Transactions of the Illinois State Academy of Science
(2012) Volume 105, #3&4 pp. 107-117
received 12/30/11
accepted 7/26/12

The Role of Oil Content and Size in Seed Selection by Wild Birds

Kathleen A. Collins and David Joseph Horn[1]
[1]Department of Biology, Millikin University
1184 W. Main St., Decatur, IL 62522, USA

ABSTRACT

We determined whether birds actively select specific varieties of a single seed species, whether seed selection is based on oil content, how birds can distinguish seeds based on oil content, and if seed preferences are equivalent among species. Three trials were conducted from winter 2007-summer 2007 at Rock Springs Environmental Center in Decatur, IL. During each trial, seed consumption and bird abundance of each species at each seed variety of black-oil sunflower (*Helianthus annuus*) were recorded. In all trials, seed consumption of the highest oil content seed was 31-49% greater than any other seed variety. House Finch (*Carpodacus mexicanus*), American Goldfinch (*Spinus tristis*), and House Sparrow (*Passer domesticus*) preferred seeds with a higher oil content when seed size was equivalent, but selected shorter, deeper seeds with a lower oil content at equivalent levels to larger seeds with a higher oil content when both varieties were present. Knowing the factors influencing seed choice allows for the development of seed varieties that will be more attractive to songbirds.

INTRODUCTION

Previous studies have examined seed species preferences of wild birds that use feeders (Geis 1980, Horn et al. 2002). Few studies have investigated whether birds choose among multiple varieties of the same seed species, and why birds prefer the seeds of the variety they select. Factors influencing seed choice may include nutritional content of the food (Schaefer et al. 2003), seed size (Willson 1972), bill size (Hespendeide 1966), and behavior of the bird (Foster 2008). In a study of seed preferences of Henslow's Sparrows (*Ammodramus henslowii*), two of the preferred seed species had higher energy content, while two of the avoided seed species had the lowest content, indicating that nutrition could play a role in seed selection (DiMiceli et al. 2007). Birds have also selected seed species based on the handling time of a particular species, which in turn, was dependent on the size and shape of the bill (Hrabar and Perrin 2002). When selecting among seeds of a single species, Black-capped Chickadees (*Poecile atricapillus*) and Red-breasted Nuthatches (*Sitta canadensis*) selected sunflower seeds based on weight (Heinrich et al. 1997). Weighing sunflower seeds could be beneficial to birds in order to minimize the energy costs of foraging while maximizing the reward (Lima 1985).

We studied four questions associated with why wild birds select specific seeds: (1) Do birds actively select varieties of the same seed species? (2) Do birds select seeds based on nutritional content? (3) Is nutritional content related to seed size? (4) Are there differences among species in regards to seed preference? We hypothesized that birds will distinguish among seed varieties of the same species, bird abundance would be greater at seed varieties with greater oil content, and that seed morphology is related to oil content.

In 2006, over 55 million Americans over the age 16 spent more than $4.1 billion on bird food, feeders, and other products (U.S. Fish and Wildlife Service 2007, 2008). Conducting studies on whether birds prefer certain seed varieties over others may lead to a better bird feeding experience if preferred varieties are introduced to bird seed blends. In turn, attracting a greater diversity of birds to one's yard may elevate awareness for the natural world, increase participation in outdoor recreation, and motivate individuals to become involved in conservation issues at a time when participation in some nature-based activities is declining (Pergams and Zaradic 2008, U.S. Fish and Wildlife Service 2009).

METHODS

Procedures

Our study consisted of three trials conducted from winter–summer 2007 at Rock Springs Environmental Center in Decatur, Illinois. Tubular bird feeders were utilized (Droll Yankees B-7R), and there were three or four feeders used, each filled with a different variety of the same species of black-oil sunflower seed, depending on the trial. Black-oil sunflower was selected as it is one of the most preferred seed types among species that commonly use feeders (Geis 1980, Horn et al. 2002). Feeders were hung from a cable approximately 3 m off the ground, and were placed approximately 1 m apart from each other in a straight line. Feeders were rotated in a systematic manner on a weekly basis to ensure that birds were selecting the seed variety not feeder location (Horn et al. 2003), and the initial location of each seed variety within a feeder was determined randomly. Feeder observations took place while seated on a bench looking through a large viewing window. The feeders were approximately 3 m from the window.

