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Characteristics of grit in Canada goose gizzards

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Abstract In many localities, Canada geese (*Branta canadensis*) have habituated to urban settings and their populations are increasing. Reproductive inhibitors contained in synthetic grit could play a role in integrated Canada goose management. We describe and quantify the physical characteristics of natural grit collected from the gizzards of Canada geese from 4 regions of the United States. The average grit sample had a weight of 14.26 g, a volume of 2.45 ml, a grit-particle count of 1,419, and a soil weight of 6.85 g. The average grit particle measured 2.02 mm long and 1.52 mm wide, and had an area of 2.05 mm^2 and a roundness rating of 1.25. Synthetic grit could be patterned after our findings to most likely be retained and utilized in the gizzards of Canada geese.

Key words *Branta canadensis,* Canada geese, gizzard, grit, reproductive inhibition

The adaptability, reproductive potential, and other physical and behavioral attributes of Canada geese (*Branta canadensis*, hereafter referred to as geese) make them as at home in big-city suburbs as they are in agricultural regions. Overabundant geese can be a nuisance, threaten human health and safety, and damage property. Geese damage lawns through grazing and by leaving droppings and feathers, contribute to algal growth in lakes, contaminate municipal water supplies, and transmit diseases to humans and other species (Friend 1987, Manny et al. 1994, Smith et al. 1999). Also, the number of geese involved in collisions with aircraft is increasing (Dolbeer 2000).

New and innovative strategies are needed to manage geese over the short and long terms and on local and landscape spatial scales. We suggest that overabundant resident geese be addressed by using an Integrated Pest Management (IPM) approach combining several management procedures into one strategy that is more effective than any single tactic. Nonlethal tactics to inhibit reproduction could be valuable in an IPM program for geese.

Synthetic grit containing chemical compounds that inhibit reproduction can potentially be used to administer predetermined doses of the compounds to geese. Once the synthetic grit reaches the gizzard, the reproductive inhibitor would be slowly and continuously made available for absorption. Synthetic grit, alone or hidden in food, currently is being evaluated as a means of delivering reproductive inhibitors to waterfowl in controlled (Hurley and Johnston 2002) and natural (VerCauteren and Marks 2002) settings. It also has the potential to be used to deliver medications, vaccines, or other chemicals to birds.

Little information exists about the grit-use patterns of birds (Gionfriddo and Best 1995), and our search of >7 databases revealed no peer-refereed papers discussing attributes of the grit of North American geese. Most research has addressed the process and dynamics of grit use by house sparrows (*Passer domesticus*) and northern bobwhites (*Colinus virginianus*) (Stafford and Best 1999) because these are ground-foraging species representative of numerous bird species most likely to

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ingest granular pesticides (Gionfriddo and Best 1996). Researchers have also studied grit use by mallards (*Anas platyrhynchos*), examining lead-shot ingestion (Trost 1981) and exposure to other contaminants (King and Bendell-Young 2000). Information on the natural grit used by geese is needed to facilitate the development of a synthetic grit that geese will readily ingest and retain in their gizzards. The objective of our study was to identify the size and shape characteristics of grit found in the gizzards of wild geese.

Methods

During July 2000 we collected goose gizzards from 4 locations across the United States during either the July molt or the December migration. Gizzards were collected at Virginia Polytechnic Institute and State University in Blacksburg, Virginia; the Puget Sound area in Washington; and the Fond du Lac, Wisconsin area. They were taken from adult geese captured during the molt by United States Department of Agriculture/Animal and Plant Health Inspection Service/Wildlife Services (WS) personnel. Geese were euthanized humanely as part of annual population management procedures. Gizzards collected during December 2000 near Lewellen, Nebraska were from hunter-harvested geese. All gizzards were removed, bagged individually, frozen, and shipped to the WS National Wildlife Research Center (NWRC, Fort Collins, Colo.) for analysis.

