice of grit size and shape, seeming to prefer small, spherical grit (Figs. 2 and 6). These species also used relatively small grit for their body size (Fig. 4). The House Sparrow also used restricted ranges of grit sizes and shapes, but in contrast to the robin and Red-headed Woodpecker, grit was almost always present in gizzards of this species. The Common Grackle and American Crow represented some interesting contrasts in grit use. The grackle was relatively restricted in its choice of grit size, selecting grit comparatively small for its body size. Yet this species showed little apparent selectivity for grit shape. The crow demonstrated exactly the opposite pattern; it used a broad range of grit sizes comparatively large for its body size, yet chose a very restricted range of grit shapes.

Grit use by birds is influenced by grit availability; thus, grit-use patterns do not necessarily reflect grit preferences. This is probably least likely a concern relative to the amounts and sizes of grit consumed because these birds were collected primarily during the summer when snow and ice cover would not have restricted bird access to the soil surface. Furthermore, most birds came from the Midwest, where the land is used mainly for agricultural production, resulting in a relatively large proportion of exposed soil, and where gravel-surfaced secondary roads surround almost every section. The availability of grit of various shapes and, in particular, the availability of grit representing various degrees of roundness are determined largely by the sources of the grit and the history of exposure of the grit to erosion. The relatively low frequencies of occurrence in gizzards of grit in the well-rounded and angular classes (Fig. 6) could be attributed

to limited availability of these forms of grit. It would be useful to sample the shape and roundness of grit available to birds in their natural environment to assess preferences. The most precise tests of grit choice, however, would require birds to be studied in captivity where grit access could be controlled. We currently have such research under way to further evaluate grit preferences in House Sparrows.

Our characterization of the grit found in birds' gizzards represents a "snapshot" appraisal of grit use. In reality, grit selection and use is a dynamic process—grit is consumed, retained in the gizzard for a finite period of time, and then voided from the gastrointestinal tract. How long grit remains in the gizzards of birds and the degree to which grit size, shape, and roundness influence grit retention are largely unknown. The grit found in birds' gizzards depends not only upon grit selection (i.e., preference and availability) by the birds but also on the mechanisms of grit retention. Grit selection determines the range of grit that can potentially be present in gizzards, but the grit retention process determines which grit particles are retained in the gizzard and for how long. Research is needed to differentiate between the grit selection and grit retention processes.

The amounts and types of grit consumed by birds are determined not only by availability (see above), but also by other factors such as diet (e.g., Norris et al. 1975, Alonso 1985) and stage in the reproductive cycle (e.g., Harper 1964, Kopischke 1966). These factors often differ among seasons or geographical locations; thus, data collected in one study may not be representative of conditions elsewhere. Our study was designed to characterize grit use by birds frequenting midwestern cornfields in spring and summer. Grit-use patterns documented under other circumstances may or may not be similar to those we report. Our study is, however, the first attempt of its kind, and thus provides important baseline data that can serve as a basis for comparison with other research findings.

Grit preferences of birds should be considered when evaluating avian risks from granular insecticides. The amount of overlap between the size, shape, and roundness of granular insecticides and the size, shape, and roundness of grit naturally selected by individual bird species can be used to evaluate the likelihood that the birds will pick up the granules as a source of grit. Where the overlap is greater, the probability that the birds will consume the granules will be greater. This would be particularly true for those species that have relatively restricted preferences for grit size, shape, or roundness. The relative importance of these three grit characteristics in determining grit use is birds in unknown but needs to be evaluated, particularly if such information is to be used in designing insecticide granules to make them less attractive to birds.

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APPENDIX I
SCIENTIFIC NAMES OF THE BIRD SPECIES STUDIED

Common name	Scientific name
Northern Bobwhite	<i>Colinus virginianus</i>
Ring-necked Pheasant	<i>Phasianus colchicus</i>
Killdeer	<i>Charadrius vociferus</i>
Mourning Dove	<i>Zenaida macroura</i>
Red-headed Woodpecker	<i>Melanerpes erythrocephalus</i>
Eastern Kingbird	<i>Tyrannus tyrannus</i>
Horned Lark	<i>Eremophila alpestris</i>
Barn Swallow	<i>Hirundo rustica</i>
Blue Jay	<i>Cyanocitta cristata</i>
American Crow	<i>Corvus brachyrhynchos</i>
American Robin	<i>Turdus migratorius</i>
European Starling	<i>Sturnus vulgaris</i>
House Sparrow	<i>Passer domesticus</i>
Red-winged Blackbird	<i>Agelaius phoeniceus</i>
Common Grackle	<i>Quiscalus quiscula</i>
Brown-headed Cowbird	<i>Molothrus ater</i>
Northern Cardinal	<i>Cardinalis cardinalis</i>
Indigo Bunting	<i>Passerina cyanea</i>
Dickcissel	<i>Spiza americana</i>
Savannah Sparrow	<i>Passerculus sandwichensis</i>
Vesper Sparrow	<i>Pooecetes gramineus</i>
Chipping Sparrow	<i>Spizella passerina</i>