To determine whether birds select seeds based on nutritional content and whether there are differences among species in regards to seed preferences, three trials were conducted. Trial 1 examined how seed consumption and relative abundance of birds differed among bird feeders filled with three varieties of small black-oil sunflower seeds (where small seeds are defined as seeds that fit through a 0.5 cm hole [seeds were provided by and sorted at D&D Commodities Ltd., Greeley, CO, USA]). Three oil contents were used: 40.2, 43.6, and 51.4% (oil contents were determined at Eurofins Scientific Inc., Des Moines, IA, USA). Trial 1 ran from 26 Feb.–6 Apr. 2007.

Trial 2 examined seed consumption and bird abundance at feeders filled with large black-oil sunflower seeds of varying oil contents (where large seeds are defined as seeds that cannot fit through a 0.5 cm hole). Three oil contents were used: 37.8, 41.1, and 48.1%. The trial ran from 6 Apr.–18 May 2007.

Trial 3 examined bird use of sunflower seeds of varying size and oil content. Four seed types were used: small 43.6, large 41.1, small 51.4, and large 48.1%. The trial ran from 18 Jun.–9 Aug. 2007.

Consumption of each seed variety was recorded as the difference in total mass of the seed at the beginning and end of each trial. For each trial, bird abundance was determined through monitoring sessions. Specifically, the number of each bird species present at each feeder was recorded every 5-min during 60-min monitoring sessions, and the means for each session were calculated. Approximately 3 monitoring sessions took place each week with 18, 15, and 24 monitoring sessions being conducted for Trials 1, 2, and 3, respectively. Observations took place from 08:00–17:00. Because relationships between bird abundance and preference, and seed consumption and preference, are similar (Horn 1995), measures of both bird abundance and seed consumption were used as indicators of preference for each trial.

To determine if nutritional content is related to seed size, we took multiple measures of each seed variety. We measured the depth, length, width, and weight of 75 seeds of each seed variety using digimatic calipers (Mitutoyo CD-6" CSX) and an analytical balance (Mettler AJ100).

To examine whether birds actively select varieties of the same seed species, we conducted another study concurrent with Trial 3. The study involved observing seed choice of individual birds immediately after feeders were rotated (Fridays) compared to seed choice after birds were adjusted to the feeders' new positions (Mondays and Thursdays), allowing us to determine if birds change the feeder they visit when the preferred seed variety is moved to a different feeder location. Recordings of seed choice by individual birds were made every 30 sec in 45-min sessions performed every Friday, Monday, and Thursday. To determine which bird to observe, six species were placed into a priority list in random order, and the species of the highest priority present in the feeder area was selected to be observed during the 30-sec interval. Upon selecting a bird to monitor, the first seed choice of the individual was recorded.

For our study, we did not put color bands on birds, and it is possible that some birds were double counted. The number of birds frequenting a feeding station, however, can be very large. Geis and Pomeroy (1993) captured birds in a single yard using mist nets and funnel traps within a lightly developed area in Clarksville, Maryland. In the summer of 1989, they established population estimates ranging from 14 for Tufted Titmouse (*Baeolophus bicolor*) to 5,798 for House Finch (*Carpodacus mexicanus*) with an estimated population size of all feeder birds combined of 6,937 individuals. In our study, the mean number of bird visits per monitoring session in Trial 3 (conducted during summer) was 151. Thus, if Geis and Pomeroy's estimate of 6,937 individuals was representative of our study site, a minimum of 46 monitoring sessions would need to be conducted each trial to record each individual within the population.

Statistical analysis

Only species with > 30 observations per trial were used in analyses. To determine whether seed choice was equivalent among the four seed types before and after feeders were rotated, chi-square tests were performed to compare the frequency each seed variety was selected by individual birds immediately after feeders were rotated (Fridays) compared to the period when birds had time to adjust to the new positions (Mondays and Thursdays combined). Chi-square tests were used because our response variable was the number of times individual birds selected a particular seed variety first as opposed to a response variable such as the mean number of bird visits to a seed variety immediately after rotation compared to 3-5 days after rotation. P-values < 0.05 were considered significantly different. To determine whether bird abundance of each species, total number of individuals of all species combined, and species richness per 60-min monitoring session differed among seed types, 95% confidence intervals (CIs) were calculated (Di Stefano 2004), as CIs provide both measures of uncertainty and effect size among treatments (where the seed varieties are the treatments, Johnson 1999). CIs were also calculated to identify differences in seed shape and weight among seed varieties. Treatments with non-overlapping CIs were considered significantly different.