We bisected gizzards from the isthmus to the thin caudal end and flushed the contents into a fine-mesh sieve (0.147 mm). Contents from the sieve were transferred to a weighing dish, and hard particles were separated from foodstuffs and other materials. We then separated the particles into 2 groups: those that could be sifted through a 1-mm mesh sieve and those that could not. The finer material that passed through the 1-mm mesh was classified as soil; this material likely was ingested inadvertently while feeding or was severely eroded grit. The remaining particles were considered grit selected for by the geese. After being dried thoroughly, the soil and grit were weighed using an electronic balance (PM 4600, Mettler-Toledo, Columbus, Oh.). We determined the volume of grit found in each gizzard by recording the displacement caused by grit when added to 10 ml of tap water in a 25-ml graduated cylinder.

The grit from each gizzard represented a single sample. To prepare samples to be photographed, we placed each in a 1,000-ml beaker that was inverted onto a Polaroid MP4 Land Camera light table (Cambridge, Mass.) with 4 internal fluorescent bulbs and 4 overhead 150-W floodlights. We separated individual grit particles to the extent possible by vibrating the table. Images were captured with a Nikon Coolpix 990 digital camera (Chiyoda-ku, Tokyo, Japan) mounted 50 cm above the light table. The camera was set on automatic focus at the high image-quality level; images were saved as TIFF files. We included a millimeter scale in the field of every image to allow for the calibration of each sample. We analyzed images from each sample using Image-Pro Plus image analysis software (Media Cybernetics, Silver Spring, Md.). The software was designed to count small to microscopic objects and measure their physical characteristics. Images of individual samples were downloaded into Image-Pro Plus with 2,048 × 1,536 lines of resolution. Though we tried to separate grit particles before capturing images, particles were occasionally touching and we used the editing option of Limited Watershed Split at a level of 3 pixels to separate these particles.

The parameters we measured with the software included the number of grit particles and the length, width, area, and perimeter of each particle. Length and width described the general dimensions of each particle. Image-Pro Plus used the area and perimeter measurements to establish a roundness rating, which most accurately described the shape of each grit particle. Roundness ratings ranged from 1.00–1.75, with 1.00 being nearly round and 1.75 being the least round (Figure 1). For all samples, we determined a mean and standard error for all

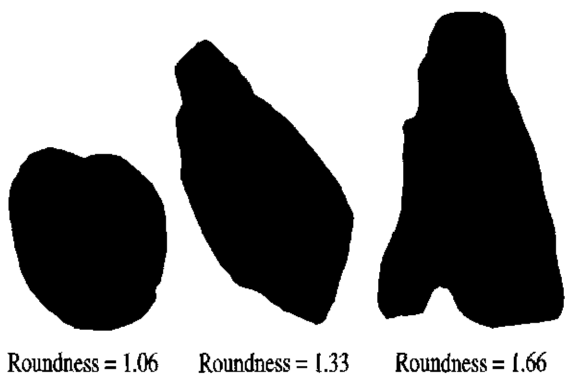
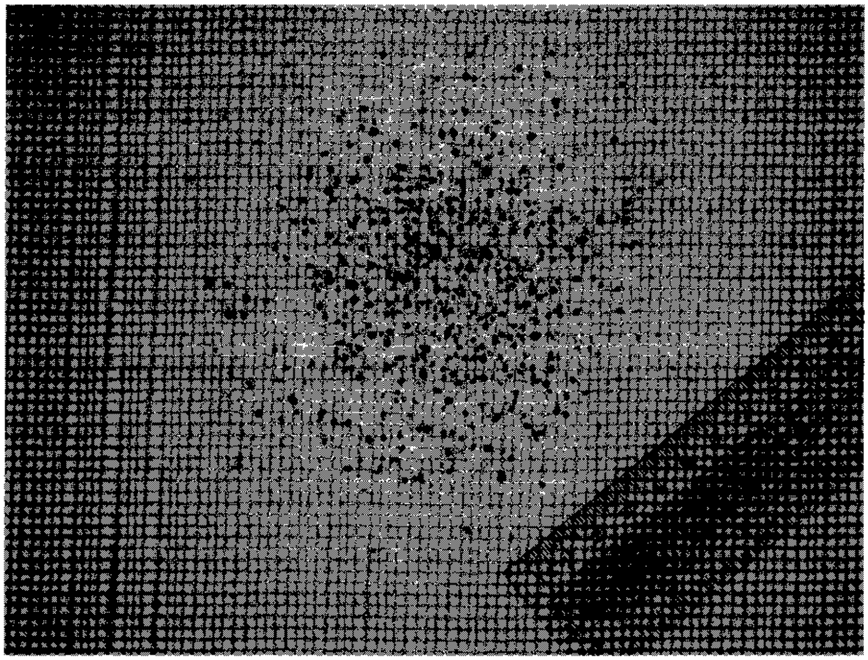