RESULTS

Do birds actively select varieties of the same seed species?

During our examination of whether birds actively select seed varieties (performed concurrently with Trial 3), six species had > 30 observations. All six species, Black-capped Chickadee (N = 83, X^2 = 166.4, df = 3, P < 0.001), Tufted Titmouse (*Baeolophus bicolor*, N = 38, X^2 = 45.7, P < 0.001), White-breasted Nuthatch (*Sitta carolinensis*, N = 48, X^2 = 11.6, P = 0.009), House Finch (N = 106, X^2 = 19.4, P < 0.001), American Goldfinch (N = 96, X^2 = 35.8, P < 0.001), and House Sparrow (N = 49, X^2 = 62.1, P < 0.001), had differences in the frequency of visits to a seed variety after adjusting to the seed variety being in a new position (Table 1, see Fig. 1 as a representative example).

Table 1. For six bird species, frequency of seed choice among four varieties of black-oil sunflower (Small - 43.6, Large - 41.1, Small - 51.4, and Large - 48.1) differed between when feeders were first rotated (Friday) compared to after rotation (Monday and Thursday).

	Small - 43.6		Large - 41.1		Small - 51.4		Large - 48.1	
Species	F[A]	M/T	F	M/T	F	M/T	F	M/T
AMGO[B]	0.19	0.25	0.22	0.06	0.52	0.62	0.07	0.07
BCCH	0.39	0.07	0.26	0.22	0.13	0.22	0.22	0.50
HOFI	0.19	0.28	0.27	0.13	0.35	0.42	0.19	0.17
HOSP	0.14	0.34	0.14	0.23	0.43	0.34	0.29	0.09
TUTI	0.44	0.21	0.00	0.10	0.11	0.28	0.44	0.41
WBNU	0.07	0.11	0.21	0.11	0.21	0.26	0.52	0.53

[A] F = Friday, M/T = Monday/Thursday.
[B] AMGO = American Goldfinch, BCCH = Black-capped Chickadee, HOFI = House Finch, HOSP = House Sparrow, TUTI = Tufted Titmouse, and WBNU = White-breasted Nuthatch.

Do birds select seeds based on nutritional content?

Seed consumption was used to determine whether birds select seeds based on oil content. During Trial 1, the greatest consumption of small seed occurred at the highest oil content seed (51.4%) with consumption of the 51.4% oil content seed at 21 kg, 40.2 at 16 kg, and 43.6 at 13 kg. During Trial 2, the greatest consumption also occurred at the seed with the highest oil content (48.1%) with 20 kg consumed followed by 41.1 at 14 kg, and 37.8 at 11 kg.

During Trial 1, no significant differences in bird abundance were observed among the three small-seed varieties with five species having > 30 observations: Downy Woodpecker (*Picoides pubescens*, N = 106), Black-capped Chickadee (N = 63), House Finch (N = 81), American Goldfinch (N = 691), and House Sparrow (N = 45).

No significant differences in bird abundance were observed during Trial 2 among the three large-seed varieties with three species being observed >30 times: Rose-breasted Grosbeak (*Pheucticus ludovicianus*, N = 61), House Finch (N = 48), and American Goldfinch (N = 197).

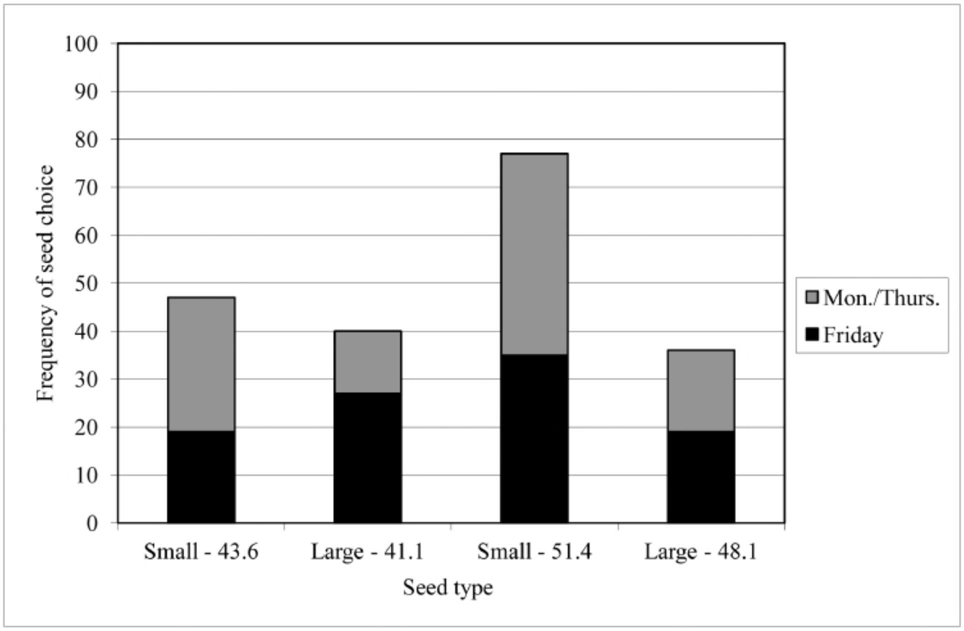


Figure 1. House Finch seed choice differed among four varieties of black-oil sunflower that varied in size and % oil content when feeders were first rotated (Friday) compared to after rotation (Monday and Thursday, $N = 106$, $X^2 = 19.4$, df = 3, $P < 0.001$). Changes in the frequency of seed choice (proportion of total bird visits made to each of the four seed varieties) indicate that birds actively choose specific varieties of seed based on size and oil content.

Is nutritional content related to seed size?

Birds may be able to assess the oil content of a seed based on the seed's depth, length, and weight, all of which differed in a predictable manner among seed varieties. Collectively, deep, short, heavy seeds may be cues that birds use to identify high oil content. For example, the depth of small seeds was greatest at the highest oil content seed (Fig. 2a). The length of large seeds, as well as small seeds, decreased with oil content (Fig. 2b). The weight of small, and large seeds, increased with oil content (Fig. 2c), with large seeds being heavier than small seeds regardless of oil content (Fig 2d).

Figure 2. 95% confidence intervals of the depth, length, and weight of black-oil sunflower seed varieties that vary in size and % oil content.

Figure 2A. The depth of small seeds was greatest for the highest oil content variety.

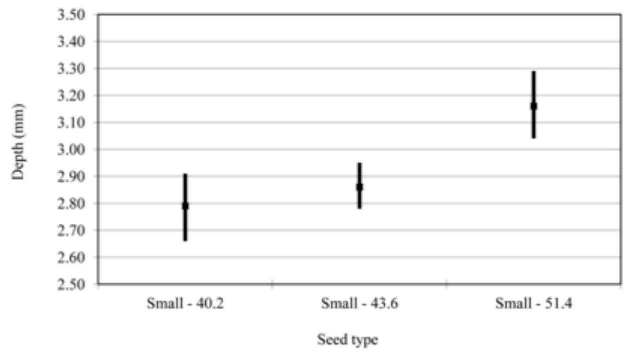


Figure 2B. The length of large seeds, as well as small seeds, decreased as oil content increased.

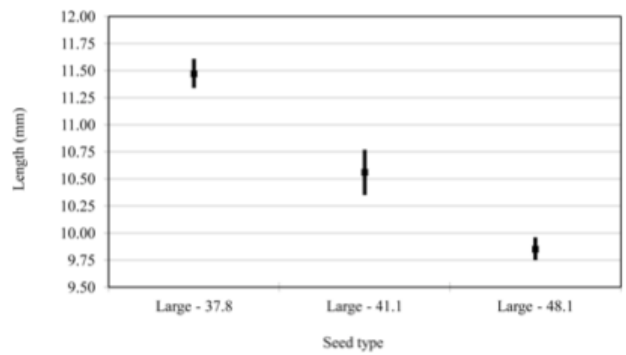


Figure 2C. The weight of small seeds, as well as large seeds, was greatest for the highest oil content variety.