Figure 1. Example of grit-particle shapes and roundness ratings from Canada goose gizzards collected in Nebraska, Virginia, Washington, and Wisconsin, 2000. Roundness scale is from 1.00–1.75, with 1.00 being the most round.



Example of a grit-sample image from a single gizzard that is ready to be imported and analyzed.

measured parameters (weight and volume of each sample; number of particles; and length, width, area, and roundness of each particle). We then compared parameter values for samples collected in July. For a seasonal comparison of grit parameters, we also compared the Nebraska samples collected in December to those collected in July. We then defined the average sample and particle.

We used a General Linear Models procedure (SAS Institute Inc. 1988) to test for differences in sample and grit particle parameters among states and seasons. We used linear contrasts to compare states within season and to compare seasons. The study protocol was approved by the NWRC Institutional Animal Care and Use Committee (QA-852).

Results

We collected gizzards (n = 177) from Nebraska, Virginia, Washington, and Wisconsin (Table 1). The overall mean weight of grit and soil material in a gizzard was 21.70 g (SE=0.63); grit represented 66% ($\bar{x}$= 14.35 g, SE=0.38) of the weight and soil 34% ($\bar{x}$=7.28 g, SE = 0.30). Table 1 contains the means and standard errors by state for each of the measured grit sample and particle variables, and the overall average.

Gizzards from Nebraska had the highest mean grit and soil weights, while those from Virginia had the lowest mean grit weight and those from Wisconsin had the lowest mean soil weight. Gizzards from Nebraska had the highest mean volume and grit count, while Wisconsin gizzards had the lowest means for these variables (Table 1). Mean grit length and width were smallest for Nebraska samples and largest for Virginia samples. Mean roundness for all samples fell in the range 1.24- 1.26, with very little variation within samples (Table 1).

Sample weight, volume, and grit count were inversely related to grit particle area (Table 1). Nebraska samples had the highest weight, volume, and grit counts, but also had grit particles of the smallest size (length, width, and area). Virginia, conversely, had the lowest grit weight, the second lowest volume, and the second lowest grit counts, but had the largest

Table 1. Mean (±SE) grit measurements from the gizzard contents of Canada geese collected in July (Virginia, Washington, and Wisconsin) and December (Nebraska) 2000. Parameters measured were grit count, grit sample weight (g), soil weight (g), grit sample volume (ml), and grit particle length (mm), width (mm), area (mm^2), and roundness. The typical sample and particle represents the median value of the range of overlap of all the measured parameters among all 4 states.

		Grit count		Grit weight (g)		Soil weight (g)		Volume (ml)		Length (mm)		Width (mm)		Area (mm^2)		Roundness	
State	n	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
NE	50	2,096	74.30	17.56	0.60	10.63	0.48	3.93	0.19	1.93	0.02	1.47	0.01	1.87	0.04	1.26	0.00
VA	54	1,049	56.49	10.88	0.55	5.41	0.33	1.94	0.14	2.08	0.02	1.56	0.01	2.24	0.05	1.24	0.00
WA	50	1,648	96.15	15.44	0.61	7.49	0.56	2.59	0.21	2.05	0.02	1.52	0.02	2.06	0.05	1.26	0.00
WI	23	883	89.14	13.15	0.99	3.85	0.43	1.32	0.17	2.00	0.02	1.51	0.02	2.04	0.05	1.24	0.00
Average		1,419		14.26		6.85		2.45		2.02		1.52		2.05		1.25	

grit-particle sizes (length, width, and area).