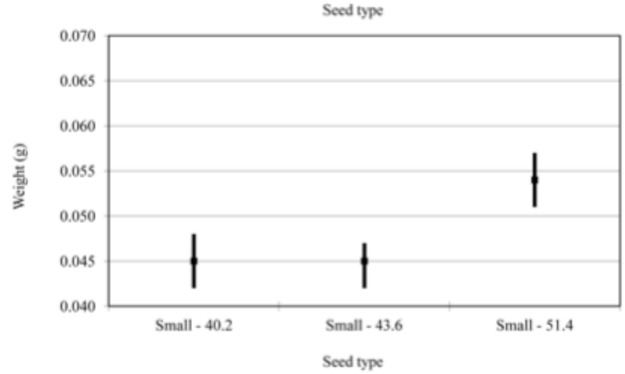
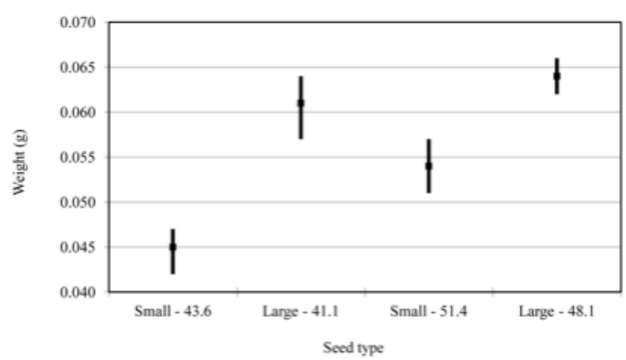


Figure 2D. Large seeds were heavier than small seeds, regardless of oil content.



Are there differences among species in regards to seed preference?

Trial 3 examined seed consumption and bird abundance in relation to both seed size and oil content. The greatest consumption occurred at the highest oil content seed (small 51.4%) at 52 kg. The small seed with the lower oil content (43.6%) was the second most consumed seed at 35 kg followed by large 48.1% at 29 kg and large 41.1 at 26 kg. Thus, while previous trials found that the higher the oil content, the greater the seed consumption; in some cases smaller seeds with lower oil content are preferred over larger seeds with higher oil content.

Small seeds were preferred over larger seeds as 43.6% and 51.4 small seeds had a greater abundance of birds of all species combined than 41.1% and 48.1 large seeds. At Rock Springs, 95% CIs of the mean number of birds per 60-min observation session ranged from 1.43-1.96 at small 43.6% seeds, 0.80-1.35 at large 41.1 seeds, 1.95-2.78 at small 51.4 seeds, and 0.77-1.20 at large 48.1 seeds.

The greater number of individuals of all species combined at small seed varieties is likely a result of differences among species in regards to seed preference. We found that species that sit and eat at a feeder would select smaller seeds with a lower oil content at an equivalent level to larger seeds with a higher oil content. House Finch (N = 1031), American Goldfinch (N = 536), and House Sparrow (N = 155) had their greatest abundance at small seeds, and had significantly greater abundances at the small 51.4% seed compared to the larger seeds (Fig. 3). 95% CIs of the mean number of House Finch per 60-min observation session ranged from 0.69-1.29 at small 43.6% seeds, 0.35-0.80 at large 41.1 seeds, 0.85-1.63 at small 51.4 seeds, and 0.31-0.69 at large 48.1 seeds. 95% CIs of the mean number of American Goldfinch per 60-min observation session ranged from 0.30-0.52 at small 43.6% seeds, 0.22-0.40 at large 41.1 seeds, 0.64-0.90 at small 51.4 seeds, and 0.14-0.32 at large 48.1 seeds. 95% CIs of the mean number of House Sparrow per 60-min observation session ranged from 0.07-0.23 at small 43.6% seeds, 0.03-0.11 at large 41.1 seeds, 0.12-0.31 at small 51.4 seeds, and 0.02-0.11 at large 48.1 seeds. Downy Woodpecker (N = 75) abundance was equivalent at each seed variety.

DISCUSSION

We found that wild birds actively choose specific varieties of a single seed, and make choices based on oil content and seed size. In addition, we found that seed characteristics can be used as an indicator of the nutritional content of the seed. Several studies have addressed seed preferences among bird species. A majority of the studies have focused on seed size and shape of multiple seed species (Hespenheide 1966, Willson 1971, Willson 1972, Pulliam 1985). These studies found that birds develop preferences toward certain seed species based on feeding efficiency, or handling time, and the relationship between seed size and bill size. In general, larger-billed birds have the ability to eat larger seeds more effectively than small-billed birds (Hespenheide 1966, Diaz 1990). Studies of a bird's ability to assess the quality of different varieties of the same seed species based on its physical characteristics are fewer, but have been demonstrated in Black-capped Chickadees (Templeton 2011). Specifically, chickadees were able to select seed heads of spotted knapweed (*Centaurea maculosa*) that had greater amounts of gall fly (genus *Urophora*) larvae using seed head size as one indicator of gall fly abundance.

We found that wild birds showed a preference for black-oil sunflower varieties with the highest oil content. Previous studies found that wild birds display preferences for specific micronutrients, and have the ability to distinguish between varying concentrations of sugars and lipids (McWillams et al. 2002, Schaefer et al. 2003, Pierce et al. 2004, Brown et al. 2010). In a study of four tanager species, Schaefer et al. (2003) concluded that birds were able to distinguish 1% differences in sugar concentrations and 2% differences in lipid concentrations, and typically selected foods with the highest concentrations of each. We found that seed-eating birds were able to distinguish differences in oil content of at least 10%.

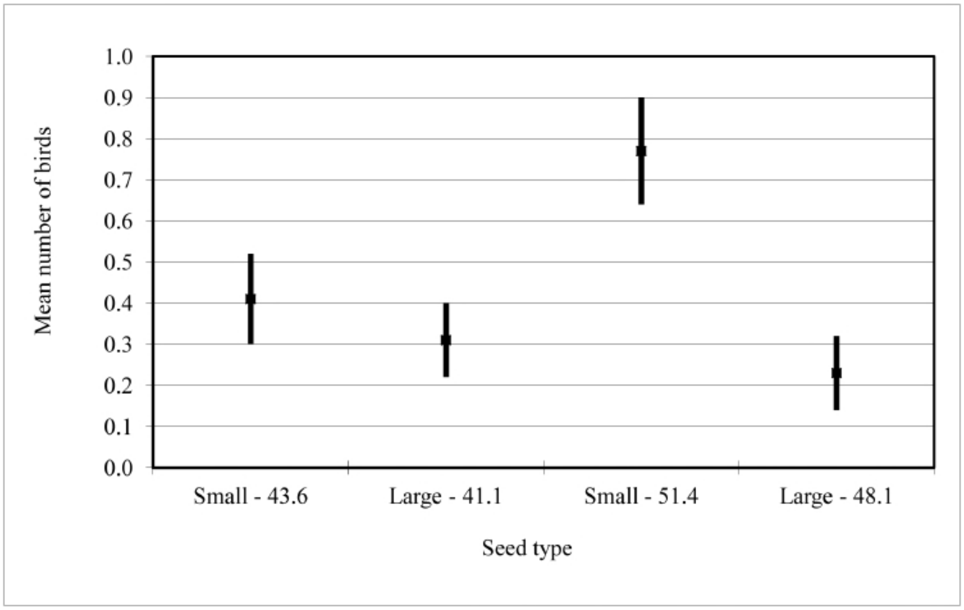


Figure 3. American Goldfinch preferred the small black-oil sunflower seeds with 51.4% oil over the three other varieties of black-oil sunflower that varied in size and/or % oil content. An equivalent number of goldfinches were found at small 43.6% seeds compared to large 48.1% seeds indicating that oil content is not the only factor influencing seed choice.

Seed size serves as both a cue for the oil content of a seed and a factor influencing seed choice. We found oil content of sunflower seeds increased with decreasing length, and increasing depth and weight. Birds "weigh" seeds before making a selection (Heinrich et al. 1997). By weighing seeds, birds may not only be maximizing energy costs of foraging (e.g., Lima 1985), but are also able to assess the seed's nutritional content. We also found that birds used seed size as a factor in seed selection, as some species consumed smaller seeds with less oil content over larger seeds with greater oil content when given a choice. In previous studies, Java Sparrow (*Padda oryzivora*) selected safflower seeds that were deeper (Van der Meij and Bout 2000), and Northern Cardinal selected sunflower seeds that were shorter, but thinner (Willson 1972).