Samples collected in December differed from samples collected during July ($P<0.006$) in all the measured dependent variables: sample weight, sample volume, grit count, mean length, mean width, mean area, and roundness. We found differences in grit counts ($P<0.001$) among gizzards from all states except when contrasting Virginia and Wisconsin ($P=0.214$). No parameters were similar among all 4 states.

Discussion

We collected gizzards from geese in 4 distinct geographic locations across the United States during two distinct biological periods (summer molt and fall migration) and found variability in the characteristics of grit samples and particles. Variability might have resulted from regional diversity of sediment types available to geese, from variation in grit hardness, or sensitivity to gastric acids, all of which could have resulted in different rates of grit-particle erosion within a gizzard. Differences in subspecies of geese collected might have been another factor affecting variability, especially for measurements related to gizzard volume. We could not confidently determine subspecies of the individuals collected. The extremely low variation in grit size (length, width, area, and roundness) within sites implied high selectivity for particular grit characteristics by geese; the variation in particle sizes available certainly exceeded that observed in gizzards. It also implied rapid turnover of grit since progressive erosion of grit particles being retained and abraded would result in increased variation when compared to newly ingested particles.

The type of food being ingested by geese at the time they were collected may also play a role in the characteristics of grit found in gizzards. For example, geese grazing on grass in urban parks in the summer might not have the same abundance of grit available or might select a different size or volume of grit when feeding on waste corn in agricultural fields late in the fall. Furthermore, geese feeding on grass may not experience the same rate of grit-particle erosion as geese feeding on corn, resulting in overall grit-particle characteristics that differ. In studies with captive mallards (Trost 1981), house sparrows, and northern bobwhites (Best and Stafford 2002), diet type could be correlated to the amount of grit ingested. Trost (1981) found that mallards fed a whole-corn diet ingested >2 times more grit than ducks fed a whole-corn-commercial-pellet combination or commercial pellets only. Both house sparrows and northern bobwhites fed a hard, wild birdseed mix retained greater amounts of grit than those fed a soft, canned dog food (Best and Stafford 2002).

The volume of grit a gizzard can hold is an important consideration when attempting to use synthetic grit to administer doses of compounds to geese. Our grit-volume measurements help define the grit capacity of a gizzard within this species. Regurgitation of grit may occur if this volume is exceeded, as has been documented in studies where geese were force-fed synthetic grit (Hurley and Johnston 2002, L. Clark unpublished data). Alternatively, excess grit may pass through the gizzard and digestive system (Best and Stafford 2002), in which case the synthetic grit would not be broken down and absorbed. Our data on the characteristics of grit samples and particles will be useful in the design and manufacture of synthetic grit. To dose geese in a management situation, the ingestion of a minimal number of typically shaped synthetic grits may optimize success. The grit could be placed where it would be selected for by geese, or, in the case of habituated resident geese, it could be hidden in bread or other foodstuffs and fed to individuals (VerCauteren and Marks 2002).

The Image-Pro Plus software we used may be valuable in further research on grit because of its ability to quickly count, measure, and quantify a variety of characteristics of many small particles. For example, grit erosion-rate measurements, color-preference evaluations, and lead-shot-ingestion examinations could be simplified with the use of this software.

More research is needed on grit selection and use by geese; comparisons should be made between geese of different ages, sexes, and subspecies. To complement the work we report here, we suggest collecting gizzards during breeding and nesting seasons, when dosing with reproductive inhibitors is most practical. Variability between the samples collected from different seasons could suggest possible differing grit preference by season. As a result, there may be a need for several season-specific synthetic grit designs. Trost (1981) found that between early May and early June, mallard females ingested an average of 129 g of oyster-shell grit (mainly calcium), compared to the average of 24 g ingested by males. We speculate that female birds may select for grit with higher calcium content during the breeding season because of an increased need for calcium during egg production. A better understanding of grit-retention time and the impact of retention time on grit-particle size and shape would aid in the development of a synthetic grit. Information on grit hardness related to selection, breakdown, and retention in the gizzard is also needed. The results we report here on the grit characteristics of geese are an important first step in developing a synthetic grit. The research directions we suggest will be important next steps. The development of synthetic grit to deliver reproduction inhibitors, medications, or other chemicals to birds appears realistic and has potential.

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