We found differences among species in the seed varieties they choose. Species that sit at a feeder and eat, such as House Finch, American Goldfinch, and House Sparrow selected smaller seeds at equivalent rates to larger seeds, even if larger seeds had higher oil contents. Thus, for birds that eat food where it is found, ease in handling seeds may be a more significant factor (Willson 1972) than for species that take a seed and consume it elsewhere, where maximizing energy gained from each seed may be a more important factor in seed choice (Lima 1985). This may explain why Black-capped Chickadee, Tufted Titmouse, and White-breasted Nuthatch had the greatest frequency of visits at large, high oil content seeds after adjusting to feeder rotation during the study conducted in conjunction with Trial 3.

Knowledge of seed preferences of birds, and the factors that influence preferences, may ultimately result in improved seed varieties and an enhanced experience for people who feed birds. Specifically, packagers of bird seed could select sunflower varieties of certain size and oil content to create specialized blends based on the birds individuals want to attract. Blends used to attract birds that sit and eat at a feeder might include smaller sunflower seeds, while blends for attracting birds that grab a seed and eat elsewhere might be comprised of larger, higher oil content seeds.

Farmers growing black-oil sunflower face a dilemma. While the seeds are developing in the plant in the field, seed varieties that are bird resistant, particularly to Red-winged Blackbirds (*Agelaius phoenicus*) should be planted (Gross and Hanzel 1991, Bullard 1988, Linz et al. 2011). However, the seed traits selected in bird-resistant varieties during the 1980's, including fibrous hulls with high levels of anthocyanins, also created seeds with low oil content and yield (Linz et al. 2011). While these varieties were less attractive to pest birds (Bullard et al. 1989), they may also be unattractive to birds at feeders that prefer high oil content seed. Future research should examine whether lower oil content black-oil sunflower with fibrous hulls would be selected over other seed species found in bird food blends. In addition, studies should examine if birds have different preferences for certain seed varieties during different seasons. For example, do birds consume even more of the higher oil content seeds in the fall and winter in order to meet the demands of their changing metabolic rates and increase in lipid and protein storage (Karasov and Pinshow 1998, Linkes et al. 2002, McWilliams et al. 2002)?

ACKNOWLEDGMENTS

Funding was provided by D&D Commodities Ltd., Wild Bird Centers of America Inc., and Millikin University. We thank M. O. Christ, M. Evans, D. Hebert, and S. M. Johansen for assistance in collecting data, and the Macon County Conservation District for allowing us to conduct the study on their property. D. Hebert, S. M. Johansen, L. Lundstrom, G. H. Petrides Sr., and T. E. Wilcoxen reviewed the manuscript before submission.

LITERATURE CITED

Brown, M., C. T. Downs, and S. D. Johnson. 2010. Sugar preferences of a generalist nonpasserine flower visitor, the African Speckled Mousebird (*Colius striatus*). Auk 127:781-786.

Bullard, R. W. 1988. Characteristics of bird-resistance in agricultural crops. Proceedings of the Vertebrate Pest Conference 13:305-309.

Bullard, R. W., P. P. Woronecki, R. A. Dolbeer, and J. R. Mason. 1989. Biochemical and morphological characteristics in maturing achenes from purple-hulled and oilseed sunflower cultivars. Journal of Agricultural and Food Chemistry 37:886-890.

Diaz, M. 1990. Interspecific patterns of seed selection among granivorous passerines: effects of seed size, seed nutritive value and bird morphology. Ibis 132:467-476.

DiMiceli, J. K., P. C. Stouffer, E. I. Johnson, C. Leonardi, and E. B. Moser. 2007. Seed preferences of wintering Henslow's Sparrows. Condor 109:595-604.

Di Stefano, J. 2004. A confidence interval approach to data analysis. Forest Ecology and Management 187:173-183.

Foster, M. S. 2008. Freeze-frame fruit selection by birds. Wilson Journal of Ornithology 120:901-905.

Geis, A. D. 1980. Relative attractiveness of different foods at wild bird feeders. U.S. Department of Interior, Fish and Wildlife Service Special Scientific Report 233. Washington, D.C.

Gross, J. F. and J. J. Hanzel. 1991. Stability of morphological traits conferring bird resistance to sunflower across different environments. Crop Science 31:997-1000.

Heinrich, B., C. C. Joerg, S. S. Madden, and E. W. Sanders Jr. 1997. Black-capped Chickadees and Red-breasted Nuthatches "weigh" sunflower seeds. Auk 114:298-299.

Hespenheide, H. A. 1966. The selection of seed size by finches. Wilson Bulletin 78:191-197.

Horn, D. J. 1995. Perching orientation affects number of feeding attempts and seed consumption by the American Goldfinch (*Carduelis tristis*). Ohio Journal of Science 95:292-293.

Horn, D. J., S. E. Fairbairn, and R. J. Hollis. 2002. Factors influencing the occurrence of birds that use feeders in Iowa. Journal of the Iowa Academy of Science 109:8-18.

Horn, D. J., M. Abdallah, M. K. Bastian, J. R. DeMartini, and R. M. Wilhemi. 2003. Bird abundance at feeders increases with decreasing distance to cover. Transactions of the Illinois State Academy of Science 96:247-254.

Hrabar, H. D. N. K. and M. Perrin. 2002. The effect of bill structure on seed selection by granivorous birds. African Zoology 37:67-80.

Johnson, D. H. 1999. The insignificance of statistical significance testing. Journal of Wildlife Management 63:763-772.

Karasov, W. H. and B. Pinshow. 1998. Changes in lean mass and in organs of nutrient assimilation in a long-distance migrant at a springtime stopover site. Physiological Zoology 71:435-448.

Lima, S. L. 1985. Maximizing feeding efficiency and minimizing time exposed to predators: a trade-off in the Black-capped Chickadee. Oecologia 66:60-67.

Linkes, E. T., S. M. Scott, and D. L. Swanson. 2002. Seasonal acclimatization in the American Goldfinch revisited: to what extent do metabolic rates vary seasonally? Condor 104:548-557.

Linz, G. M., J. H. Homan, S. J. Werner, H. M. Hagy, and W. J. Bleier. 2011. Assessment of bird-management strategies to protect sunflowers. Bioscience 61:960-970.

McWilliams, S. R., S. B. Kearney, and W. H. Karasov. 2002. Diet preferences of warblers for specific fatty acids in relation to nutritional requirements and digestive capabilities. Journal of Avian Biology 33:167-174.

Pergams, O. R. W. and P. A. Zaradic. 2008. Evidence for a fundamental and pervasive shift away from nature-based recreation. Proceedings of the National Academy of Sciences 105:2295-2300.

Pierce, B. J., S. R. McWilliams, A. R. Place, and M. A. Huguenin. 2004. Diet preferences for specific fatty acids and their effect on composition of fat reserves in migratory Red-eyed Vireos (*Vireo olivaceous*). Comparative Biochemistry and Physiology, Part A 138:503-514.

Pulliam, H. R. 1985. Foraging efficiency, resource partitioning, and coexistence of sparrow species. Ecology 66:1829-1836.

Schaefer, H. M., V. Schmidt, and F. Bairlein. 2003. Discrimination abilities for nutrients: which difference matters for choosy birds and why? Animal Behaviour 65:531-541.

Templeton, C. N. 2011. Black-capped Chickadees select spotted knapweed seedheads with high densities of gall fly larvae. Condor 113:395-399.

U.S. Fish and Wildlife Service. 2007. 2006 national survey of fishing, hunting, and wildlife-associated recreation. National overview.

U.S. Fish and Wildlife Service. 2008. Wildlife watching in the U.S.: The economic impacts on national and state economies in 2006. Addendum to the 2006 national survey of fishing, hunting, and wildlife-associated recreation.

U.S. Fish and Wildlife Service. 2009. Wildlife watching trends: 1991-2006 a reference report. Addendum to the 2006 national survey of fishing, hunting, and wildlife-associated recreation.

Van der Meij, M. A. A. and R. G. Bout. 2000. Seed selection in the Java Sparrow (*Padda oryzivora*): preference and mechanical constraint. Canadian Journal of Zoology 78:1668-1673.

Willson, M. F. 1971. Seed selection in some North American finches. Condor 73:415-429.

Willson, M. F. 1972. Seed size preference in finches. Wilson Bulletin 84:449-455.